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New Zealand Late Miocene Biostratigraphy and Biochronology

Studies of planktic foraminifers and bolboforms at oceanic Sites 593 and 1123, and selected onland sections

A thesis submitted in fulfilment
of the requirements for the degree of

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by

MARTIN PETER CRUNDWELL

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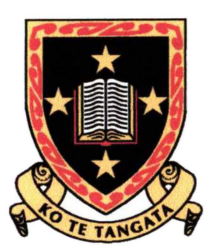

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The University of Waikato
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Abstract

Using high-resolution suites of core samples, including 940 samples from Deep Sea Drilling Project (DSDP) Site 593 in southern Tasman Sea off western New Zealand, and 353 samples from Ocean Drilling Program Site 1123 in the Southwest Pacific Ocean off eastern New Zealand, this study documents for the late Miocene interval (about 11.6 to 5.2 million years ago) the nature and abundance of planktic foraminifers in these uncomplicated and virtually uninterrupted oceanic sequences. The discovery and documentation of bolboforms at both sites – an enigmatic group of marine calcareous protophytes new to New Zealand – has enabled a highly-refined and integrated planktic foraminiferal and bolboform zonation to be established with 69 well-defined biostratigraphic events – highest and lowest occurrences, acme zones, and coiling zones – that are potentially useful for the correlation and subdivision of the late Miocene in New Zealand. It has also enabled these bioevents to be correlated with the excellent paleomagnetic record at ODP Site 1123 (Wilson et al. in prep.) and age calibrated directly or indirectly with the geomagnetic polarity time scale GPTS-95 (Cande & Kent 1995). This represents a major advance in New Zealand late Miocene biostratigraphy and biochronology and it is the first time a robust late Miocene chronology has been developed entirely from local data.

The study also links the major microfossil bioevents established in the offshore records at Sites 593 and 1123 back into selected onland New Zealand sections (730 samples), where the late Miocene is rather poorly resolved, thereby improving our ability to date, correlate, and interpret the paleoceanographic significance of late Miocene events more widely. Reassessment of faunal criteria used for the operational recognition and correlation of the late Miocene Tongaporutuan Stage in onland New Zealand, shows that the current defining faunal criterion for the base of the stage, the lowest occurrence of benthic foraminifers of the *Bolivinita quadrilatera* group, does not maintain a consistent position with respect to the robust biostratigraphic framework of planktic foraminiferal and bolboform events at Sites 593 and 1123. Consequently, it is proposed that the lower Tongaporutuan Stage boundary should be redefined as the base of the Kaiti Coiling Zone and (secondarily) by the highest common occurrence of *Neogloboquadrina mayeri* s.l. The redefinition of the Tongaporutuan Stage locates the Waiauan-Tongaporutuan Stage boundary close to the earliest New Zealand occurrences of the *B. quadrilatera* group. Because all of these events occur near to the base of base of Chron C5n.2n (10.95 Ma), at a stratigraphic level that is about 1.3 million years older than rocks at the base of the Tongaporutuan stratotype in North Taranaki, a new reference section is needed for the base of the stage.

Extended abstracts

This thesis examines the late Miocene planktic foraminiferal biostratigraphy and biochronology of high-resolution suites of core samples from Deep Sea Drilling (DSDP) Site 593 and Ocean Drilling Program (ODP) Site 1123, and it establishes a robust correlation between these offshore sequences and the New Zealand land-based stage classification, thereby improving our ability to date, correlate, and interpret the paleoceanographic significance of late Miocene sequences both onshore and offshore. Important results from studies included herein are detailed more specifically in the following abstracts:

STUDY 1
Introduction to late Miocene planktic foraminifers and their distribution at DSDP Site 593

The introductory section outlines the rationale behind the studies and explains the format of the thesis and the conventions adopted for use in each study. Study 1 serves as an introduction to late Miocene planktic foraminifers and their distribution at Site 593. It is important to the work as a whole as it introduces a Neogene phylogenetic classification for planktic foraminifers based on Kennett & Srinivasan (1983) – the first time such a classification has been adopted for use in New Zealand. It also explains taxonomic concepts that underpin the biostratigraphic component of subsequent studies.

STUDY 2
Important late Miocene planktic foraminiferal bioevents: DSDP Site 593, temperate Southwest Pacific (southern Tasman Sea)

A high-resolution study of late Miocene (upper Waiauan to lower Opoitian) planktic foraminifers at DSDP Site 593, southern Tasman Sea, identifies at least 37 significant bioevents that are potentially useful for biostratigraphic correlation within the New Zealand and Tasman Sea regions. This represents a nine-fold improvement in resolution over the existing late Miocene land-based stage classification. Important bioevents include narrow intervals of dextrally-coiled *Globoconella Gc*-593/A (Kaiti), *Gc*-593/B (Mapiri), *Gc*-593/C (Tukemokihi), *Gc*-593/D1, *Gc*-593/D2, *Gc*-593/D3 (Palliser) Coiling Zones; intervals of dextrally-coiled *Neogloboquadrina Nq*-593/A1, *Nq*-593/A2 (Glomar), *Nq*-593/B (Challenger) Coiling Zones; acme zones associated with *Truncorotalia juanai* and *Hirsutella panda*; biogeographically controlled disappearances, HCO *Neogloboquadrina mayeri* s.l., HO *Neogloboquadrina mayeri* s.l., LO *Neogloboquadrina pachyderma,* HO

Globoquadrina dehiscens, HO *Hirsutella* cf. *ichinosekiensis* (weakly keeled); evolutionary appearances and disappearances, HO *Hirsutella panda* (strongly keeled), HO *Hirsutella* cf. *ichinosekiensis* (weakly keeled), LO *Globoconella conomiozea,* LO *Globoconella mons,* LO *Truncorotalia neojuanai* n. sp., LO *Globoconella sphericomiozea,* LO *Truncorotalia* aff. *crassaconica,* LO *Globoconella pliozea,* HO *Globoconella sphericomiozea,* LO *Globoconella puncticulata,* LO *Truncorotalia crassaformis.*

These biostratigraphic events occur within the context of a staged withdrawal of warm-water taxa from the southern Tasman Sea – notably the disappearance of *Neogloboquadrina mayeri* s.l. in the early late Miocene (lowermost Tongaporutuan) and the disappearance of *Globoquadrina dehiscens* in the early late Miocene (Tongaporutuan). The appearance for the first time of hirsutellid populations with significant contributions of sinistrally-coiled shells in the middle late Miocene (upper Tongaporutuan) marks another important biological threshold and an extended period of evolutionary stasis. This ends with the disappearance of sinistrally-coiled hirsutellid populations in the latest Miocene (Kapitean) and the onset of major morphotypic expansions and evolutionary radiations in the clades *Globoconella* and *Truncorotalia.*

The greatest density of bioevents occurs in the early late Miocene (lower Tongaporutuan) and in the vicinity of the Miocene-Pliocene boundary (upper Kapitean). The intervening middle late Miocene (upper Tongaporutuan and lower Kapitean) interval has very few well defined events and faunal variation is largely restricted to fluctuations in the relative proportions of common taxa and coiling reversals in *Hirsutella scitula.* These events offer little scope for significant biostratigraphic refinement and there is need to research other microfossil groups that will resolve this interval.

STUDY 3
Biostratigraphy of late Miocene *Bolboforma* (enigmatic marine protophyta): DSDP Site 593, southern Tasman Sea

High-resolution bolboform distribution data from the very well preserved older part of the late Miocene section (12 to 8 Ma) of DSDP Site 593, in the southern Tasman Sea, are described and integrated with the planktic foraminiferal zonation from the same site. Contrary to most bolboform studies, this one adopts a population approach and takes size

related intraspecific morphologic variability into account when interpreting species and species ranges.

The record consists of a well-defined sequence of narrow bolboform subzones punctuated by intervals without bolboforms. Lower subzonal occurrences from the upper Waiauan to lowermost Tongaporutuan (593-36X to 593-33X) are mainly heterogeneous and include overlapping morphotypic populations of *Bolboforma subfragoris* s.l., which are described under open nomenclature: *B.* sp. spirospinosa, *B.* sp. serrata, *B.* sp. echinus, and *B.* sp. spinulosa. The pattern of morphotypic variation is poorly resolved in this part of the bolboform sequence, although the punctuated record includes at least five subzones that are potentially useful for correlation. They are collectively included in the BBs-Range Zone. Zonal occurrences from the lower to lowermost upper Tongaporutuan (593-32X to 593-26X) are largely monospecific. They comprise a well-defined succession of distinct bolboform species that are restricted to eight zones and subzones. In ascending species order, the succession includes, *Bolboforma gruetzmacheri* n. sp., *B. capsula, B. pentaspinosa, B. gracilireticulata* s.l., *B. metzmacheri* s.s. (subzones BBm-593/A and C), *B. metzmacheri ornata,* and *B. praeintermedia.* Another subzone, BBm-593/B comprising small smooth-walled phases of uncertain affinity, also occurs between subzones BBm-593/A and C.

The potential biostratigraphic resolution offered by bolboforms is better than planktic foraminifers and calcareous nannofossils in the middle and late Miocene and it is far superior to both fossil groups in deep-water sequences affected by calcite dissolution. The future, however, for greater biostratigraphic refinement lies in the integration of bolboforms with other fossil groups.

STUDY 4

Intraspecific morphological variation in late Miocene bolboforms: Implications for the classification, ecology, and biostratigraphic utility of *Bolboforma*

A preliminary morphological study of large well preserved bolboform populations from the late Miocene section of DSDP Site 593, in the southern Tasman Sea, reveals a relationship between test size and intraspecific morphological variation involving a gradual transformation in test shape and surface ornamentation in single-chambered species. The transformation begins with a small, smooth, thin-walled subspheroidal-shaped test and as

size increases rudimentary ornaments become more common and the test shape becomes more lagenoid. As the test increases in size, test walls thicken and ornaments become more structured, but specimens still retain a rounded lagenoid shape. In larger tests, the ornament becomes more prominent – most notably on meridional surfaces – and tests develop a squatter shape with flatter aboral surfaces. The morphological transformation generally ends with large, thick-walled, highly ornate phases with squat lagenoid-shaped tests, robust meridional ornaments, and relatively flat aboral surfaces. Although the size of the test increases notably through the transformation there appears to be no corresponding change in the size of the internal chamber – the transformation is largely due to the addition of calcite to the outer surface of the test wall. This appears to be an inherent biological feature and does not involve calcite dissolution or other retrograde processes. The detail of the transformation varies between species, although the pattern is similar for *Bolboforma subfragoris* s.l., *B. gruetzmacheri,* and *B. metzmacheri* s.s. that have different types of ornament – spinose, irregularly-ridged, and cancellate.

Because different morphological phases in the transformation have contrasting test shapes and ornaments they have the potential to be interpreted as different species, even when they occur in the same sample and belong to the same species. Taxonomic confusion is further compounded by the morphological similarity of many small smooth-walled and weakly ornamented phases of different species. These features are common in bolboform populations and have contributed to the misinterpretation of some species. Differences in test shape and ornament are most notable in large ornate phases and taxonomic interpretations should be based wherever possible on such phases.

For the studied populations, the transformation involving the addition of calcite to the outer surface of the test wall appears to have occurred while the bolboforms were entrained in subsurface flows of Southern Component Intermediate Water (SCIW). In this respect, the increased complexity of ornamentation may have been a morphological adaptation to counter the loss of buoyancy as calcite was added to the outer surface of the test wall. This would have presumably contributed to the entrainment and dispersal of bolboforms in the flow of subsurface water masses, and it suggests the tests of some bolboforms at least, may represent a disseminal phase in the lifecycle of this enigmatic group of microfossils.

STUDY 5

A magnetostratigraphically-constrained chronology for late Miocene bolboforms and planktic foraminifers in the temperate Southwest Pacific

High-resolution bolboform and planktic foraminiferal distribution data from the late Miocene section of ODP Site 1123, Chatham Rise, New Zealand, have been integrated with the magnetostratigraphic record from the same site to establish a magnetobiochronology based on the geomagnetic polarity time scale (GPTS-95). Although the late Miocene sequence is adversely affected by dissolution, 33 bioevents are identified based on dissolution resistant taxa that are also found at DSDP Site 593 – an important biostratigraphic reference section for the Neogene in the Tasman Sea. A scatter plot based on the stratigraphic positions of shared bioevents at the oceanic sites approximates a linear line of correlation. The tight grouping of the biostratigraphic data around the line of correlation, and the consistency of their stratigraphic order, suggest most events are synchronous or near-synchronous, even though the sites were more than 1500 km apart and associated with different water masses. This implies that even though the biostratigraphic construct is based on only two oceanic sites, it provides a robust late Miocene biochronostratigraphic framework for the temperate Southwest Pacific.

Shared bolboform events include the appearances and disappearances of *B. subfragoris* s.l. (11.56-10.61 Ma), *Bolboforma* sp. H (10.46-10.31 Ma), *B. capsula* (10.20-10.13 Ma), *B. pentaspinosa* (10.15-10.08 Ma), *B. gracilireticulata* s.l. (9.75-9.61 Ma), *B. metzmacheri* s.s. (lower subzone 9.54-9.34 Ma, upper subzone 9.01-8.78 Ma), *B. metzmacheri ornata* (8.45-8.28 Ma), *B. praeintermedia* (8.25-8.21 Ma), and abundance spikes associated with the uppermost *B. subfragoris* s.l. subzone (10.61 Ma) and the lower *B. metzmacheri* s.s. subzone (9.54 Ma). Shared planktic foraminiferal events include dextral coiling excursions in *Globoconella miotumida* (10.93-10.82 Ma and 9.62-9.42 Ma), the regional disappearance of *Globoquadrina dehiscens* (8.88 Ma), and the evolutionary appearances of *Globoconella conomiozea* (ca. 6.87 Ma), *Globoconella mons* (ca. 5.72 Ma), *Globoconella sphericomiozea* (ca. 5.53 Ma), *Globoconella pliozea* (ca. 5.39 Ma), *Truncorotalia crassaformis* (ca. 5.15 Ma), and *Globoconella puncticulata* (ca. 5.11 Ma).

STUDY 6

A refined biochronology for New Zealand late Miocene planktic foraminifers and bolboforms based on robust biostratigraphically constrained age models for DSDP Site 593

ABSTRACT: Well-founded late Miocene age models have been established for DSDP Site 593, using magnetostratigraphically age-calibrated bolboform and planktic foraminiferal data from ODP Site 1123. The age models are based on dissolution resistant species and are constrained by 33-shared bioevents. The tight grouping of the biostratigraphic data and the consistency of their stratigraphic order suggest most events are reliable homotaxial criteria, except for the Tukemokihi Coiling Zone which occurs about 170-320 k.y. later at Site 593 than at Site 1123. They also suggest the late Miocene section of Site 593 is relatively complete with respect to Site 1123, except for a short hiatus between the highest occurrence of *Globoquadrina dehiscens* and the top of the upper *Bolboforma metzmacheri* subzone (ca. 8.87-8.78 Ma).

A linear (L-Age) model, based on a regression line fitted to all 33-shared bioevents provides a close fit to the biostratigraphic data, but does not take into account short-term sedimentary variations between the sections. An alternative segmented (S-age) model, based on linear regressions fitted to pairs of shared bioevents, accommodates hiatuses and short-term sedimentary variations between the sections, and biostratigraphic error derived from sample resolution, core recovery, and fossil preservation and identification. The older part of the S-Age model (11.56-8.21 Ma) is constrained by 22-pairs of closely spaced bioevents, and the younger part of the S-Age model (8.21-3.58 Ma) is constrained by only two chronostratigraphic tie-points – the highest occurrence of *Bolboforma praeintermedia* and the base of Chron C2An.3n.

The new biochronostratigraphic framework for Site 593 has enabled interpolated ages to be assigned to 36 bioevents that are poorly defined or missing at Site 1123, and have not been reliably dated before. This effectively doubles the number of late Miocene bioevents from the greater New Zealand region that have been correlated either directly or indirectly with the geomagnetic polarity time scale (GPTS-95).

STUDY 7

Reassessment of faunal criteria used for the operational recognition and correlation of the Tongaporutuan Stage (late Miocene, New Zealand)

ABSTRACT: The Waiauan-Tongaporutuan Stage boundary cannot be resolved in many oceanic sequences and some neritic sequences because of the absence of the defining faunal criterion, the lowest occurrence of the *Bolivinita quadrilatera* group. *Bolivinita* is a benthic species that is largely found in slope environments (water depths ca. 300-1500 m). A review of planktic foraminiferal events in the vicinity of the boundary at oceanic Sites 593 and 1123 and uplifted marine sequences in New Zealand identifies intervals of dextrally-coiled *Globoconella miotumida* that are potentially useful for biostratigraphic subdivision and correlation of the Tongaporutuan Stage. From oldest to youngest they include the Kaiti Coiling Zone (KCZ) and the newly named Mapiri (MCZ) and Tukemokihi (TCZ) Coiling Zones. To date, no onland section has been found with all three coiling zones, but they have been reliably identified and correlated on the basis of a robust biostratigraphic framework of planktic foraminiferal and bolboform events that has been developed for Site 593 (Studies 2 and 3).

The Kaiti Coiling Zone occurs in the upper part of the *Bolboforma subfragoris* s.l. Zone and is associated with the highest common occurrence of *Neogloboquadrina mayeri* s.l. (>5% planktic abundance). It is found in eastern North Island sequences (e.g. Kaiti Beach, Gisborne) near some of the earliest known New Zealand occurrences of the *Bolivinita quadrilatera* group. The Mapiri Coiling Zone also occurs in the upper part of the *Bolboforma subfragoris* s.l. Zone, above the Kaiti Coiling Zone, and between distinctive acmes of *Hirsutella panda* where this typically rare planktic foraminiferal species is more common than *Globoconella miotumida.* It is also closely associated with the entry of the *B. quadrilatera* group in at least one sequence, Tukemokihi Stream, in northern Hawkes Bay. The Tukemokihi Coiling Zone occurs in the lower part of the *Bolboforma metzmacheri* Zone near the highest occurrence of *Globoquadrina dehiscens,* substantially above the Kaiti and Mapiri Coiling Zones. Significantly, it occurs just above the entry of the *B. quadrilatera* group at the Tongaporutuan stratotype in the northern Taranaki, but substantially above the entry of the *B. quadrilatera* group in eastern North Island sequences (e.g. Tukemokihi Stream). These relationships suggest the entry of the *B. quadrilatera* group does not maintain consistent position and that it is the least reliable of the boundary criteria examined. Consequently, it is proposed that the Tongaporutuan Stage

boundary should be redefined (primarily) by the base of the Kaiti Coiling Zone and (secondarily) the highest common occurrence of *Neogloboquadrina mayeri* s.l. The entry of the *B. quadrilatera* group is potentially diachronous, but remains useful as a low-resolution proxy for the base of the stage in suitable facies – water depths of 300-1500 m.

The redefinition of the Tongaporutuan Stage resolves a long-standing enigma of Tongaporutuan biostratigraphy, namely the anomalous absence of *Neogloboquadrina mayeri* s.l. near the base of the Tongaporutuan stratotype, and it locates the Waiauan-Tongaporutuan Stage boundary near the base of Chron C5n.2n (10.97 Ma). A new reference section for the stage boundary has yet to be nominated, but a sequence where the entry of the *B. quadrilatera* group can be unambiguously related to the proposed planktic foraminiferal stage criteria is most likely to be found in eastern North Island.

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This thesis is dedicated to my late father, without whose support I would never have embarked on this endeavour, and certainly would not have not had the strength and conviction to bring it to a conclusion.

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Introduction

Background to studies and thesis outline

Introduction: Background to studies and thesis outline

NEW ZEALAND STAGE CLASSIFICATION

The correlation of geographically isolated marine sequences exposed onland in New Zealand and the development of a regional synthesis for the late Miocene have been underpinned by the New Zealand Cenozoic stage classification, which includes two late Miocene stages: the Tongaporutuan and Kapitean. Finlay and Marwick (1940, 1947) proposed these stages early in the development of the stage classification when distinctive lithostratigraphic units were being nominated as bases for sequential biostratigraphic units that might be recognized throughout New Zealand. As originally proposed, the Tongaporutuan and Kapitean were thought to be broadly equivalent to the Tortonian and Messinian in Europe and were based on an eclectic selection of molluscan and foraminiferal criteria that were considered to be characteristic of the stage, but not necessarily unique or critical boundary events. Although suitable for the correlation and subdivision of clastic sequences deposited in nearshore basins, these criteria were largely based on shallow-water benthic taxa and were only partially applicable to oceanic sequences within the greater New Zealand region.

Subsequent planktic foraminiferal studies of cored oceanic sequences drilled during the international Deep Sea Drilling Project (DSDP) have extended the application of land-based stages, to offshore sequences (Figure 0.1 and Table 0.1). As a consequence, most late Miocene stage boundaries can now be related to planktic foraminiferal events distributed in latitudinally extensive water masses. These events allow the New Zealand stage classification to be used throughout the New Zealand sector of the temperate Southwest Pacific where they provide a robust low-resolution framework for regional syntheses. Despite the utility of this biostratigraphic framework, there is an ever increasing demand for unique events to tie regional sequences to global chronological time scales and improve our ability to calibrate and orbitally tune sedimentary sequences. This is especially the case in the late Miocene prior to the Messinian salinity crisis, when oceanic conditions appear to have been relatively stable and there is a paucity of events suitable for biostratigraphic correlation (Figure 0.2).

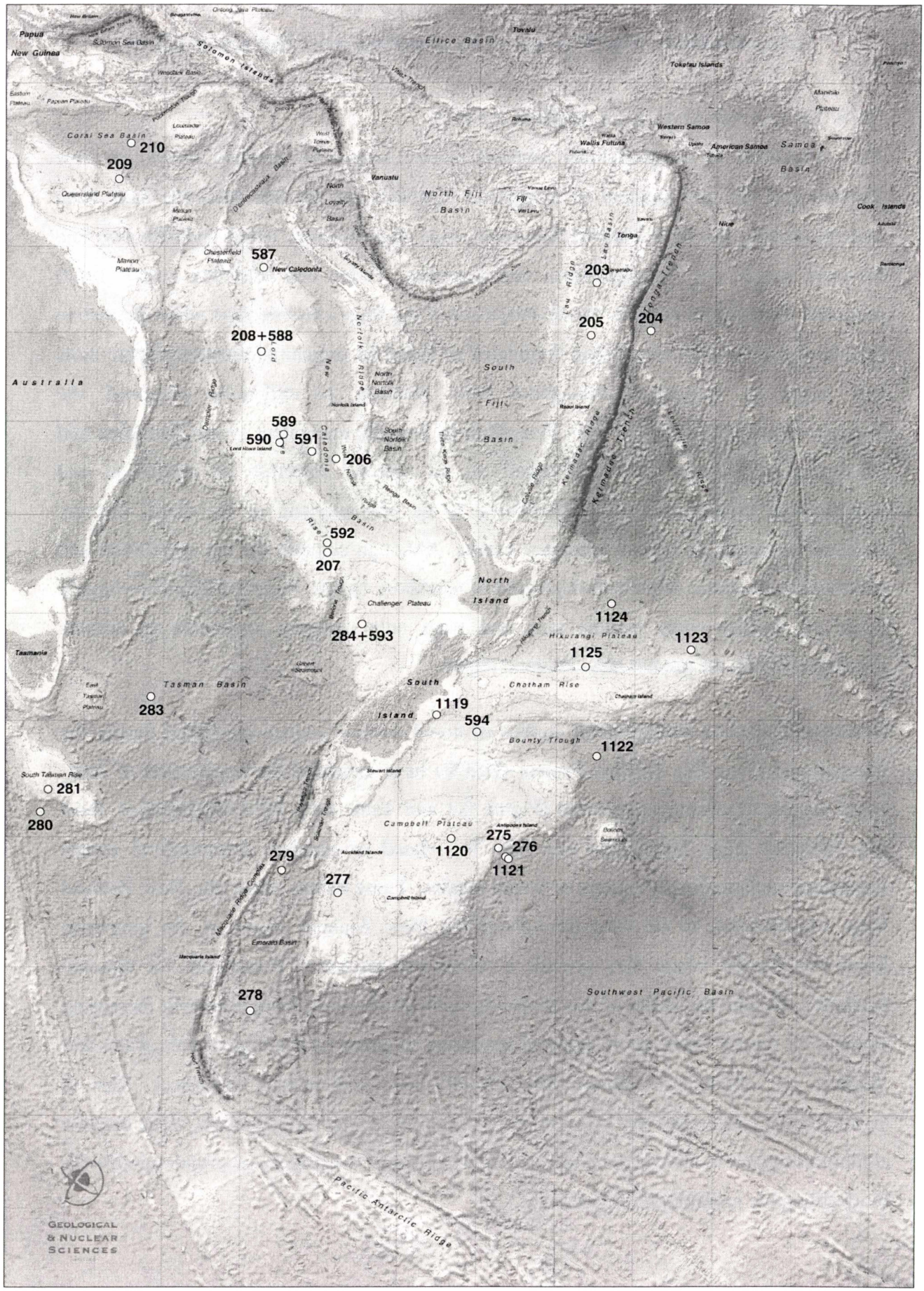

Figure 0.1 – Locations of Deep Sea Drilling Project (DSDP) and Ocean Drilling Program (ODP) Sites in the New Zealand sector of the Southwest Pacific – see Table 0.1 for site data.

Table 0.1 – Locations of Deep Sea Drilling Project (DSDP) and Ocean Drilling Program (ODP) Sites in the New Zealand sector of the Southwest Pacific – see Figure 0.1. Site data from Burns & Andrews (1973), Kennett & Houtz (1975), Kennett & von der Borch (1986), and Carter et al. (1999).

Leg / Site	Latitude	Longitude	Water depth (m)	Penetration (m)	Oldest sediments	Comments	Age
DSDP Leg 21 (November 1971–January 1972)							
203	22° 09.22' S	177° 32.77' W	2720	409	Middle Pliocene	Uninterrupted sequence	0-4 Ma
204	24° 57.27' S	174° 06.69' W	5354	160	?Cretaceous	Uninterrupted sequence	0-22 Ma
205	25° 30.99' S	177° 53.95' E	4320	355	Middle Oligocene	Major unconformity, uninterrupted middle Miocene to Recent sequence	0-16, 25-31 Ma
206	32° 00.75' S	165° 27.15' E	3196	734	Middle Paleocene	Two major unconformities, Neogene uninterrupted	0-33, 43-51, 59-62 Ma
207	36° 57.75' S	165° 26.06' E	1389	513	Late Paleocene	Two major unconformities, uninterrupted middle Miocene to Recent sequence	0-15.5, 46-52, 54-65+ Ma
208	26° 06.61' S	161° 13.27' E	1545	54	Late Cretaceous	Two major unconformities, Neogene uninterrupted	0-27, 46-50, 59+ Ma*
209	15° 56.19' S	152° 11.27' E	1428	344	Middle Eocene	Two major unconformities, late Miocene to early Pliocene missing	0-3.3, 12-25, 43-48 Ma
210	13° 45.99' S	152° 53.78' E	4643	711	Early Eocene	Major unconformity, late Eocene to early Oligocene missing, Neogene uninterrupted	0-35, 43-49.5 Ma
DSDP Leg 29 (March–April 1973)							
275	50° 26.34' S	176° 18.99' E	2800	62	Late Cretaceous	No Cenozoic sequence	71+ Ma
276	50° 48.11' S	176° 48.40' E	4671	23	Paleogene	??	??
277	52° 13.43' S	166° 11.48' E	1214	473	Middle Paleocene	Two major unconformities, uninterrupted middle Paleocene to middle Oligocene	0-0.5, 1.5, 27-58 Ma
278	56° 33.42' S	160°04.29' E	3675	439	Middle Oligocene	Major unconformity, middle to late Pliocene missing, Neogene otherwise complete	0-2.4, 4-33 Ma
279	51° 20.14' S	162° 38.10' E	3341	202	Middle early Miocene	Two major unconformities, Neogene poorly represented	0-0.1, 1.5-2, 11-20 Ma
280	48° 57.44' S	147° 14.08' E	4176	524	Early-middle Eocene	Two major unconformities, Neogene poorly represented	0-0.1, 5, 36-48 Ma
281	47° 59.84' S	147° 45.85' E	1591	169	Late Eocene	Two major unconformities, uninterrupted Neogene	0-23, 36, 42-43 Ma
282	42° 14.76' S	143° 29.18' E	4202	311	Late Eocene	Three major unconformities, Neogene poorly represented	0-0.1, 10, 20-22, 31-43 Ma
283	43° 54.60' S	154° 18.96' E	4729	592	Paleocene	Three major unconformities, Neogene poorly represented	1-2.4, 40-48, 54-64 Ma
284	40° 30.48' S	167° 40.81' E	1066	208	Late Miocene	Uninterrupted sequence	0-8 Ma
DSDP Leg 89 (October–November 1982)							
586	00° 29.84' S	158° 29.89' E	2208	623	Early Miocene	Uninterrupted sequence	0-22 Ma
DSDP Leg 90 (Decmeber 1982–January 1983)							
587	21° 11.87' S	161° 19.99' E	1101	147	?Late Miocene	Uninterrupted sequence	0-7 Ma
588	26° 06.70' S	161° 13.60' E	1533	344	Late Cretaceous	Middle Paleocene to early Eocene and late Eocene to Middle Miocene missing	0-27, 46-49, 57.5-65+ Ma
589	30° 42.72' S	163° 39.39' E	1391	36	Quaternary	Uninterrupted	??
590	31° 10.02' S	163° 21.51' E	1299	499	Earliest Miocene	Uninterrupted middle middle Miocene sequence, and late early Miocene	0-16.5, 17.5-20.5 Ma
591	31° 35.06' S	164° 26.92' E	2131	500	Latest early Miocene	Uninterrupted sequence	0-18 Ma
592	36° 28.40' S	165° 26.53' E	1098	389	Middle late Miocene	Middle Oligocene to earliest Miocene missing	0-20, 34.5-42 Ma
593	40° 30.47' S	167° 40.47' E	1068	572	Late Eocene	Uninterrupted sequence	0-42 Ma
594	45° 31.41' S	174° 56.88' E	1204	640	Late early Miocene	?Uninterrupted sequence	0-20 Ma
ODP Leg 181 (January–March 2000)							
1119	44° 45.33' S	172° 23.59' E	396	495	Late Pliocene	Uninterrupted sequence	0-2.5 Ma
1120	50° 03.80' S	173° 22.30' E	543	221	Early Miocene	Several major unconformities, Pliocene missing	0-0.5, 1-1.5, 6-14, 16-21.5 Ma
1121	50° 53.88' S	176 59.86' E	4488	140	Early Paleocene	Eocene to Pliocene missing	0-1.5, 56-63 Ma
1122	46° 34.78' S	177° 23.61' W	4435	627	Middle Miocene	Late Miocene and most Pliocene missing	0-2.5, 3.5-4, 11-16 Ma
1123	41° 47.17' S	171° 29.94' W	3290	633	Late Eocene	Oligocene and earliest Miocene mising	0-20, 33-37 Ma
1124	39° 29.90' S	176° 31.89' W	3968	473	Late Cretaceous	Several major unconformities	0-11, 13-17, 22-27, 33-34, 37-39, 60-65+ Ma
1125	42° 33.00' S	178° 09.99' W	1365	552	Late Miocene	Uninterrupted sequence	0-11 Ma

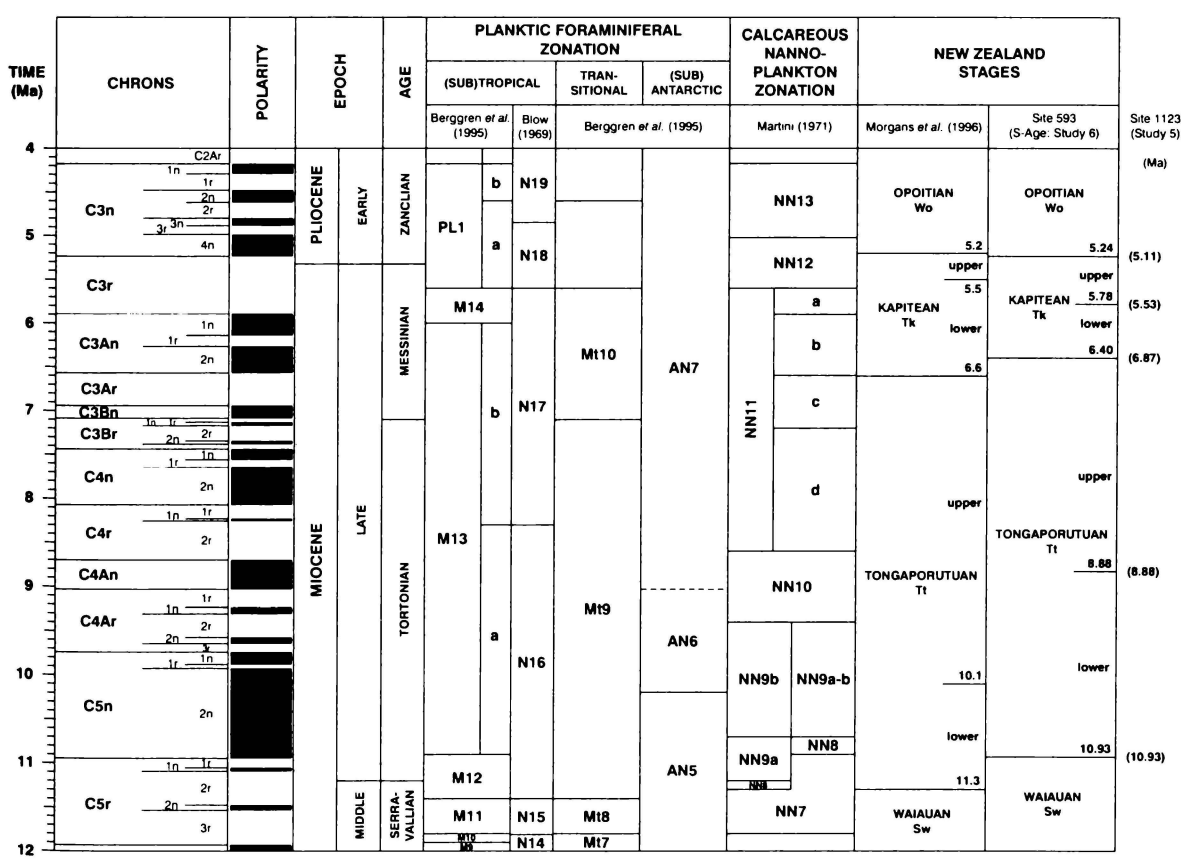

Figure 0.2 – Correlation of New Zealand late Miocene stages, and planktic zonations from tropical-subtropical, temperate, and antarctic-subantarctic regions (after Berggren et al. 1995).

OCEANIC SEDIMENTARY RECORDS

The first extended records of cored oceanic sediments in the New Zealand sector of the Southwest Pacific were obtained during DSDP Legs 21 (November 1971–January 1972) and 29 (March-April 1973) using the drilling vessel *Glomar Challenger*, namésake of *HMS Challenger*, which undertook the world's first major oceanographic expedition between 1872-1876. The coring of oceanic sites on Lord Howe Rise and Challenger Plateau to the north and west of New Zealand, and on Chatham Rise and Campbell Plateau to the east and south, recovered thick Neogene sequences of calcareous oozes with excellent transitional zone (mid-latitude) calcareous microfossil assemblages, similar to those found in age-equivalent rock sections in onland New Zealand (Figure 0.1). The next DSDP Leg to visit the region, Leg 90 (December 1982–January 1983), reoccupied some of these sites and, using the newly developed hydraulic piston corer and extended core barrel systems, recovered much longer and less disturbed sequences than had been recovered by conventional rotary coring during Legs 21 and 29. DSDP Site 593, cored on Challenger Plateau as a reoccupation of Site 284, recovered sediments extending back to the late Eocene, with a virtually uninterrupted Miocene to Recent (ca. 24-0 Ma) record of foraminiferal bearing nannofossil oozes. No tenable Miocene or early Pliocene magnetostratigraphic record was obtained for Site 593 below Chron C2An at 3.58 Ma (Barton & Bloemendal 1986). Consequently, the chronology for this part of the cored section is largely based on a small number of tenuous biostratigraphic and stable isotope correlations with dated horizons or interpolated horizons in onland New Zealand (e.g. Head & Nelson 1992; Schneider & Kennett 1996) and biochronostratigraphic data from outside the New Zealand region (Lazarus et al. 1995; Spencer-Cervato 1999). Despite the poor Neogene chronology, this core is presently the most intensively studied of the suite of DSDP cores available for the New Zealand sector of the Southwest Pacific. However, the integration and correlation of Miocene sedimentological, stable isotope, and microfossil distribution data from this site with similar data from other oceanic sites and age-equivalent rock sections in onland New Zealand has continued to be a problem.

In late 1998 the Ocean Drilling Program (ODP) vessel *Joides Resolution*, which superseded *Glomar Challenger* and the Deep Sea Drilling Project in 1985, drilled seven new oceanic sites off eastern New Zealand during Leg 181. Improved coring and logging capabilities compared to those back in 1983 when Site 593 was drilled enabled near-continuous sediment cores to be obtained that have a very complete Neogene

paleomagnetic stratigraphy, so the sediments can often be dated directly in terms of the geomagnetic polarity time scale, the basis of most modern geological time scales. The most complete Neogene paleomagnetic record (ca. 20-0 Ma) occurs at ODP Site 1123, which was drilled at similar latitude to Site 593, but off the eastern, Pacific Ocean side of New Zealand (Shipboard Scientific Party 1999). Despite having an excellent chronology, the Miocene sedimentary record at this site has been affected by calcite dissolution and the potential for precisely age calibrating planktic foraminiferal events that underpin the correlation of New Zealand late Miocene stages is limited to a small number of taxa that are resistant to dissolution. This is in contrast to DSDP Site 593 which has a poor late Miocene chronology, but a very well preserved record of calcareous microfossil events.

THESIS FORMAT AND CONTENT

This thesis comprises a series of seven studies, each covering potentially publishable topics, with abstracts, references, and important appendices included within each. Large data appendices are included separately on an enclosed disk in order to make the data more accessible. Taking a topic approach, a certain degree of repetition has been unavoidable, especially with respect to aspects of oceanographic setting and locality information. While the focus is on New Zealand late Miocene biostratigraphy and biochronology, a parallel PhD study by Cooke (2002) which uses many of the same samples, examines the Neogene paleoceanographic history recorded by the DSDP Site 593 sediments. Aspects of both studies will subsequently be combined for publication.

The first part of this thesis (Studies 1–4) involves the establishment of a highly-refined late Miocene biostratigraphic framework for regional correlation based on DSDP Site 593 in the southern Tasman Sea. The second part (Studies 5–6) establishes a robust late Miocene magnetobiochronologic framework at ODP Site 1123 on Chatham Rise and transfers this across to Site 593 on the basis of shared biostratigraphic events. The final study correlates the offshore record of planktic foraminiferal and bolboform events at Sites 593 and 1123, with selected age-equivalent rock sections onland in New Zealand.

THESIS OUTLINE

Study 1: Introduction to planktic foraminifers, Site 593 – This introductory study defines species concepts and tolerances used in the compilation of census data for late Miocene planktic foraminifers at DSDP Site 593 in a suite of 572 samples at an average

stratigraphic spacing of 0.3 m (ca. 11 kyr). It does this within the context of a phylogenetic classification based on Kennett & Srinivasan (1983), which is emended for use at Site 593 and in New Zealand. Coiling data are also compiled for selected globoconellid and neogloboquadrinid species from a suite of 931 samples at an average stratigraphic spacing of 0.2 m (~7 kyr). These microfossil distribution data are fundamental to the thesis as a whole as they provide a robust framework for the correlation and calibration of sequences in subsequent biostratigraphic studies. While the late Miocene biostratigraphy of planktic foraminifers at Site 593 has been examined before, this is the first time that the relative abundances of planktic foraminifers associated with species appearances and disappearances, and changes in coiling, have been detailed in a high-resolution study at the site. It is also the first such study of a virtually uninterrupted and uncomplicated sequence in New Zealand spanning the entire late Miocene period.

Study 2: Planktic foraminiferal biostratigraphy, Site 593 – This study builds on the census data acquired in Study 1 and it locates the positions of all important biostratigraphic events – evolutionary appearances, extinctions, migrations, and coiling changes – at Site 593, providing a comprehensive and highly-resolved set of biostratigraphic data for the correlation and subdivision of late Miocene sequences in the New Zealand region. At least 37 well-defined planktic foraminiferal events are identified that are potentially useful for the correlation and subdivision of New Zealand Late Miocene stages. This represents a nine-fold increase in resolution over the existing land-based biostratigraphic stage classification.

Study 3: Bolboform biostratigraphy, Site 593 – This study arose from the unexpected discovery of bolboforms at Site 593, an enigmatic group of marine calcareous microfossils. While bolboforms are important for the correlation and dating of mid to high latitude sequences in the northern hemisphere, particularly sequences affected by calcite dissolution, they are new to New Zealand and their distribution is resolved in order to determine their potential for regional biostratigraphic correlation. This represents the most detailed biostratigraphic record presently available for late Miocene bolboforms in southern mid latitudes and it draws striking parallels with documented sequences in the Northern Hemisphere.

Study 4: Bolboform morphology – This study documents morphological variation in three single-chambered bolboform populations that have different types of surface ornament, in order to elucidate how the range of observed intraspecific morphotypic variation relates to bolboform taxonomy. It clearly shows a continuum of intraspecific variation, from small smooth-walled phases, to large ornate phases in all three populations. Because different morphological phases in the transformation have contrasting test shapes and ornaments they have the potential to be interpreted as different species, even when they occur in the same sample and belong to the same species. While this is not the first time that size-related intraspecific morphological variation has been described, it is the first time that such variation has been related to the growth and development of bolboform tests. This provides important new insights into the ecology and biostratigraphic utility of bolboforms.

Study 5: Magnetobiochronology Site 1123 – This study arose from the authors involvement as a shore-based participant in ODP Leg 181, which drilled seven Southwest Pacific sites off eastern New Zealand. The recovery of a near-continuous Neogene sediment core from ODP Site 1123, on Chatham Rise, with a very complete paleomagnetic stratigraphy, enabled many of the biostratigraphic events that had been identified at DSDP Site 593 to be age calibrated in terms of the geomagnetic polarity time scale (GPTS-95). This is the first time a robust and highly-refined magnetobiochronologic framework has been established in the New Zealand sector of the temperate Southwest Pacific, albeit only for taxa that have a high-resistance to dissolution.

Study 6: Age model Site 593 – This study transfers the magnetobiochronologic framework from ODP Site 1123 across to DSDP Site 593 in the southern Tasman Sea on the basis of shared planktic foraminiferal and bolboform events. It develops a robust chronology that enables all planktic foraminiferal and bolboform events identified at Site 593 to be age calibrated either directly or indirectly with respect to the geomagnetic polarity time scale (GPTS-95). This represents a major advance in New Zealand late Miocene biostratigraphy and chronology, and it is the first time that a robust biochronologic framework has been established entirely from local data. It also enables dating of late Miocene bioevents, including evolutionary appearances, extinctions, migrations, and coiling changes that the New Zealand region shares with other regions, to be tested for synchroneity.

Study 7: Tongaporutuan Stage correlations – The final study attempts to link important microfossil bioevents identified in the offshore records of Sites 593 and 1123 back into selected age-equivalent rock sections in onland New Zealand, where the late Miocene is rather poorly resolved. It enables a reassessment of the reliability of faunal criteria that are presently used for the operational recognition and correlation of the late Miocene Tongaporutuan Stage.

EDITORIAL PRACTICES

Several editorial practices are applied in this thesis, including:

1) Referencing style follows the format of the *New Zealand Journal of Geology and Geophysics*.

2) For consistency, lower-case lettering is used for all subdivisions of ages and stages. Early, middle, and late are used for subdivisions of internationally defined ages (e.g. late Miocene); and lower, middle, and upper are used for subdivisions of New Zealand biostratigraphically defined stages (e.g. lower Tongaporutuan).

3) Page numbering is independent for each study and is prefixed with the study number (e.g. S7–28). While the thesis consists of seven studies (S1–S7), the introduction is prefixed S0 and the synopsis is prefixed S8.

4) Full taxonomic names of microfossil species are generally only used at the start of sentences and for species relating to genera not previously mentioned in a section or paragraph. Abbreviations for genera follow Kennett & Srinivasan (1983) and use a two letter code to avoid taxonomic confusion. A full list of these codes is given in Table 2.1 on page S2–4.

5) References to magnetostratigraphic horizons associated with biostratigraphic events at ODP Site 1123 give the proportional position within a chron or subchron from its younger end. A reference to C5n.2n(0.35) for example relates to a position within the younger part of this chron. This is in accord with procedures for more precise magnetostratigraphic correlations outlined by Berggren *et al.* (1995).

6) Lowest and highest occurrences (LO's and HO's) are adopted in this thesis, as these terms have an implicit stratigraphic meaning. Although first and last occurrences (FO's and LO's) are more commonly used, they have both a stratigraphic and time context. This distinction is important when it comes to describing the distribution of taxa in oil

wells, where references to the first evolutionary occurrence of a taxon and its first downhole occurrence can be confusing. It is for this reason that the use of LO's and HO's have been endorsed in the New Zealand Time Scale monograph (Roger Cooper pers. com. 2002).

Matters arising from oral examination

CURRENT UNDERSTANDING OF PLANKTIC FORAMINIFERAL PHYLOGENY

Classical typological approaches to planktic foraminiferal classification, such as Bolli *et al.* (1957) and, in particular, Blow (Banner & Blow 1959; Blow 1969, 1979) which use a morphological hierarchy to assign specimens to generic categories, are relatively simple to apply, but are equally arbitrary and artificial. For example, the former classification assigns subgenus-level significance to the presence of an imperforate carina, and of the latter, greater importance to the location and modifications of the aperture. In both cases, the phylogenetic interrelationships of species are largely ignored.

The classification of Neogene planktic foraminifers that is adopted in this thesis is based on our present understanding, of ancestor-descendant relationships, and assigns generic-level significance to lineages with similar surface ultrastructure – one of the few conservative morphological features that distinguish different lineages (Kennett & Srinivasan 1983). Generic concepts and the interrelationships of Neogene planktic foraminiferal species are largely based on Kennett & Srinivasan (1983), but some emendments have been made to accommodate the views of Cifelli and Scott (1986), and Scott et al. (1990), and observations by the author. The inferred phylogeny of major planktic foraminiferal (globorotalid) groups and lineages is shown in Figure 0.3, and the classification of taxa is given in Table 0.2. The work by Kennett & Srinivasan (1983) is still widely used as the basis for biostratigraphic studies, as little research has been published recently on systematics. Because the focus of this thesis is biostratigraphic rather than systematic, critical assessment of Kennett & Srinivasan (1983) is generally considered to be outside its scope. However, specific issues of systematics raised during the examination of this thesis are addressed below. Discussions relating to the classification and identification of selected taxa are also given in Study 2.

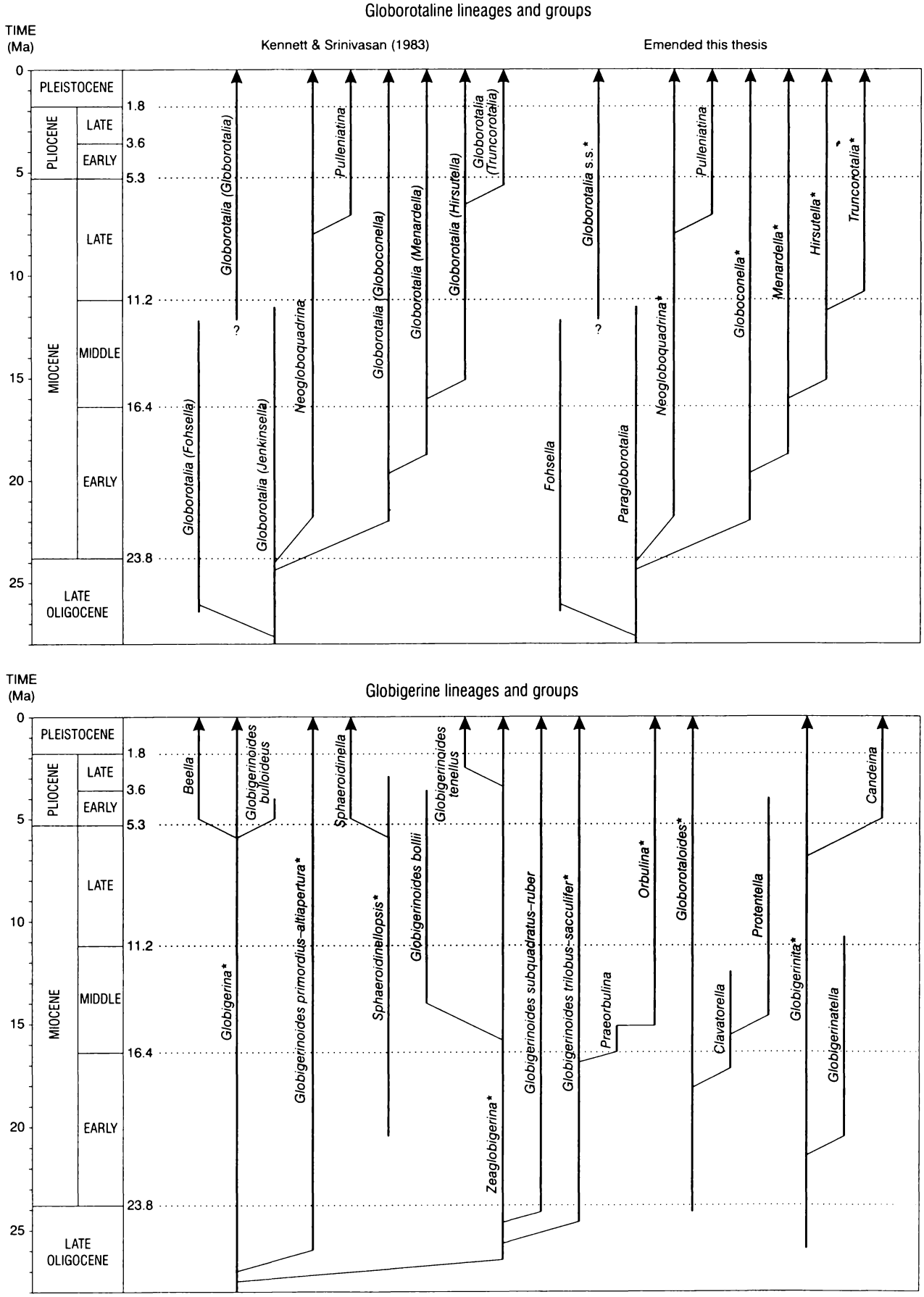

Figure 0.3 – Inferred phylogeny of Neogene planktic foraminiferal (globorotaline and globigerine) lineages and groups, after Kennett & Srinivasan (1983). Shaded area represents the time period studied in this thesis; * lineages and groups identified in this thesis.

Surface ultrastructure of major groups and lineages

- *Globigerina*: Type species *Globigerina bulloides* d'Orbigny, 1826.
  Characterized by hispid surface, penetrated by roughly circular pores. No evidence of pore pits or interpore ridges. Pores occupy interspaces between short, blunt projections, which represent the bases of long, slender spines observed in living specimens.

  NB. The *Globigerina angustiumbilicata* lineage is considered by the author to warrant separation as a new genus, based the inferred phylogenetic relationships of species and their microperforate surface ultrastructure, which differs from the more coarsely perforate surface of *Gg. bulloides*.

- *Globoconella*: Type species *Globorotalia conomiozea* Kennett, 1966.
  Characterized by a finely perforate surface, with pustules developed strongly on the umbilical side of early-formed chambers. The continuum of forms in this lineage includes keeled and unkeeled, inflated and compressed, and thin-walled and thick-walled forms.

- *Globigerinoides*: Type species *Rotalina hirsuta* d'Orbigny, 1839.
  A polyphyletic group distinguished by its supplementary sutural apertures. Includes forms with surfaces covered with spines and spine bases, and forms with a cancellate surface ultrastructure with less distinct evidence of spinosity.

- *Hirsutella*: Type species *Rotalina hirsuta* d'Orbigny, 1839.
  The name *Hirsutella* is used throughout this thesis, although Haman *et al.* (1981) consider *Hirsutella* Bandy, 1972 (Foraminiferida) to be a junior homonym of *Hirsutella* Cooper and Muir-Wood, 1951 (Brachipoda). As the name is preoccupied, they proposed the new name *Obandyella* as a replacement for *Hirsutella.*

  A polyphyletic group that includes spiroconical forms with finely perforate surface covered with pustular projections, concealed on early-formed chambers by secondary thickening, and scituline forms with smooth densely perforate surfaces and pustules on the umbilical side of early formed chambers.

- *Neogloboquadrina*: Type species *Globigerina dutertrei* d'Orbigny, 1839.
  Characterized by, a cancellate (honeycomb-like) surface, with pores at the centers of pore pits. Thickened extropical specimens typically have a surface covered with rosettes of euhedral calcite crystals.

- *Truncorotalia*: Type species *Rotalia truncatulinoides* d'Orbigny, 1839.
  Characterized by a finely perforate surface that is pustulate on both umbilical and spiral sides. The continuum of forms in this lineage includes both keeled and unkeeled, conicotruncate and compressed, and thin-walled and thick-walled forms.

- *Zeaglobigerina*: Type species *Globigerina woodi* Jenkins, 1960.
  Characterized by a cancellate (honeycomb-like) surface with regular subhexagonal pore pits with pores at the centers. The surface ultrastructure of *Zeaglobigerina* is similar to *Globigerinoides,* which is spinose during life, although no indication of spines or spine bases has been observed in species of *Zeaglobigerina.*

TABLE 0.2 – Inferred phylogenetic classification of late Miocene planktic foraminifers used in this thesis, after Kennett & Srinivasan (1983). Bold text identifies emendments to the phylogenetic scheme – see following discussions of phylogeny and classification.

Family CANDEINIDAE Cushman, 1927
Globigerinita lineage
Ga. glutinata (Egger)
Ga. uvula (Ehrenberg)

Family CATAPSYDACIDAE Bolli, Loeblich, and Tappan, 1957
Catapsydrax lineage
Cs. parvulus Bolli, Loeblich, and Tappan

Globorotaloides lineage
Gd. hexagona (Natland) → ***Globorotaloides hexagonus***

Globoquadrina lineage
Gq. dehiscens (Chapman and Jarvis)
Gq. venezuelana (Hedberg)

Family GLOBIGERINIDAE Parker and Jones, 1862
Globigerina group
- *Globigerina angustiumbilicata* lineage
  Gg. angustiumbilicata Bolli
  Gg. quinqueloba Natland

- *Globigerina praebulloides* lineage
  Gg. eamesi Blow
  Gg. bulloides d'Orbigny
  Gg. falconensis Blow

Globigerinella lineage
Ge. aequilateralis (Brady)

Globigerinoides group
- *Globigerinoides primordius/bulloideus* lineage
  Gs. obliquus Bolli

- *Globigerinoides quadrilobatus* lineage
  Gs. immaturus LeRoy → ***Gs. quadrilobatus immaturus***
  Gs. quadrilobatus (d'Orbigny) → ***Gs. quadrilobatus quadrilobatus***
  Gs. sacculifer (Brady)
  Gs. triloba (Reuss) → ***Gs. quadrilobatus trilobus***

Globigerinopsis lineage
Ge. obesa Bolli → ***Globigerinopsis obesa***

Orbulina lineage
Or. bilobata (d'Orbigny)
Or. universa d'Orbigny

Sphaeroidinellopsis lineage
Ss. paenedehiscens Blow
Ss. seminulina (Schwager)

Zeaglobigerina lineage
Zg. apertura (Cushman) → ***Zg. woodi apertura***
Zg. decoraperta (Takayanagi and Saito) → ***Zg. woodi decoraperta***
Zg. druryi (Akers)
Zg. nepenthes (Todd)
Zg. woodi (Jenkins) → ***Zg. woodi woodi***

Family GLOBOROTALIIDAE Cushman, 1927
Globoconella lineage
Gc. conoidea (Walters) → ***Globoconella miotumida***
Gc. conomiozea (Kennett)
***Gc. mons* (Hornibrook)**
***Gc. pliozea* (Hornibrook)**
Gr. puncticulata (Deshayes)
Gc. sphericomiozea (Walters)

Gr. (Hr.) cibaoensis (Bermúdez) → ***?Globoconella cibaoensis***

Hirsutella → **new name *Obandyella* (see following discussion)**
Hirsutella scitula group
Hr. scitula (Brady)

Hirsutella hirsuta lineage
***Hr.* cf. *ichinosekiensis* (Takayanagi and Oda)**
Hr. margaritae (Bolli and Bermúdez)
Gc. panda* (Jenkins) → *Hirsutella panda

Jenkinsella → ***Neogloboquadrina* (see following discussion)**

Menardellai lineage
Mn. limbata (Fornasini)
Mn. menardii (Parker, Jones, and Brady)

Truncorotalia lineage
***Tr. crassaconica* (Hornibrook)**
Tr. crassaformis (Galloway and Wissler)
Hr. juanai (Bermudez and Bolli) → ***Truncorotalia juanai***
***Tr. neojuanai* Crundwell n. sp.**

Neogloboquadrina lineage
Nq. continuosa (Blow) → ***Nq. mayeri continuosa***
Nq. dutertrei (d'Orbigny)
Gr. (Jn.) mayeri mayeri (Cushman and Ellisor) → ***Nq. mayeri mayeri***
***Nq. mayeri nympha* (Jenkins)**
Nq. pachyderma (Ehrenberg)

ISSUES OF PHYLOGENY AND CLASSIFICATION

Raising the status of subgenera to genera

The introduction by Kennett & Srinivasan (1983) of subgenera for certain Neogene planktic foraminiferal lineages (e.g. *Globorotalia* and *Globigerina*) was viewed, at the time, as an intermediate step toward recognition of separate phylogenetic lineages of Cenozoic planktic foraminifers at the full generic ranking. In raising the status of lineages encountered in this thesis, from subgeneric rank to full generic rank, the author acknowledges this concept. This follows the example of various workers (e.g. Cifelli & Scott 1986; Wei 1994; Eijden 1995; Schneider & Kennett 1996; Li & McGowran 2000; Winter & Pearson 2001) that have used full generic ranking for at least some, or all, of the "phylogenetic lineages" used in this thesis. Raising the rank of a valid subgenus, to the level of a genus, is consistent with the rules of the International Code of Zoological Nomenclature and requires no formal procedure.

In raising the rank of the various subgenera proposed for *Globorotalia,* the author does not agree with Loeblich & Tappan (1988) who synonymize them on the basis that the postulated lineages are contemporaneous and not morphotypically distinct. It is significant that they do not document their case, and with respect to the latter statement at least, they do not take into account differences in surface ultrastructure that are associated with some lineages (Fleisher 1974; Kennett & Srinivasan 1983).

Species concepts relating to the *Globoconella* lineage

The *Globoconella* lineage, especially the evolutionary series *Gc. conomiozea* → *Gc. sphericomiozea* → *Gc. puncticulata* is considered by most biostratigraphers to represent a continuum of variation linking successive species. Within this multidimensional-morphospace, neither the holotype, nor the paratypes determine the content of the species; the majority of individuals fall outside the range of variation represented by the "types".

Kennett (1966) in describing *Globorotalia conomiozea* as a new species, included strongly keeled, weakly keeled, and unkeeled forms, in his species concept, as well as forms with different "conical angles" (60-80°), and different numbers of chambers in the outer whorl. The embodiment of such variation is in keeping with the modern biological concept for *Globoconella conomiozea*, but is at odds with the classical typological approach to classification. It is also significant that the subgenus *Globorotalia (Globoconella)* Kennett & Srinivasan, 1983, was originally based on considerations of surface ultrastructure and phylogeny, and not traditional typological criteria, such as the presence of an imperforate carina (Bolli 1957), or the location and modifications of the aperture (Banner & Blow 1959; Blow 1969, 1979).

In the case of the *Globoconella* lineage, where the phylogenetic relationships of fossil species are well understood, the ability of individuals to reproduce, and the uniqueness of genotypes, cannot be used to determine the content of a species. As a consequence, it is necessary to define the limits of species based on evolving morphological criteria that are simple to measure (e.g. presence or absence of a keel, chamber number). In this context, the limits of the species are somewhat arbitrary, but as long as the morphological limits of the species are clearly defined, the species can be used consistently by different workers. This philosophy is used in this thesis for all species of *Globoconella*.

Use of *Neogloboquadrina, Jenkinsella*, and *Paragloborotalia*

Various workers have assigned latest Paleogene to Neogene turborotalid forms, with cancellate surface wall textures, to *Neogloboquadrina, Paragloborotalia,* and *Globorotalia (Jenkinsella),* although there is no consensus surrounding the ancestry of such forms.

- *Neogloboquadrina* Bandy, Frerichs, and Vincent, 1967: type species *Globigerina dutertrei* d'Orbigny, 1839.
- *Globorotalia (Jenkinsella)* Kennett & Srinivasan, 1983: type species *Globigerina siakensis* LeRoy, 1939.
- *Paragloborotalia* Cifelli, 1982: type species *Globorotalia opima* subsp. *opima* Bolli, 1957.

The restriction by some workers of the name *Neogloboquadrina* Bandy, Frerichs, and Vincent, to specimens with distinct tooth-like apertural flaps, as found in the type species *Globigerina dutertrei* d'Orbigny, is contrary to the original designation of Bandy *et al.* (1967), who also used the name for forms without tooth-like apertural flaps that they considered to be ecophenotypic variants. In this "population" context, tooth-like apertural flaps were clearly not considered to be a distinctive morphological feature of

Neogloboquadrina. This is consistent with the broadened species concept of Kennett & Srinivasan (1983), and other workers, who have included all species descended from and including *Globorotalia opima* Bolli subsp. *continuosa* Blow, 1959.

Kennett & Srinivasan (1983) proposed the new subgenus *Globorotalia (Jenkinsella)* for a continuous group of forms that they considered to be phylogenetically unrelated to *Neogloboquadrina,* and included in this group a number of taxa, including *Globigerina siakensis* LeRoy and *Globorotalia mayeri* Cushman and Ellisor. Contrary to this view, Bolli & Saunders (1982) consider *Globigerina siakensis* LeRoy to be a junior synonym of *Globorotalia mayeri* Cushman and Ellisor, 1939 and *Globorotalia opima continuosa* Blow to be a four-chambered variant of *Globorotalia mayeri* Cushman and Ellisor. This latter view, at least, which based on a reinvestigation of type material, is consistent with the continuum of variation that exists in large, late Miocene, assemblages from the New Zealand region. In this context, the assignment by Kennett & Srinivasan (1983) of the above taxa to different genera (i.e. lineages) cannot be justified, and *Globorotalia mayeri* Cushman and Ellisor is reassigned in this thesis to *Neogloboquadrina.*

Most workers consider *Globorotalia (Jenkinsella)* Kennett & Srinivasan, 1983 to be a junior homonym of *Paragloborotalia* Cifelli, 1982, although the use of either name can only be justified if the forms that are assigned to these genera are phylogenetically unrelated to *Neogloboquadrina* Bandy, Frerichs, and Vincent. This is a contentious issue, which requires a better understanding of the evolutionary development of cancellate surface ultrastructure in forms that have been variously assigned to *Paragloborotalia* and *Neogloboquadrina*.

Use of *Zeaglobigerina* and *Globoturborotalita*

The question as to whether *Zeaglobigerina* or *Globoturborotalita* has priority for cancellate specimens of the lineage that includes *Globigerina woodi* Jenkins, 1960 is a contentious issue that arises from uncertainty concerning the ancestry of *Globigerina rubescens* Hofker, 1956. Hofker (1977) described *Globoturborotalita* with the type species being *Globigerina rubescens* Hofker, 1956, and Kennett & Srinivasan (1983) subsequently described the subgenus *Globigerina (Zeaglobigerina)* with *Globigerina woodi* Jenkins, 1960 as the type species. Although Kennett & Srinivasan (1983) provisionally included *Globigerina rubescens* as an end member in *Globorotalia (Zeaglobigerina),* they were

uncertain of its phylogenetic link to the subgenus. This was largely because of the *Globigerinoides*-like surface ultrastructure and its possible phylogenetic relationship with *Globigerinoides tenellus* Parker, 1958. Until this uncertainty is resolved, *Globoturborotalita* cannot be deemed to have priority over *Zeaglobigerina.*

Use of *Hirsutella* and *Obandyella*

Haman *et al.* (1981) proposed *Obandyella* as a new name for *Hirsutella* Bandy, 1972 (Foraminiferida), because the name was preoccupied. It is a junior homonym of *Hirsutella* Cooper and Muir-Wood, 1951 (Brachiopoda). In this context, it is appropriate to use *Obandyella* for planktic foraminifers of the *Obandyella hirsuta* lineage. A different generic name, however, may be warranted for inflated scituline forms that were assigned by Kennett & Srinivasan (1983) to *Globorotalia (Hirsutella).* Cifelli & Scott (1986) considered such forms to be part of a different plexus.

Use of *Globoquadrina, Dentoglobigerina* and *Subbotina*

The basis for the use of *Globoquadrina* that is adopted in this study is argued in Kennett & Srinivasan (1983). They assign taxa of the *Gq. tripartita*-lineage to *Globoquadrina* and taxa of the *Dn. galavisi*-lineage to *Dentoglobigerina.* These species form two distinct lineages that are phylogenetically unrelated and it is this concept that is adopted in this thesis.

On the generic assignment of *Gq. venezuelana,* the author also follows Kennett & Srinivasan (1983) in provisionally assigning this species to *Globoquadrina.* Its ancestry is unknown, although speculations are that it is probably related to *Gq. tripartita* (Fleisher 1974), or the *Subbotina lineaperta* group (Stainforth 1974).

Use of *Globoconella miotumida* and *Gc. conoidea*

Globoconella miotumida (Jenkins) is used throughout the study for the dominant globoconellid species in New Zealand late Miocene sequences, although Kennett & Srinivasan (1983) use the name *Globoconella conoidea* (Walters). The latter name is considered by Scott *et. al.* (1990) and other New Zealand workers to be a junior synonym of *Globoconella miotumida.*

Use of *Neogloboquadrina mayeri* s.l.

The use of *Neogloboquadrina mayeri* s.l. in this thesis is defined on page S2-46. The range of intraspecific morphotypic variation that is attributed to *Nq. mayeri* s.l., extends from forms with four and one-half full-sized chambers in the outer whorl [*Nq. mayeri continuosa* (Blow)], kummerforms with less than four and one-half chambers in the outer whorl (*Nq. mayeri nympha* (Jenkins), and forms with four and one-half chambers or more in the outer whorl [*Nq. mayeri* s.s. (Cushman and Ellisor)].

Such usage follows Bolli & Saunders (1982), who consider *Globorotalia continuosa* Blow to be a four-chambered variant of *Globorotalia mayeri* Cushman and Ellisor.

In defence of this population concept, it is significant that the stratigraphic ranges of all three morphotypes, of *Nq. mayeri* s.l., are the same at Site 593 (Data Appendix 1.1). The continuum of morphotypic variation in large, well preserved, assemblages at Site 593 is considered by the author to be consistent with the intraspecific variation of a single species. The use of *Nq. mayeri* s.l. in subsequent studies acknowledges this population concept and conveys a meaning for the HCO and HO of *Nq. mayeri* s.l. that may differ from the less well defined species concepts of other workers that consider *Globorotalia mayeri* Cushman and Ellisor, *Globorotalia continuosa* Blow, and *Globorotalia mayeri nympha* Jenkins, to be discrete taxa.

CONSIDERATIONS OF TAXONOMIC PHILOSOPHY

There is ongoing controversy surrounding the definitions and concepts of species used by biostratigraphers to elucidate the evolutionary record of fossil remains, especially in relation to gradually evolving populations where there is a degree of arbitrariness and ambiguity in the taxonomic method (Mayr 1982). A major failing of the classical typological method is that it uses a hierarchical system of morphological features that are perceived to be important at various levels of taxonomic classification and it largely ignores phylogenetic considerations.

The phylogeny of planktic foraminifers is well understood compared to most marine microfossil groups, and there is little debate surrounding the interrelationships of most Neogene forms, especially those that are abundant. This was the basis for the introduction

of a phylogenetic classification by Kennett & Srinivasan (1983), and it is also why a classification of this type has been adopted for use in this thesis.

Limits to species and genera

Workers such as John Ray and Carl Linnaeus, in the 1700's, believed in the essentialist species concept, where each individual organism was viewed as an imperfect reflection of the ideal form, or essence, that characterized the species to which it belonged. When naming a new species, a single "type" specimen was selected which was believed to exhibit the most important features of the species. This concept pervades all classical typological classifications. It is also entrenched in modern taxonomy, as the rules of the International Code of Zoological Nomenclature require a "type" to be nominated before a species is considered valid.

Nowadays, species are generally viewed as natural populations, or groups of individuals, which have a spectrum of genetic and morphological variability, but are united in being reproductively isolated from other groups (Mayr 1942). The typological method fails to recognize the extent of this biological diversity and determines species content on the basis of the "types" which are perceived, albeit falsely, to be somehow typical of the groups in which they are placed. In contrast, the modern biological species concept views mean values and ranges of variation as typical, and not one specimen, or group of specimens (Mayr *et al.* 1953). Consequently, in the biological context, species content is determined on the basis of artificial boundaries that cut through the morphological continuum. Such boundaries may be based on the range of variation encountered at different stratigraphic levels (chronospecies), or according to the morphological similarity of individuals (morphospecies), which is the underlying principle of the typological method (Pearson 1998).

In practise the criteria that determine species content of fossil groups, such as planktic foraminifers and bolboforms, may be based on statistical procedures, or chosen arbitrarily. It is more important, however, that the criteria that determine species content are clearly defined, and easy to apply, to ensure taxonomic consistency between biostratigraphers. Under the typological method, where species content extends beyond the "types", such consistency is often lacking.

Subjective and objective taxonomy [Distinguish between]

For taxonomy to be objective, in the strictest sense of the word, species content must be clearly defined, and to do so unambiguously, the multidimensional-morphological continuum (morphospace) that exists between phylogenetically related forms, must be partitioned in some way. Pearson (1998), notes, that there are two principle options for the subdivision of the morphospace between related forms. Populations can be subdivided according to the range of variation encountered at different stratigraphic levels (chronospecies), and individuals can be distinguished according to their morphological similarity (morphospecies). The latter, is essentially the principle behind the typological method of classification.

The principle source of subjectivity in taxonomy stems from the fact that morphology is multidimensional and it cannot be reduced to a single dimension, unlike time. In this respect, the determination of morphospecies content is inherently subjective, unlike the determination of chronospecies content. This is the philosophy behind the use of chronospecies concepts in this thesis.

Importance of types

Under the typological method, "types" are supposed to be name bearers, and also the bases on which group concepts are erected and the standards of comparison for those concepts. As noted previously, such concepts are entrenched in modern taxonomy as the rules of the International Code of Zoological Nomenclature require a "type" to be nominated before a species is considered valid.

Under the modern biological species concept, the "type" is primarily the name bearer, and it is no more typical of species content than any other individual that comprises a part of the species. It simply represents one point in the spectrum of morphological variation, or morphospace that is attributed to a species.

A VIEW POINT ON STAGES [Summarise personal views, e.g. Hornibrook "A view point on stages"]

The author concurs with the views expressed by Scott (1960), who provides an excellent review of the type locality concept in time-stratigraphy. In referring to New Zealand stages Scott maintains that – *"The composite nature of some stage definitions makes it clear that type localities do not hold a central position in the concept of these units, which are by*

nature homotaxial and rely on simple inductively-based inferences drawn from many sections. Apart from their function as name bearers, type localities are conceded no special importance, and definitions framed solely in terms of them are considered to be inadequate for the working of a homotaxial system."

The revised second edition of the International Stratigraphic Guide (Salvador 1994), which replaces Hedberg (1976), notes that a "stage" is a chronostratigraphic unit that is defined by its boundary-stratotypes (the Global Boundary Stratotype Section and Points, or GSSP's, of Cowie *et al.* 1986). Furthermore, the stratigraphic guide stipulates that the boundary-stratotypes of a stage should be within sequences of essentially continuous deposition. In this aspect at least, the stratotypes and reference sections for most New Zealand stages do not comply with the International Stratigraphic Guide – stage bases are often associated with known unconformites, where there are abrupt faunal changes.

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PUBLICATIONS AND PRESENTATIONS

In the course of this thesis, aspects of various studies have been presented at national and international conferences, and at an industry forum, and have been incorporated into a commercial report, and one co-authored paper has been published and another paper is in press, as follows:

Refereed publications

Cooke, P. J.; Nelson, C.S.; Crundwell, M. P.; Spiegler, D. 2002: *Bolboforma* as monitors of Cenozoic palaeoceanographic changes in the Southern Ocean. *Palaeogeography, Palaeoclimatology, Palaeoecology 188*: 73-100.

Crundwell, M. P. in press: A magnetostratigraphically-constrained chronology for Late Miocene bolboforms and planktic foraminifers in the temperate Southwest Pacific. *Micropaleontology*.

Commercial reports and presentations

Crundwell, M. 2000: Dating and correlating late Miocene sequences. New Zealand Concepts Workshop, New Plymouth (15-17 May 2000).

Crundwell, M. 2002: Miocene biostratigraphy of Pukearuhe-1. Client Report (Openfile), Geological and Nuclear Sciences, Lower Hutt. 24 p.

Conference publications and presentations

Crundwell, M. P.; Cooke, P. J.; Nelson, C. S. 1997: Bolboformids: Enigmatic microfossils in New Zealand late Miocene sediments. *Geological Society of New Zealand Miscellaneous Publication 95A*: 46.

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Study 1

Introduction to late Miocene planktic foraminifers and their distribution at DSDP Site 593

Introduction to late Miocene planktic foraminifers and their distribution at DSDP Site 593

ABSTRACT: This study provides an overview of the distribution of taxa identified in a census of late Miocene planktic foraminifers from DSDP Site 593, in the southern Tasman Sea, 470 km west of central New Zealand (41.5°S, 167.5°E; 1069 m water depth). It focuses on morphological variability and the criteria used to distinguish between closely related or morphologically similar taxa. These data provide a robust taxonomic framework for subsequent biostratigraphic and magnetobiochronologic studies. It also introduces a Neogene phylogenetic classification for planktic foraminifers based on Kennett & Srinivasan (1983) – the first time such a classification has been adopted for use in New Zealand.

A total of 931 samples have been examined, from the base of core 593-36X (336.60 mbsf) to the top of 593-14X at (120.30 mbsf). The interval spans c. 11.6-5.2 Ma, from the upper Waiauan to lower Opoitian, average sample spacing c. 7 k.y.

INTRODUCTION

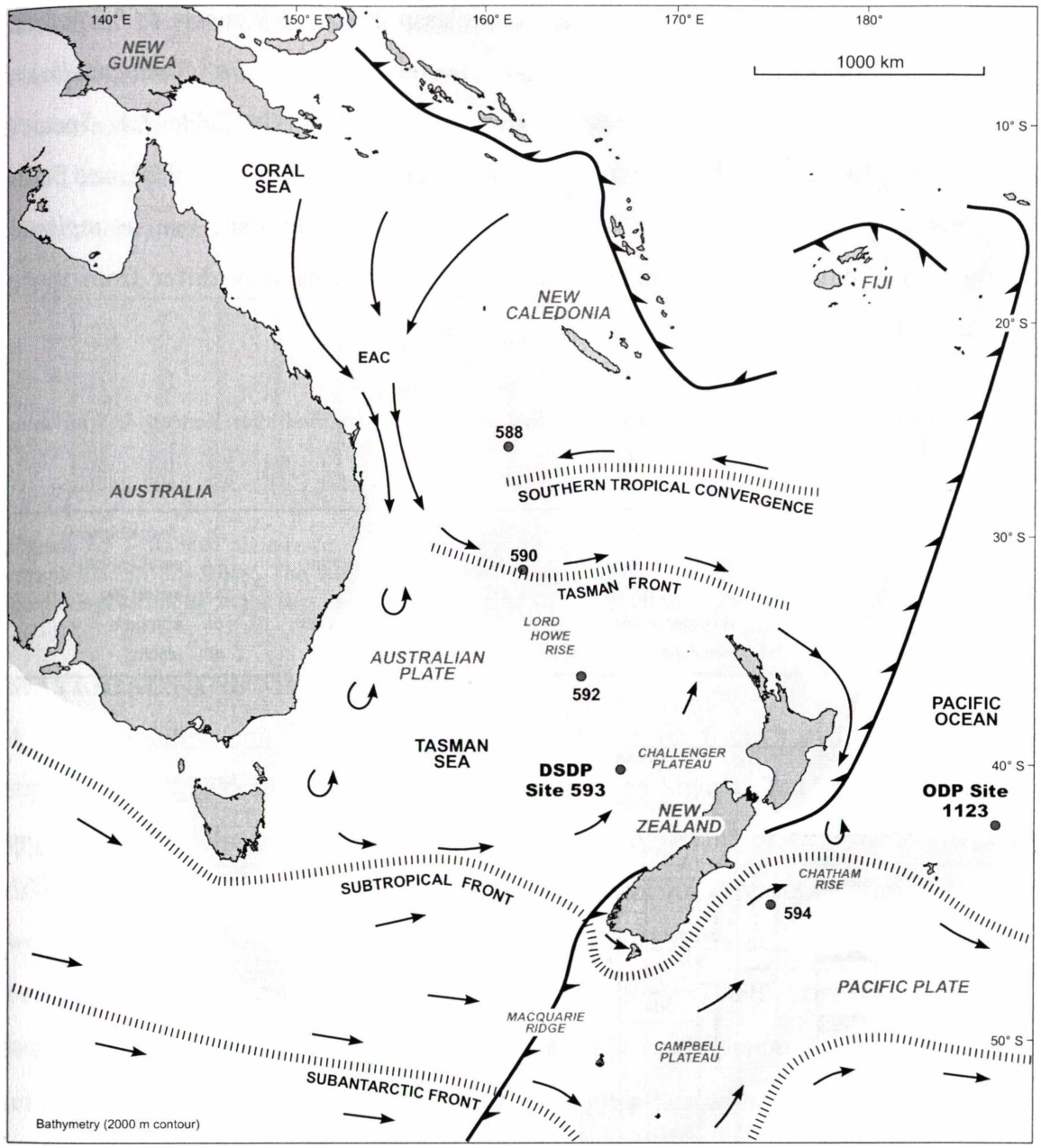
Methodology fundamental to census studies of planktic foraminifers differs from traditional biostratigraphic and paleoenvironmental studies in that it deals with populations and absolute abundances of taxa. As noted in a philosophical discussion of taxonomic considerations by Fleisher (1974, p. 1009):

> *"The necessity, in the paleontological application of Linnaean taxonomy, of fitting a continuously intergrading population of related forms into rigid nomenclatorial categories requires a multitude of subjective decisions concerning the degree of variation tolerable within a species unit. If a sequence of fossil faunas is being considered, the problem is one of defining the taxonomic limits to be placed on an evolving population."*

Despite this self-evident truism, the amount of variation that different workers tolerate within a "species unit" is seldom qualified, and as a consequence, there is often widespread confusion over the stratigraphic and paleoecological ranges of taxa. Biostratigraphic and environmental studies generally overcome this by focusing on holotypic proxies or "classic morphotypes" and ignoring the majority of specimens that fall outside this very limited range of morphological variation. Census studies on the other hand, require an antithetic approach that accommodates a wide range of morphological variation within relatively

small unbiased subpopulations. Special considerations are needed to minimize subjectivity while classifying individual specimens in representative aliquots, particularly small juvenile specimens that lack diagnostic adult features. Foremost, species concepts and morphologic tolerances have to be clearly defined and tailored to accommodate local ecophenotypic variability. This is most important when the taxonomic bounds of species have to be defined in terms of overlapping morphological populations. Consequently, the taxonomy utilized in this study is a compromise of traditional and utilitarian principles. To a great extent, taxa are assigned ranges of morphological variation based on diagnostic characteristics that are quick and easy to identify with the aid of a stereo-microscope.

The following taxonomic review of DSDP Site 593, a relatively shallow oceanic site (1069 m water depth) in the southern Tasman Sea, 470 km west of central New Zealand (Figure 1.1), qualifies species concepts and tolerances used in the compilation of census data for the site, and outlines general observations and elements of discussion relating to the taxonomy and stratigraphic distribution of species that are potentially useful for biostratigraphic subdivision of the late Miocene. Synonyms are not listed, but they can be found in more detailed taxonomic treatments by Jenkins (1971), Kennett & Srinivasan (1983), Cifelli & Scott (1986), Li (1987), and Scott et al. (1990). Taxa are discussed in alphabetical order and, unless otherwise stated, observations refer to specimens in the >150 µm fraction. All ages are quoted in terms of New Zealand onland stages (Morgans et al. 1996). Figure 1.2 shows the correlation of New Zealand stages with the International Age classification and global polarity time scale (GPTS-95, Cande & Kent 1995), as well as approximate correlations with the mid-latitude planktic foraminiferal transitional zonation of Berggren et al. (1983, 1995) and the calcareous nannoplankton zonation of Martini (1971). Assemblages of planktic foraminifers from twelve stratigraphic horizons spanning the late Miocene are illustrated in Plates 1.1–1.36. The images provide a visual guide to morphological variation and faunal change associated with common species. They have been arranged with particular reference to surface-ultrastructure and gross morphological features. Selected late Miocene species and morphological variants that are less common are illustrated in Plates 1.37–1.39.



Modern oceanic fronts and surface water masses after Cooke (2002)	Abbreviation	Neogene biogeography Kennett & Srinivasan (1983)		Late Miocene biogeography (THIS STUDY)	Example
		Subtropical		Subtropical	Site 588
SOUTHERN TROPICAL CONVERGENCE	**- STC -**	**- STC -**		**- STC -**	**- STC -**
Warm Subtropical Water	WSTW	Transitional	Cool subtropical assemblage		Site 590
TASMAN FRONT	**- TF -**	**- TF -**		Temperate	**- TF -**
Cool Subtropical Water	CSTW	Temperate			Sites 592, 593, 1123
SUBTROPICAL FRONT	**- STF -**	**- STF -**		**- STF -**	**- STF -**
Subantarctic Surface Water	SASW				Site 594
SUBANTARCTIC FRONT	**- SAF -**	Subantarctic		Subantarctic	**- SAF -**
Circumpolar Surface Water	CSW				Site 278 (56°33.7'S; 160°04.5'E)

Figure 1.1 – Location of DSDP Site 593, drilled during Leg 90 of the Deep Sea Drilling Project, and ODP Site 1123, drilled during Leg 181 of the Ocean Drilling Project. Modern bathymetry (light-grey areas <2000 m water depth), oceanic fronts and general circulation of surface water in the Tasman Sea region, after Heath (1985). EAC = East Australian Current. The relationships between modern oceanic fronts, surface water masses, and biogeography are given in the table beneath the location map.

The adopted taxonomy follows the phylogenetic classification of Kennett & Srinivasan (1983), except subgenera are raised in status to genera (e.g. *Globorotalia* (*Globoconella*) = *Globoconella*). Abbreviations for the adopted genera are given in Table 1.1. Species concepts are largely based on Hornibrook (1981, 1982), Hornibrook et al. (1989), and Scott et al. (1990), although some have been emended to facilitate their use in regional biostratigraphy (Study 2). Consequently some species concepts may differ from those employed by other biostratigraphers.

Table 1.1 – Adopted abbreviations for genera identified at Site 593, modified after Kennett & Srinivasan (1983).

Ga.	*Globigerinita*	*Gp.*	*Globigerinopsis*	*Mn.*	*Menardella*	*Zg.*	*Zeaglobigerina*
Gc.	*Globoconella*	*Gq.*	*Globoquadrina*	*Nq.*	*Neogloboquadrina*	s.s.	*sensu stricto*
Gd.	*Globorotaloides*	*Gr.*	*Globorotalia*	*Ob.*	*Orbulina*	s.l.	*sensu lato*
Ge.	*Globigerinella*	*Gs.*	*Globigerinoides*	*Ss.*	*Sphaeroidinellopsis*	cf.	compare
Gg.	*Globigerina*	*Hr.*	*Hirsutella*	*Tr.*	*Truncorotalia*	aff.	affinity

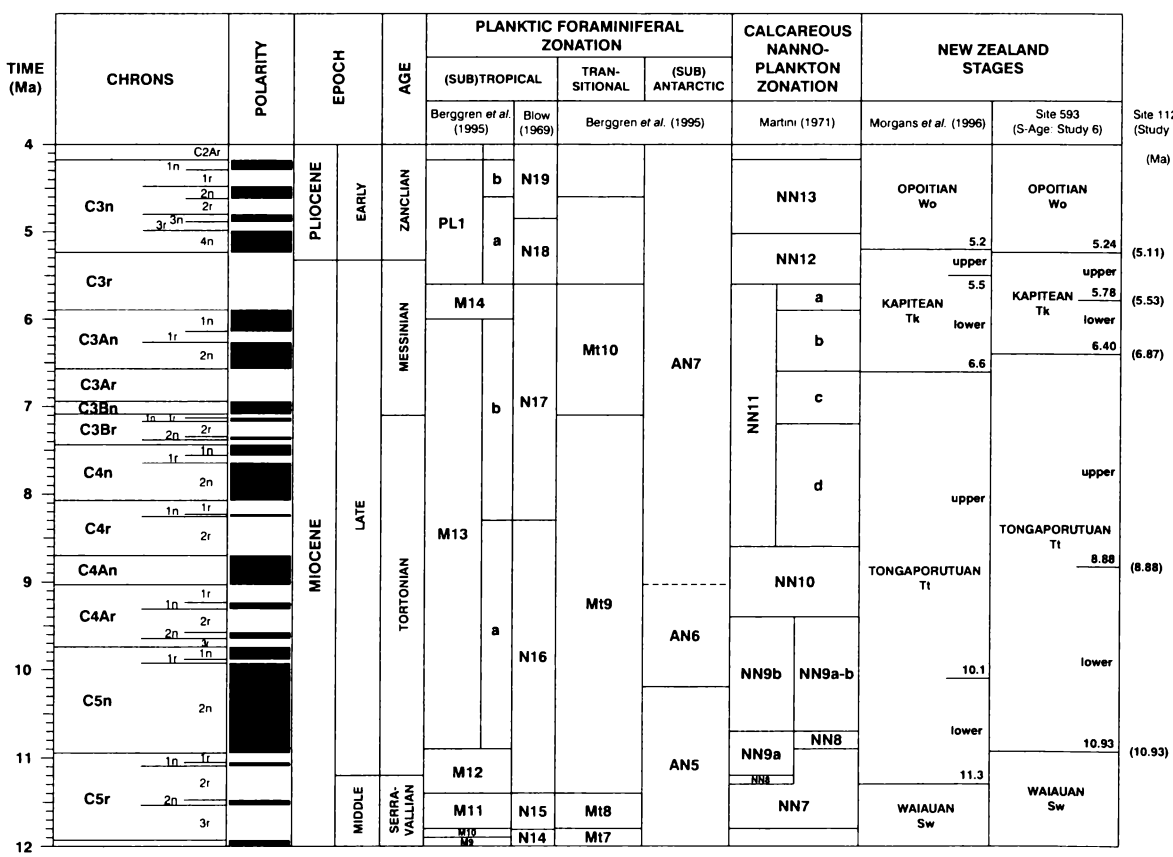


Figure 1.2 – Correlation of late Miocene planktic zonations from tropical-subtropical, temperate, and antarctic-subantarctic regions – see explanation of biogeography (Figure 1.1). New Zealand stages are reliably correlated, except for the Tongaporutuan-Kapitean boundary, using the S-Age model from Site 593 (Study 6). The younger part of the S-Age model differs from the magnetobiochronology of Site 1123 (Study 5) – ages given in brackets.

A total of 17 genera are recognized in this study. Eleven genera, namely *Zeaglobigerina, Globoconella, Globigerina* (*Gg. bulloides* group), *Neogloboquadrina, Hirsutella, Truncorotalia, Orbulina, Globigerinita, Globoquadrina, Menardella*, and *Globigerinoides,* reach abundances of 5% or more, although only the first five have average late Miocene abundances in excess of 5% (Figure 1.3).

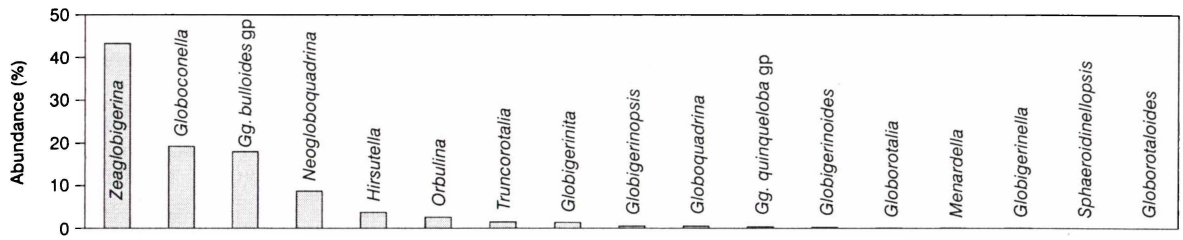


Figure 1.3 – Ranked abundance of genera, cores 593-14X to 593-36X (120.30–336.60 mbsf), based on census data in this study. The dominance of *Zeaglobigerina* contrasts with modern planktic foraminiferal assemblages from the in the seas around New Zealand where the clade is not represented (Hayward 1983).

MATERIALS AND METHODS

A high-resolution suite of samples, comprising 931 (c. 6 cm^3) cylindrical core plugs supplied by the Ocean Drilling repository in College Station, Texas, were prepared for quantitative micropaleontological analysis. Nominally 4 cm^3 of each sample was oven dried for 24 hours at 35° C, then cooled in a desiccator for at least one hour, before being weighed. Samples were then transferred to 50 ml conical flasks and soaked in 40 ml of buffer distilled water (pH c. 9.4), as per Dudley & Nelson (1989). After soaking overnight, samples were washed over a 63 μm-mesh screen. The mud fraction (<63 μm) was retained and allowed to settle before being transferred to glass jars with buffer distilled water, for archival storage. The sand fraction (>63 μm) was rinsed with distilled water and air dried, then sieved into fine sand (63-150 μm) and coarse sand (150 μm) fractions, and weighed. The coarse fraction was then divided with a microsplitter for separate microfossil and stable oxygen and carbon isotope analysis (Cooke 2002).

Census data

Microfaunal residues were sieved over a 150 μm-mesh screen to remove any remaining fines, then weighed and divided with a microsplitter to obtain unbiased aliquots with about 300 to 600 foraminifers. Suitable aliquots were weighed and spread on a picking tray and all biogenic and non-biogenic material was picked and mounted onto faunal slides in predetermined order (Table 1.2). Picked categories included planktic and benthic

foraminifers, bolboforms, ostracods, fish teeth, mollusc fragments, echinoid spines and plate fragments, and grains of pyrite, dolomite, celestite, and gypsum. Fragments of foraminifers less than 65% complete were transferred to separate slides and counted in order to determine fragmentation ratios.

Table 1.2 – Faunal map of census slides giving the distribution of taxa and miscellaneous biogenic and non-biogenic material mounted on 32-box faunal slides.

Box No.	Taxon	Box No.	Taxon
1–5	*Globoconella*	17–18	*Neogloboquadrina*
6–8	*Truncorotalia*	19–20	*Globigerinita, Globoquadrina, Globorotaloides, Sphaeroidinellopsis*
6–8	*Hirsutella*	20	*Gg. quinqueloba* gp, *Globigerinoides*
8	*Menardella, Globorotalia*	21	*Globigerinella, Globigerinopsis*
9–12	*Zeaglobigerina* sp.	22–23	*Globigerina sp.* (*Gg. bulloides* gp)
13–14	*Zeaglobigerina woodi*	24	*Globigerina bulloides/falconensis*
15	*Zeaglobigerina apertura/decoraperta*	25–31	Benthic foraminifers
12, 15	*Zeaglobigerina nepenthes*	31	Miscellaneous biogenic material
16	*Orbulina*	32	Miscellaneous biogenic and non-biogenic material

Initially, every tenth sample was examined (c. 2 m spacing) to identify the range of morphological variation associated with planktic assemblages and to establish tolerable species limits. Representative specimens of taxa noted in the pilot study were mounted on reference slides and compared with published type descriptions and reference material in national micropaleontological collections maintained by Geological and Nuclear Sciences (GNS), Lower Hutt, to ensure correct taxonomic assignment and consistent identification throughout the section. After reviewing textural and microfaunal pilot data, key intervals were selected for high resolution study (c. 20 cm sample spacing) and remaining intervals were worked up at a nominal spacing of c. 40 cm. Identifications and counts were recorded with the aid of a PC-based biostratigraphic data entry program developed by George Scott (GNS). During the census, sinistral- and dextral-coiled variants of selected globorotaliids, encrusted and crust-free variants of selected species, and distinctive variants of selected species were treated as discrete taxonomic entities. On completion, raw census data were reformatted as a spreadsheet and checked and edited prior to detailed analysis (Appendices 1.1 and 1.2).

Supplementary data

Census data were supplemented with random scans of at least 5000 specimens in the >150 μm fraction of all 931 samples – average stratigraphic spacing 20 cm (c. 7 k.y.) – to identify rare species, to verify the appearances and disappearances of important taxa, and to

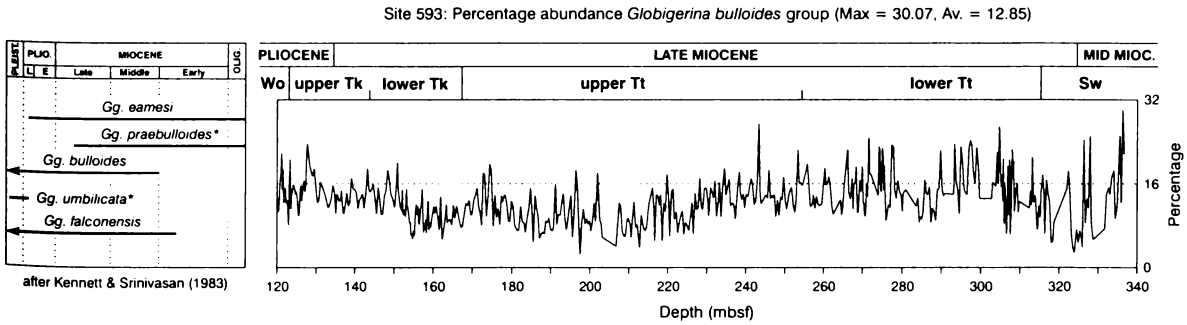
improve the reliability of coiling data where census counts of specimens were low. Supplementary coiling data were compiled for species associated with the *Globoconella miotumida* bioseries (*Gc. miotumida* – *Gc. conomiozea* – *Gc. sphericomiozea* – *Gc. puncticulata*). This included counts of about 100 specimens (>150 μm) found in random scans of aliquots spread over a picking tray – Data appendix 1.3. Further counts of specimens in three size fractions (63-150 μm, 150-250 μm, and >250 μm) were also made from three short intervals with significant contributions of dextral shells to see if there was any relationship between ontogeny and coiling. Supplementary coiling data were also compiled for *Neogloboquadrina* in the vicinity of coiling excursions and where specimen counts were low – Appendix 1.4.

All materials resulting from this study, including faunal slides, are deposited in the DSDP/ODP micropaleontological reference collections maintained by Geological and Nuclear Sciences, Lower Hutt, New Zealand.

TAXONOMIC NOTES

GLOBIGERINA – *Gg. bulloides* group

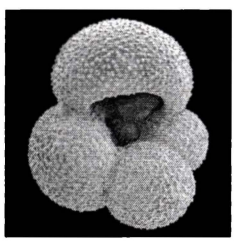
The use of *Globigerina* in this study is based on the subgeneric classification of Kennett & Srinivasan (1983), although the subgenus is raised to the status of a genus. The genus *Globigerina* includes only spinose globigerine species and excludes forms with a cancellate surface-ultrastructure (i.e. pore pits or interpore ridges), which are here included in *Zeaglobigerina.* The finely spinose, low trochospiral species *Gg.* cf. *angustiumbilicata* and *Gg. quinqueloba* are associated with a different lineage to the globose species of *Globigerina* (Kennett & Srinivasan 1983) and are discussed separately from the *Gg. bulloides* group.

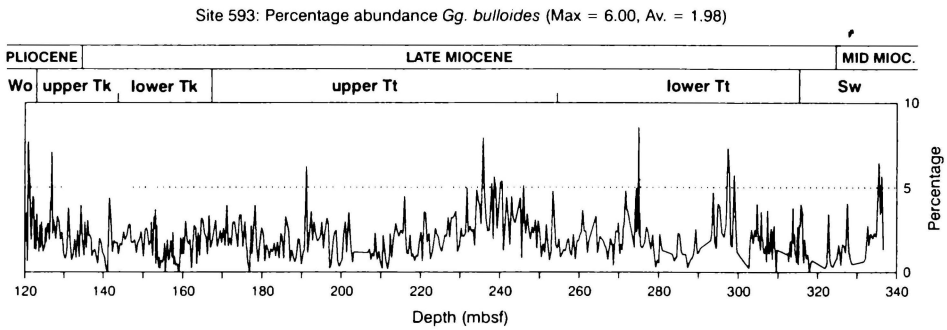


Globigerina is very common in all late Miocene assemblages and is the third most abundant genus overall (Figure 1.3). Abundances are generally higher in the lower Tongaporutuan and upper Kapitean than at any other part of the late Miocene.

Globigerina bulloides d'Orbigny

1826 *Globigerina bulloides* d'Orbigny, p. 277 (no figure) list No. 1 (fide Ellis & Messina, 1940, *et seq.*).





Plates: 1.1/1, 1.4/1, 1.7/1, 1.10/1, 1.13/1, 1.16/1-2, 1.19/1, 1.22/1, 1.25/1, 1.28/1, 1.31/1, 1.34/1–2.

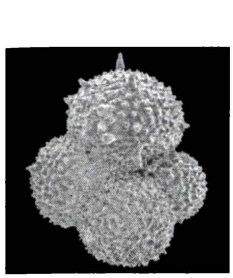
Remarks: As an adjunct to high-resolution stable isotope studies (Cooke 2002), use of the name *Globigerina bulloides* was restricted to hispid specimens of moderate size with open high-arched symmetrical apertures. This differs from previous quantitative and semi-quantitative studies at DSDP Site 284 and Site 593, where a wider range of morphological variation was tolerated (Jenkins 1975; Kennett & Vella 1975; Jenkins & Srinivasan 1986). These earlier studies included forms with moderately oblique apertures and low-arched apertures similar to *Gg. praebulloides* Blow – such forms are here assigned to *Globigerina* sp.

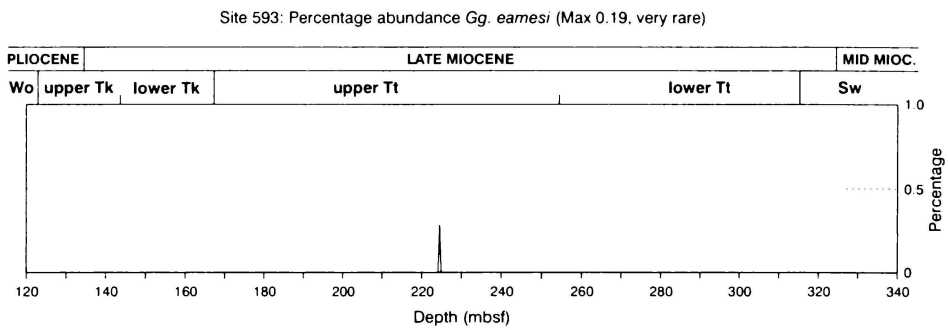
Some specimens of *Globigerina bulloides* are difficult to separate from moderate sized specimens of *Globigerinopsis obesa* (e.g. Plates 1.13/1 and 1.13/14). The species clearly differ in terms of their surface-ultrastructure when viewed under a SEM, but in the census there was a necessity to focus on distinguishing morphological characters that could easily be observed with a stereomicroscope. In general, *Gg. bulloides* has a smaller, more compact test, with a lower rate of chamber expansion, and the aperture is aligned with the antepenultimate chamber, whereas in *Gp. obesa* the aperture is more oblique. Intermediate forms that could not be confidently assigned to either taxon are included in *Gp. obesa*? The identification problem is important as *Gg. bulloides* is commonly used in stable isotope studies of mid- to high-latitude Neogene sequences and failure to correctly identify the species has the potential to introduce spurious isotope values when dual species mixes are used.

Distribution: A relatively common species that occurs in most late Miocene samples. Compared to this study, Kennett & Vella (1975) noted significantly higher abundances through the late Miocene of DSDP Site 284 – the site reoccupied by Site 593. This is attributed to the coarser >175 μm fraction that they examined and the more restricted species definition used here (see above).

Globigerina eamesi Blow

1959 *Globigerina eamesi* Blow, p. 176, pl. 9, figs. 39a-c.





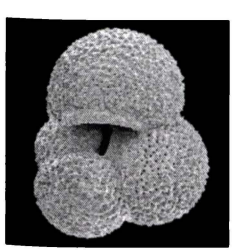
Plates: 1.10/3, 1.28/3.

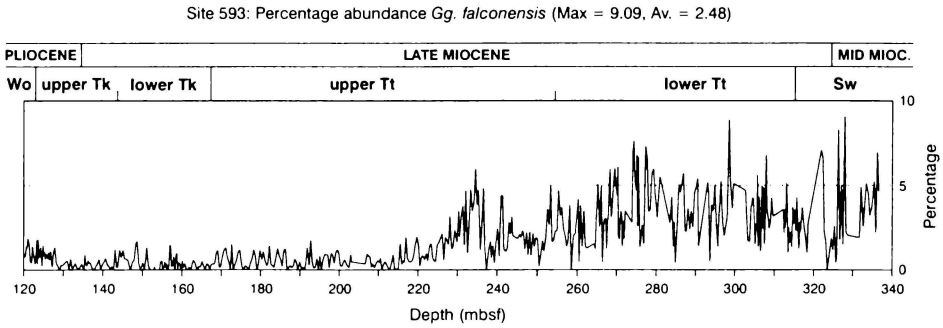
Remarks: Typical specimens of *Globigerina eamesi* are extremely rare and only one specimen was noted in the census. Very small specimens were noted with four chambers in the outer whorl, finely hispid surfaces, and small thin-lipped umbilical apertures, but they lack the large scattered spine bases that are typical of *Gg. eamesi.* Due to the taxonomic uncertainty surrounding these specimens they are assigned to *Globigerina* sp.

Distribution: Very rare specimens were noted throughout the late Miocene in supplementary scans of >150 μm bulk residues, but the species is more common in the 63-150 μm fraction.

Globigerina falconensis Blow

1959 *Globigerina falconensis* Blow, p. 177, pl. 9, figs. 40-41.



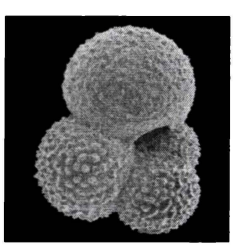


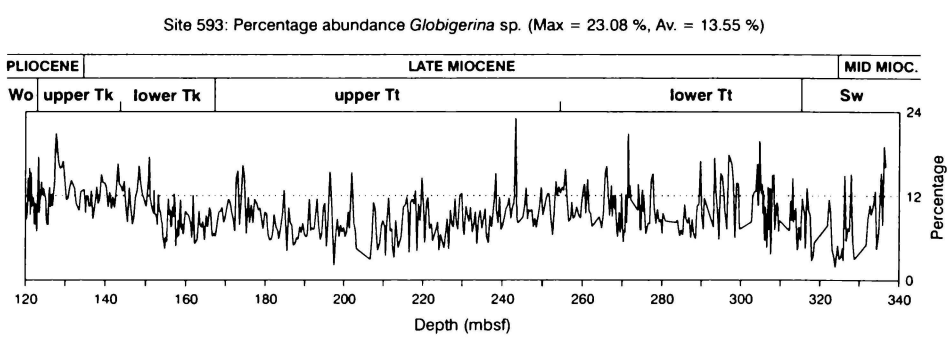
Plates: 1.1/2, 1.4/2, 1.7/2–3, 1.10/2, 1.13/2, 1.16/3, 1.19/3–4, 1.22/2, 1.25/2, 1.28/2, 1.31/2, 1.34/3.

Remarks: Use of the name *Globigerina falconensis* was limited in this study to moderate sized, four-chambered specimens, with a perforate, finely spinose surface ultrastructure, and an intraumbilical aperture with a distinct linear or gently curved apertural lip. The apertural lip is orthogonal to the leading edge of the lip of the penultimate chamber and forms a T-like intersection (Plates 1.1/2 and 1.13/2). In most adult specimens the final chamber is slightly kummerform and positioned lower over the umbilicus than earlier chambers. Small specimens were also noted with larger final chambers and well developed, relatively straight apertural lips (Plate 1.7/3-4). It is possible that they are juveniles of *Gg. falconensis,* but they are here assigned to *Globigerina* sp. on the basis that they lie outside the acceptable range of morphological variation.

Distribution: *Globigerina falconensis* is a relatively common late Miocene species, particularly in assemblages below 230 mbsf. Above this level, there is a three-fold decrease in the species overall abundance. Kennett & Vella (1975) noted higher abundances throughout the late Miocene at DSDP Site 284, but they examined a coarser >175 μm fraction and they accepted a wider range of morphological variation.

Globigerina sp.





Plates: 1.1/3–4, 1.4/3–5, 1.7/4–6, 1.10/4–5, 1.13/3–4, 1.16/4–6, 1.19/5–6, 1.22/3–4, 1.25/3, 1.28/4–6, 1.31/3–4, 1.34/4.

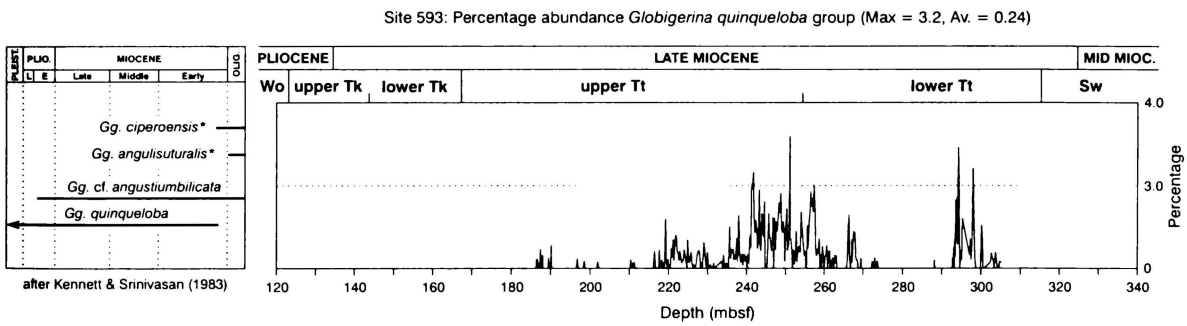
Remarks: An eclectic group of hispid globigerine species that do not fit within the tolerable morphological limits of species already described, particularly juveniles that lack diagnostic adult morphological characteristics. The collective includes morphotypes that resemble *Gg. praebulloides* Blow, *Gg. foliata* Bolli, *Gg.* aff. *eamesi*, and possible juveniles of *Gg. bulloides* and *Gg. falconensis*. Separation of these morphotypes is beyond the scope of this study. Low trochospiral specimens with four chambers in the outer whorl and

interiomarginal umbilical-extraumbilical apertures, similar to *Neogloboquadrina pachyderma,* are also assigned to *Globigerina* sp. on the basis of their spinose surface ultrastructure (Plate 1.13/3).

Distribution: Species that are collectively assigned to *Globigerina* sp. comprise a major part of all late Miocene assemblages, but abundances are generally higher in the lower Tongaporutuan and upper Kapitean.

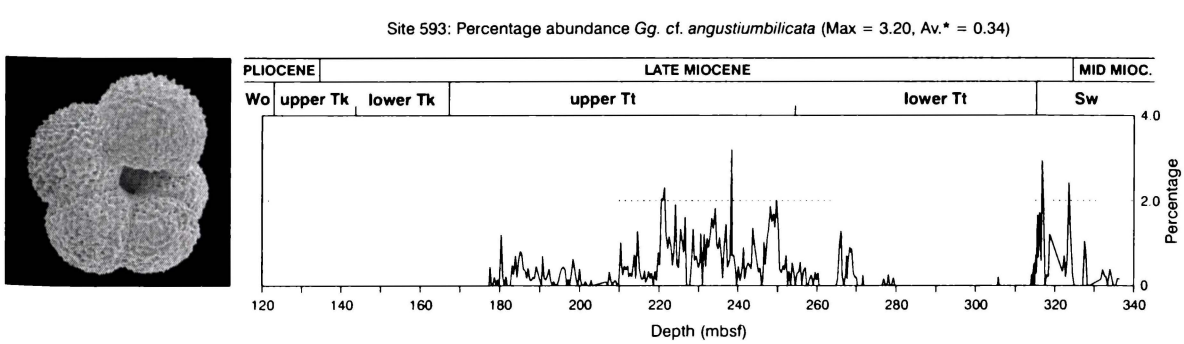
GLOBIGERINA – Gg. quinqueloba group

Kennett & Srinivasan (1983) identify two main lineages of spinose globigerine species: *Gg. praebulloides – Gg. bulloides* and *Gg. angustiumbilicata – Gg. quinqueloba.* To highlight this distinction, species of the latter lineage are discussed here as a separate phylogenetic group. The group includes forms with low to medium trochospiral tests and four to five chambers in the outer whorl, and low-arched interiomarginal, umbilical apertures.



Globigerina cf. *angustiumbilicata* (Bolli)

1957 *Globigerina ciperoensis angustiumbilicata* Bolli, p. 109, pl. 22, figs. 12a-13c.



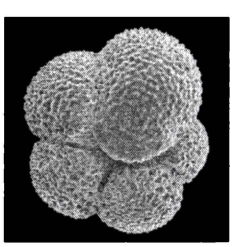
Plates: 1.4/7, 1.7/7, 1.13/7–8, 1.19/8, 1.22/9–11, 1.25/5–7, 1.28/4–5, 1.31/7–9, 1.34/5–6, 1.37/5–7.

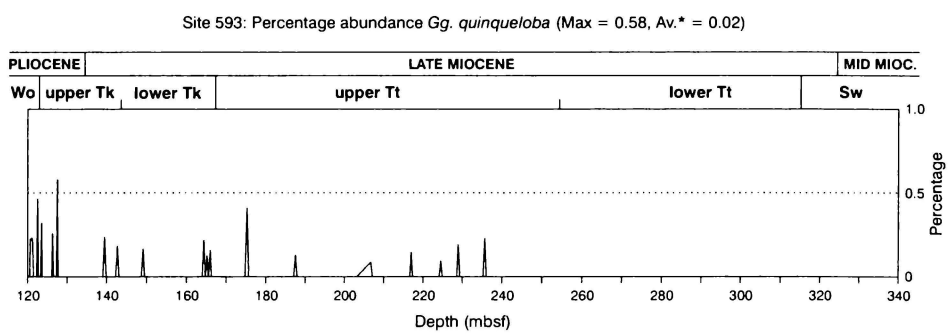
Remarks: The name *Globigerina* cf. *angustiumbilicata* is employed here for small spinose forms with a low trochospiral test and four and one-half to five chambers in the outer whorl, a low-arched interiomarginal, umbilical aperture, and a distinctly open umbilicus. Such forms superficially resemble *Tenuitellinata angustiumbilicata*, but they have finely perforate and spinose test walls, whereas *Tn. angustiumbilicata* has a densely microperforate and pustulate surface ultrastructure (Li 1987).

Distribution: *Globigerina* cf. *angustiumbilicata* constitutes a small, but relatively persistent component of late Miocene assemblages below 593-19X-7, 22-25 cm (177.52 mbsf). It is more common in the 63-150 um size fraction.

***Globigerina quinqueloba* (Natland)**

1938 *Globigerina quinqueloba* Natland, p. 146, pl. 6, figs. 7a-c.





Plates: 1.1/5, 1.4/6, 1.7/8–9, 1.10/6–7, 1.13/5–6, 1.16/7–8, 1.19/7–8.

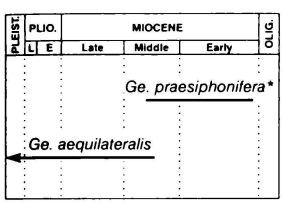
Remarks: Specimens assigned to *Globigerina quinqueloba* are similar to *Gg.* cf. *angustiumbilicata* and have a small, low trochospiral test, with four and one-half to five chambers in the outer whorl, and a finely spinose, microperforate surface ultrastructure. *Globigerina quinqueloba* is distinguished, however, in having a distinctive umbilical flap-like extension of the final chamber that sometimes covers the umbilicus. Chamber outlines are lobate in equatorial view and tend to be slightly asymmetric. Encrusted specimens with a thick layer of secondary calcite sometimes have deep, almost canal-like sutures (Plate 1.7/7–8) and bear a superficial resemblance to *Gg. angulisuturalis*.

Distribution: *Globigerina quinqueloba* is poorly represented in the late Miocene on account of its very small size. In the census it is first noted in assemblages above 593-26X-1, 23-25 cm (235.73 mbsf), but supplementary searches of the 63-150 μm size fraction suggest it is present in most late Miocene samples, including those below 235.73 mbsf. It is

uncertain if the entry of the species in the census is due to increases in the species abundance or test size.

GLOBIGERINELLA

Cushman (1927) erected the genus *Globigerinella* for finely hispid forms with an initial trochospiral test that later becomes nearly planispiral in the adult. The genus *Globigerinella* is considered by Kennett & Srinivasan (1983) to have evolved from *Globigerina praebulloides* in the late Oligocene. Two main lineages are recognized: *Ge. praesiphonifera – Ge. aequilateralis* and *Ge. obesa – Ge. pseudobesa.* Only the former lineage is here included in *Globigerinella* and the latter is included in *Globigerinopsis* (Bolli 1962). Both genera have a finely spinose, densely perforate surface ultrastructure.



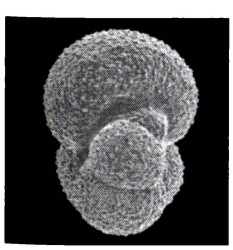
after Kennett & Srinivasan (1983)

Distribution and abundance - see *Ge. aequilateralis* (below)

The genus *Globigerinella* is noted by Kennett & Srinivasan (1983) to possess spines that are initially rounded and become triradiate with later growth, whereas the closely related genus *Hastigerina* has spines that are triradiate in all stages of growth.

Globigerinella aequilateralis (Brady)

1879 *Globigerina aequilateralis* Brady, p. 285, figures in Brady (1884), pl. 80, figs. 18-21.



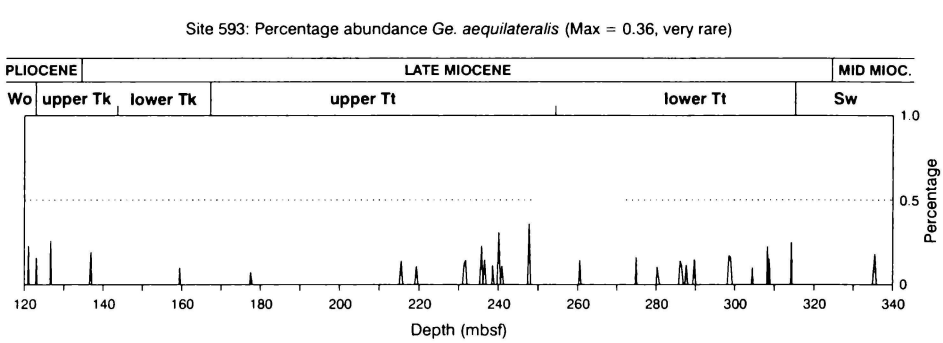


Plate: 1.37/1.

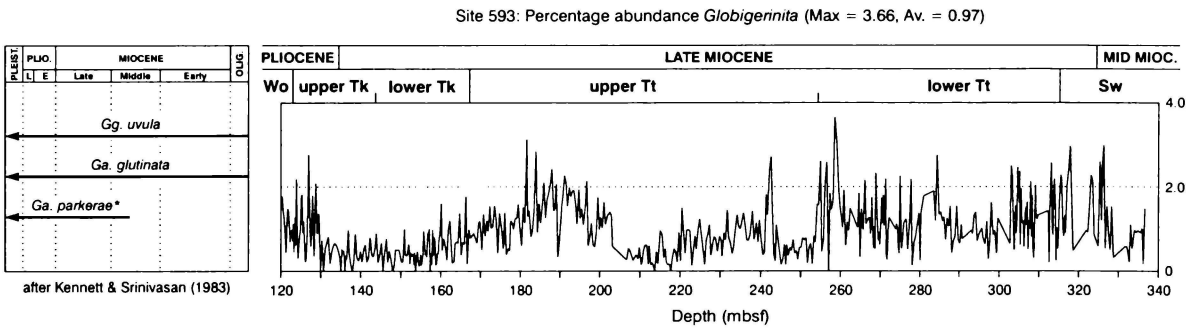
Remarks: Typical *Globigerinella aequilateralis* with five or more chambers in the outer whorl and a spiral-umbilical apertural habit was not observed during the census, but forms were noted with low trochospiral shells, with a low-rate of chamber expansion and with interiomarginal, umbilical-extraumbilical apertures that approach the spiral side. The

surface ultrastructure is similar to *Ge. aequilateralis*, although most specimens have less than five chambers in the outer whorl. Specimens with more than four and one-half chambers in the outer whorl are assigned to *Ge. aequilateralis,* and those with less chambers are assigned to *Ge. aequilateralis*?

Distribution: The species occurs throughout the late Miocene, but it is extremely rare.

GLOBIGERINITA

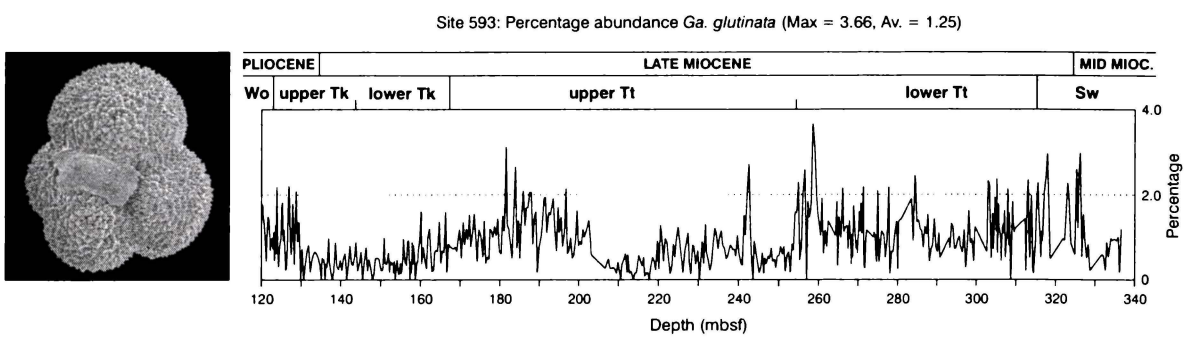
The genus *Globigerinita* was erected by Brönnimann (1951) and subsequently emended by Blow & Banner (1962). The genus evolved from *Tenuitellinata* in the Late Oligocene (Li 1987) and is characterized by small forms with a microperforate test and small pustules that cover an otherwise smooth surface. A bulla is often, but not always present.



Globigerinita constitutes a small but persistent component of late Miocene assemblages, but is generally more common in the lower and uppermost Tongaporutuan and uppermost Kapitean.

Globigerinita glutinata (Egger)

1893 *Globigerina glutinata* Egger, p. 371, pl. 13, figs. 19-21.



Plates: 1.1/6–7, 1.4/8–9, 1.7/10–11, 1.10/8–9, 1.13/9–11, 1.16/9–10, 1.19/12, 1.22/8–9, 1.25/6, 1.28/10–11, 1.31/7–8, 1.34/8.

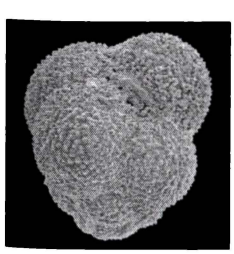
Remarks: The name *Globigerinita glutinata* is employed here for small, medium- to low-spired specimens, with four chambers in the outer whorl and finely pustulate, microperforate test walls. Bullate and non-bullate forms are included in the species. The bulla is highly varied in its development, ranging from small umbilical flaps (Plate 1.4/8) to large blister-like structures with sutural lobes and infralaminal apertures (Plate 1.19/12). *Globigerinita glutinata* displays considerable variation in the rate of whorl translation along the coiling axis, and high-spired specimens (*Ga. uvula*) are considered to be end-members in this range of morphological variation. In view of the apparent morphological intergrade, and the identical stratigraphic and latitudinal distributions of the species (Kennett & Srinivasan 1983), it is likely that the low-spired and high-spired forms represent a single genotype. They are distinguished here on the basis of a simple ratio – the length of the coiling axis (L) over the maximum spiral diameter (D). In *Ga. glutinata* the L/D ratio is less than or equal to one, and in *Ga. uvula* the ratio of L/D is greater than one.

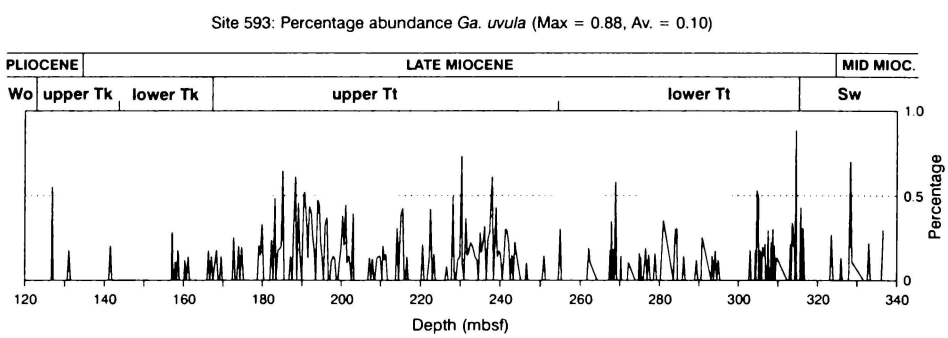
Most specimens of *G. glutinata* are thin-walled, but rare individuals are encrusted and have a thick secondary layer of calcite covering chamber walls and the bulla. In some specimens this causes the pustules to coalesce and form a pseudo-cancellate surface (Plates 1.13/10 and 1.13/11).

Distribution: *Globigerinita glutinata* occurs in most late Miocene samples, but it constitutes only a minor part of assemblages. It is slightly more common in the lower Tongaporutuan, uppermost Tongaporutuan, and uppermost Kapitean. It is also notably more common in the 63-150 μm fraction.

Globigerinita uvula (Ehrenberg)

1861 *Pylodexia uvula* Ehrenberg, 1861: p. 206, 207, 308; figures in Ehrenberg 1873, pl. 2, figs. 24 and 25.





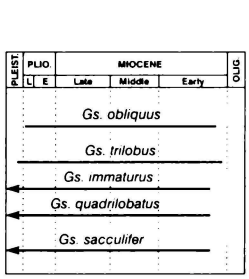
Plates: 1.7/12, 1.10/10–11, 1.13/12, 1.28/12, 1.31/9, 1.34/9.

Remarks: A small tenuitellid with a finely pustulate microperforate test. It is considered here to represent a high-spired end-member within the variation field of *Ga. glutinata*. Use of the name *Ga. uvula* is restricted here to specimens where the length of the coiling axis (L) exceeds the maximum spiral diameter of the test (D). Specimens with L/D ratios of less than or equal to one, are included in *Ga. glutinata.*

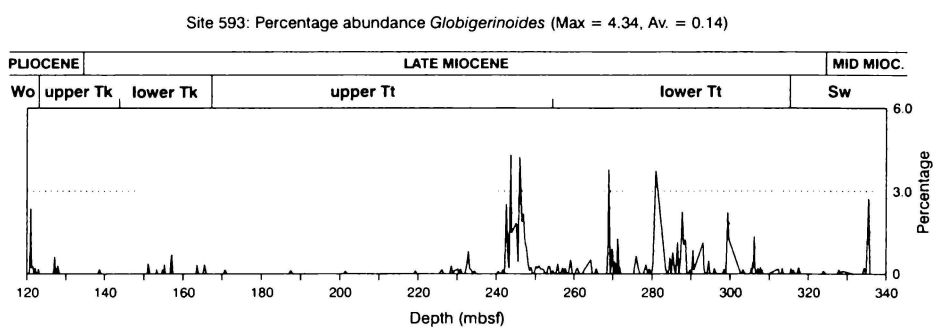
Distribution: *Globigerinita uvula* is seldom found in the census on account of its very small test. It is more common in the 63-150 µm fraction and occurs throughout the late Miocene.

GLOBIGERINOIDES

Kennett & Srinivasan (1983) consider *"Globigerinoides"* is a polyphyletic group with spinose species evolving from *Globigerina* and cancellate species evolving from *Zeaglobigerina.* Only cancellate species with pore pits or interpore ridges and supplementary sutural apertures are included here in *Globigerinoides.*



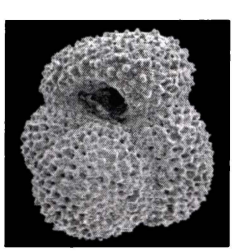
after Kennett & Srinivasan (1983)

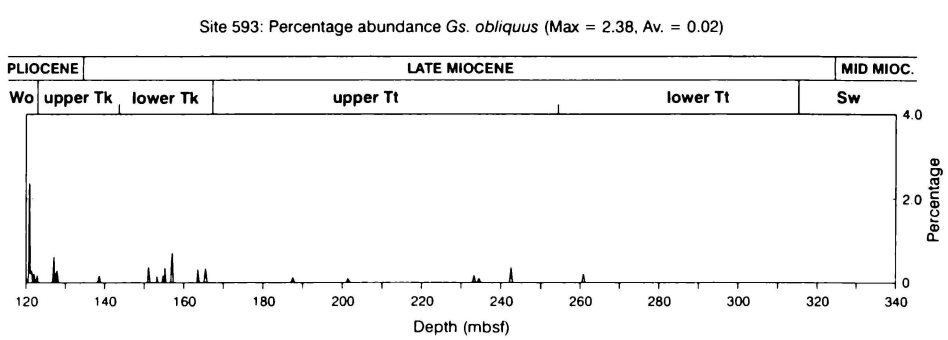


The genus *Globigerinoides* is most commonly found in the Tongaporutuan, below 593-25X-1, 23-25 cm (226.13 mbsf), although even in this part of the sequence it forms only a minor part of assemblages.

Globigerinoides obliquus Bolli

1957 *Globigerinoides obliqua* Bolli, p. 113, pl. 25, figs. 10a-c.





Plates: 1.1/12, 1.37/2–3.

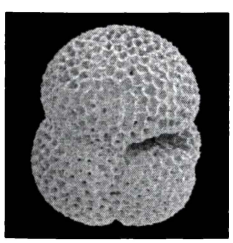
Remarks: Late Miocene and earliest Pliocene representatives of *Globigerinoides obliquus* include a variety of morphotypes. They range from subspherical chambered forms similar to those illustrated by Kennett & Srinivasan (1983, p. 57, pl. 11, figs. 7-9), to kummerforms resembling *Gs. extremus* Bolli, with a distinctly flattened final chamber (e.g. Kennett & Srinivasan 1983, p. 59, pl. 12, fig. 1).

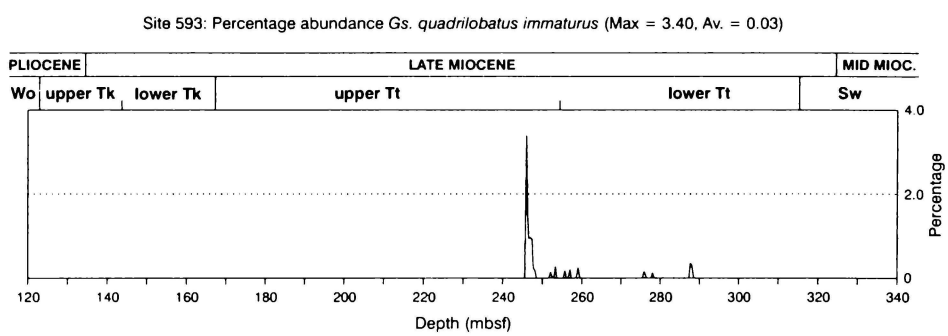
Globigerinoides obliquus differs from the similar species *Gs. ruber* (d'Orbigny) in having an oblique aperture that is aligned with the anti-penultimate chamber, whereas in *Gs. ruber* the aperture is aligned with the suture between the penultimate and anti-penultimate chambers.

Distribution: Typical *Gs. obliquus* is extremely rare in the late Miocene and it is only found in assemblages above 593-23X-3, 132-1134 cm (201.42 mbsf). Questionable specimens are noted in assemblages down to 593-28X-5, 16-18 cm (260.86 mbsf). The species becomes slightly more common in the lower Opoitian.

Globigerinoides quadrilobatus immaturus LeRoy

1939 *Globigerinoides sacculiferus* (Brady) var. *immatura* LeRoy, p. 263, pl. 3, figs. 19-21.





Plates: 1.23/3–4, 1.29/4.

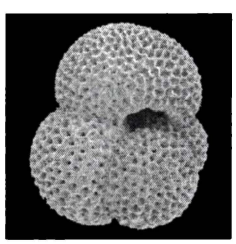
Remarks: *Globigerinoides quadrilobatus immaturus* is used here for intermediate forms in a group of subspecies that includes *Gs. quadrilobatus quadrilobatus* and *Gs. quadrilobatus trilobus* – forms that are collectively referred to here as the *Gs. quadrilobatus* plexus. The three subspecies occur in the same samples and they intergrade morphologically. *Globigerinoides quadrilobatus immaturus* is distinguished in having three to three and one-half chambers in the outer whorl, a large moderately embracing final chamber, and a low-arched interiomarginal, umbilical primary aperture. *Globigerinoides quadrilobatus trilobus* has only three chambers in the outer whorl and a larger more embracing final chamber, and

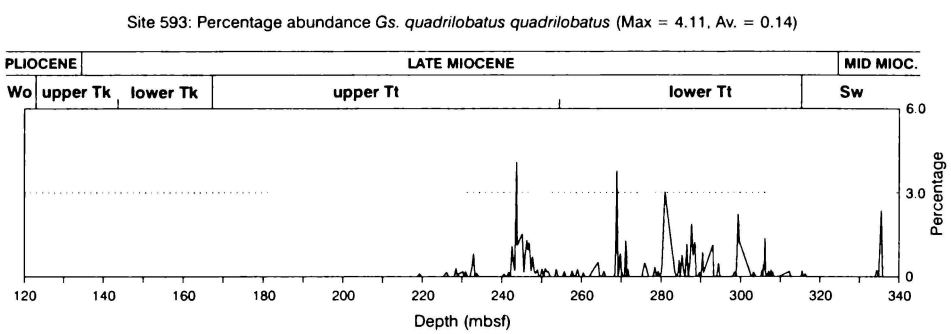
Gs. quadrilobatus quadrilobatus has a smaller less embracing final chamber and a higher-arched aperture. Previous studies at Site 593 (Jenkins 1975; Scott 1992) have included all three subspecies in *Gs. trilobus.*

Distribution: *Globigerinoides quadrilobatus immaturus* is found in the lower part of the sequence below 593-27X-1, 81-83 cm (245.91 mbsf), in association with *Gs. quadrilobatus quadrilobatus* and *Gs. quadrilobatus trilobus.* It is rare in the late Miocene, except for a very short interval in the vicinity of 593-27X-1 (246 mbsf).

Globigerinoides quadrilobatus quadrilobatus (d'Orbigny)

1846 *Globigerina quadrilobata* d'Orbigny, p. 164, pl. 9, figs. 7-10.





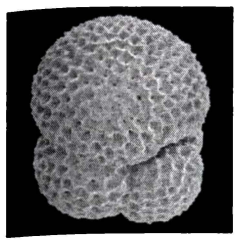
Plates: 1.23/1–2, 1.25/14–15, 1.29/3.

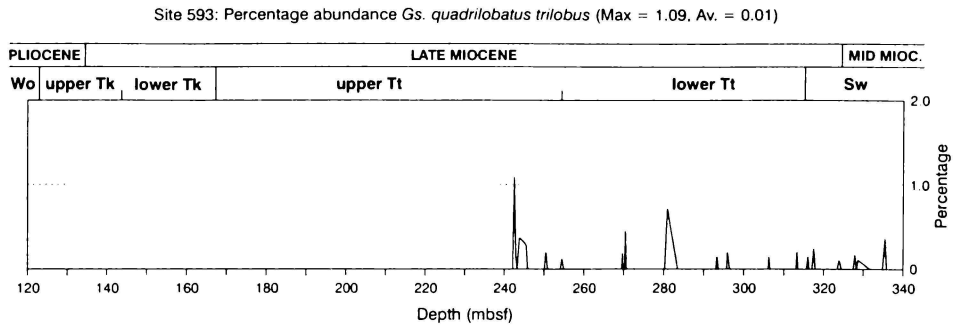
Remarks: *Globigerinoides quadrilobatus quadrilobatus* is the most common late Miocene representative of the *Gs. quadrilobatus* group (see remarks concerning *Gs. quadrilobatus immaturus*). Specimens closely resemble those illustrated by Kennett & Srinivasan (1983, pl. 14/1-3). They have four chambers in the outer whorl and a low-arched interiomarginal, umbilical primary aperture, which distinguishes them from *Gs. quadrilobatus trilobus* and *G. quadrilobatus immaturus.*

Distribution: *Globigerinoides quadrilobatus quadrilobatus* constitutes a small but moderately persistent component of Tongaporutuan assemblages below 593-25X-2, 112-114 cm (228.52 mbsf), although abundances rarely exceed 4%. It is generally associated with *Gs. quadrilobatus immaturus* and *Gs. quadrilobatus trilobus.*

Globigerinoides quadrilobatus trilobus (Reuss)

1850 *Globigerina triloba* Reuss, p. 374, pl. 447, figs. 11a-c.





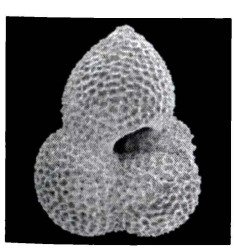
Plates: 1.23/5–6, 1.26/1–2.

Remarks: Use of the name *Globigerinoides quadrilobatus trilobus* is confined here to elements of the *Gs. quadrilobatus* group that have three chambers in the outer whorl, a strongly embracing final chamber and a slit-like interiomarginal, umbilical primary aperture (see remarks concerning *Gs. quadrilobatus immaturus*). This differs from Jenkins (1975) and Scott (1992) who assigned all elements of the *Gs. quadrilobatus* plexus to *Gs. trilobus*.

Distribution: Typical *Gs. quadrilobatus trilobus* is very rare in the late Miocene, but small numbers of specimens are found in association with *Gs. quadrilobatus quadrilobatus* and *Gs. quadrilobatus immaturus,* below 593-26X-5, 102-104 cm (242.52 mbsf).

Globigerinoides sacculifer (Brady)

1877 *Globigerina sacculifera* Reuss, figures in Brady (1884), p. 604, pl. 80, figs. 11-17, and pl. 81, fig. 4.



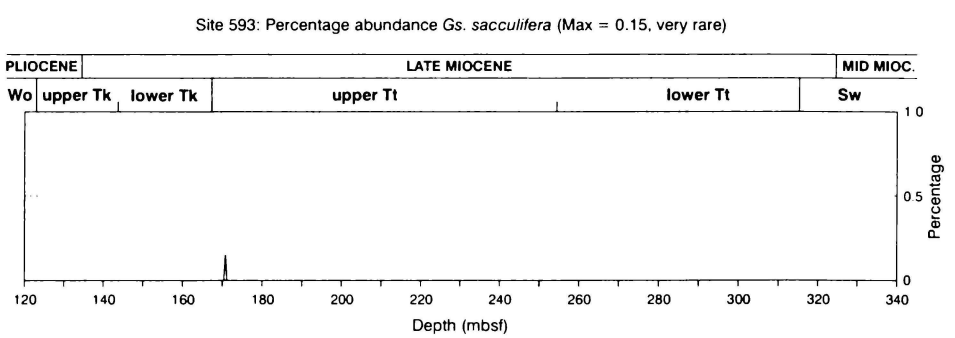


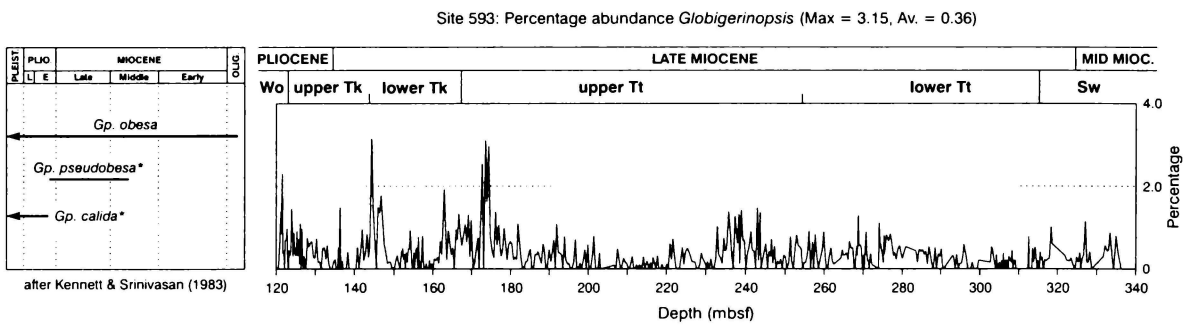
Plate: 1.39/10.

Remarks: Specimens of *Globigerinoides sacculifer* with a sac-like final chamber are extremely rare in the late Miocene. Only one specimen was noted in the census and no other specimens were noted in supplementary scans of bulk residues.

GLOBIGERINOPSIS

The genus *Globigerinopsis* was introduced by Bolli (1962) for spinose, low trochospiral species, with four to four and one-half rapidly expanding, globose chambers in the outer whorl, and an initial interiomarginal, umbilical aperture that later becomes interiomarginal, spiroumbilical in the adult. It includes species from a lineage that evolved from *Globigerina praebulloides* in the Late Oligocene (Kennett & Srinivasan 1983).

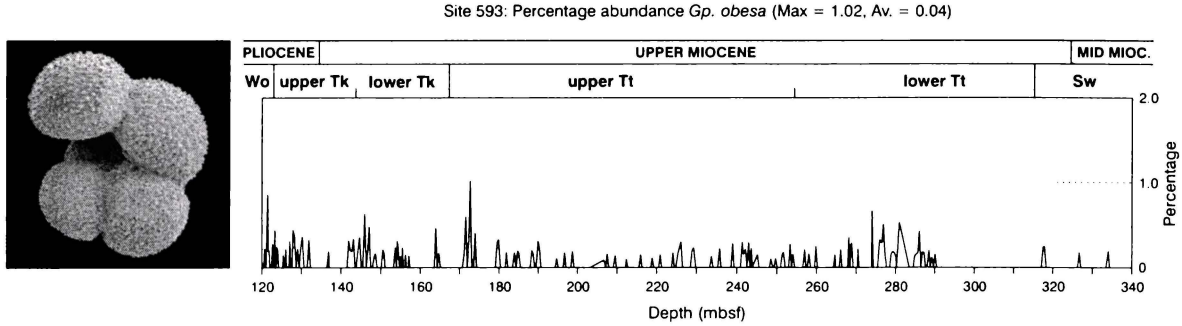
Late Miocene specimens of *Globigerinopsis* at Site 593 closely resemble those illustrated by Kennett & Srinivasan (1983) under the name *Globigerinella obesa*, but there is a tendency for large specimens to develop an interiomarginal, spiroumbilical aperture that is typical of *Globigerinopsis*. The persistence of trochospiral coiling through all growth stages supports the inclusion of such specimens in *Globigerinopsis*.



Globigerinopsis constitutes a relatively minor, but persistent part of all late Miocene assemblages. Abundances rarely exceed 2%.

Globigerinopsis obesa (Bolli)

1957 *Globorotalia obesa* Bolli, p. 119, pl. 29, figs. 2a-3.



Plates: 1.1/8, 1.7/13–15, 1.10/12–15, 1.13/13–15, 1.16/13–14, 1.19/13–15, 1.22/10–12, 1.25/7–10, 1.28/13–15, 1.31/10.

Remarks: *Globigerinopsis obesa* superficially resembles *Globigerina bulloides*, but specimens have more rapidly expanding, globose chambers and tend to be bigger. There is also a tendency for the aperture to adopt a more oblique interiomarginal, spiroumbilical position, particularly in large specimens. *Globigerinopsis obesa* is also distinguished on the basis of its densely perforate and very finely spinose surface ultrastructure. As noted in the discussion of *Globigerina bulloides,* moderate-sized specimens of *Gp. obesa* with slightly oblique apertures can easily be confused with *Gg. bulloides,* particularly when details of the surface ultrastructure are obscured by the addition of a thick layer of secondary calcite. Such specimens of uncertain affinity are included here in *Gp. obesa*?

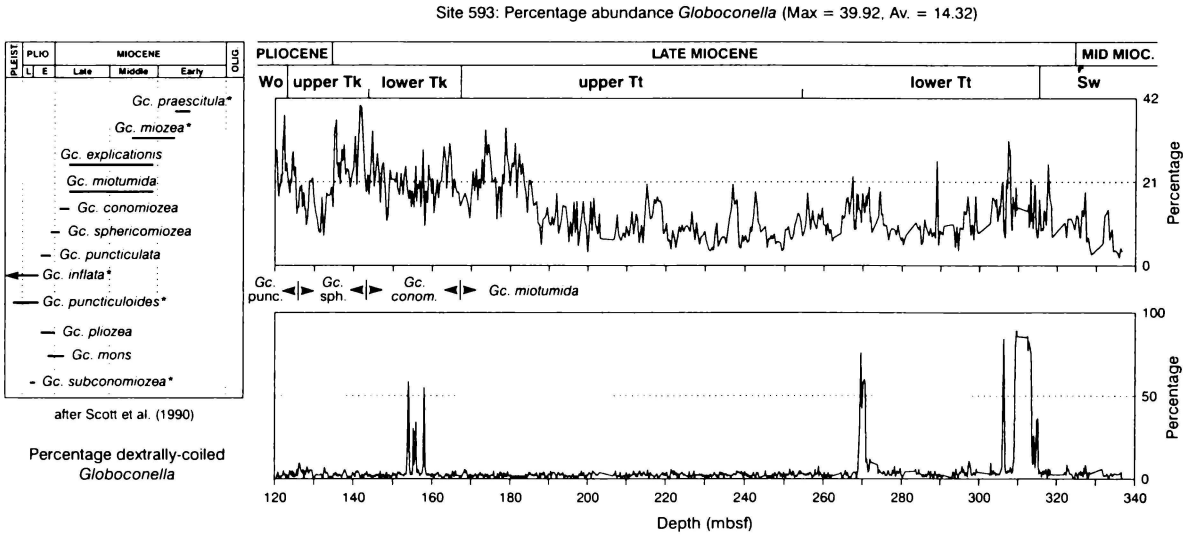
Distribution: Typical specimens of *Globigerinopsis obesa* are relatively rare below 593-31X-5, 62-64 cm (290.12 mbsf), but they constitute a small and moderately persistent part of assemblages in the upper part of the sequence. Abundances rarely exceed 1%.

GLOBOCONELLA

Bandy (1975) introduced the subgenus *Globoconella* for globorotaliids of the *"Globorotalia" miozea* lineage that have high-arched apertures, and it was subsequently emended by Srinivasan & Kennett (1981a, b) to include all species of the *Gc. incognita - Gc. inflata* lineage. Cifelli & Scott (1986) and Scott et al. (1990), however, consider *Globorotalia incognita* and *Globorotalia zealandica* belong to a separate phylogenetic group – the *Zealandica* lineage. For this reason the use here of *Globoconella* is confined to species of the *Gc. praescitula – Gc. inflata* lineage, which is the major globorotaliid group in temperate areas and the most useful for biostratigraphic subdivision of Neogene temperate sequences. The late Miocene and earliest Pliocene part of this lineage, which includes the anagenetic transformation between *Gc. miotumida – Gc. conomiozea – Gc. sphericomiozea – Gc. puncticulata,* is referred to here as the *Gc. miotumida* bioseries.

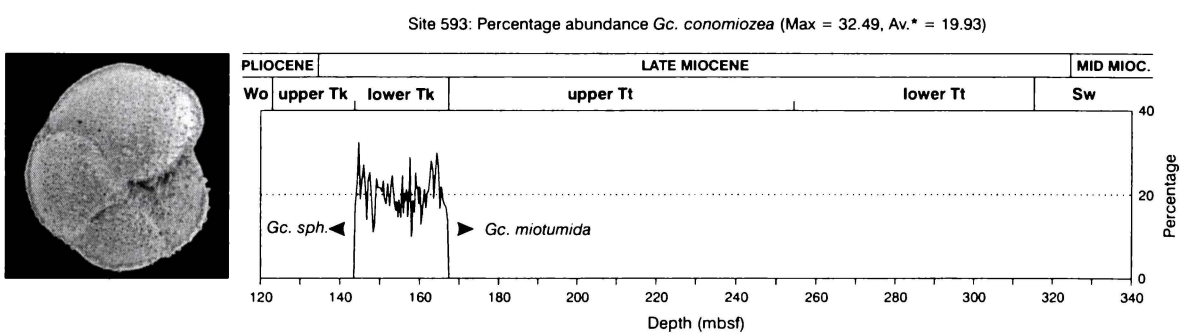
Globoconella constitutes a major component of all late Miocene assemblages, but the abundance of the genus almost doubles in the Kapitean, above 593-20X-6, 7-9 cm (185.49 mbsf). In the lower part of the sequence, *Globoconella* maintains an average abundance of 10.9% and is ranked third in overall abundance next to *Zeaglobigerina* and *Globigerina*, and in the upper part of the sequence, *Globoconella* maintains an average abundance of 21.3% and is ranked second in abundance next to *Zeaglobigerina*. The abundance of

Globoconella decreases in the vicinity of the Miocene-Pliocene boundary, but increases again in the Opoitian.



Globoconella conomiozea (Kennett)

1966 *Globorotalia conomiozea* Kennett, p. 235, text figs. 10a-c.



Plates: 1.6/10–12 and 14–15, 1.9/6–9, (s.l.) 1.3/10–12.

Remarks: The morphotypic concept of *Globoconella conomiozea* that is employed in this study is based on low trochospiral forms with four to four and one-half chambers in the outer whorl, a ventroconical axial profile, a well developed peripheral keel, a high-arched aperture, a small open umbilicus, and a finely perforate, pustulate surface ultrastructure. The species concept differs, however, and extends to a much wider range of acceptable morphological variation. It encompasses all elements of the *Gc. miotumida* bioseries that occur in the stratigraphic interval above the lowest occurrence of *Gc. conomiozea* s.s. – the level where at least 10% of forms within the *Gc. miotumida* bioseries have less than four and one-half chambers in the outer whorl – and below the highest occurrence of *Gc. conomiozea* s.s. – the level where more than 5% of specimens in the *Gc. miotumida* bioseries lack a keel.

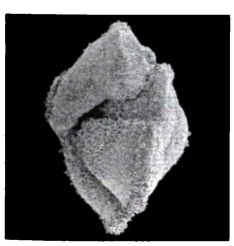
The lowest occurrence of *Gc. conomiozea* s.s. occurs in the vicinity of a significant, almost five-fold increase in the ratio of crusted versus crust-free specimens. The large number of encrusted specimens with a thick layer of secondary calcite and poorly defined sutures makes it difficult to locate the precise position of the biostratigraphic boundary, but it occurs in the vicinity of an abrupt increase in the number of specimens with less than four and one-half chambers in the outer whorl.

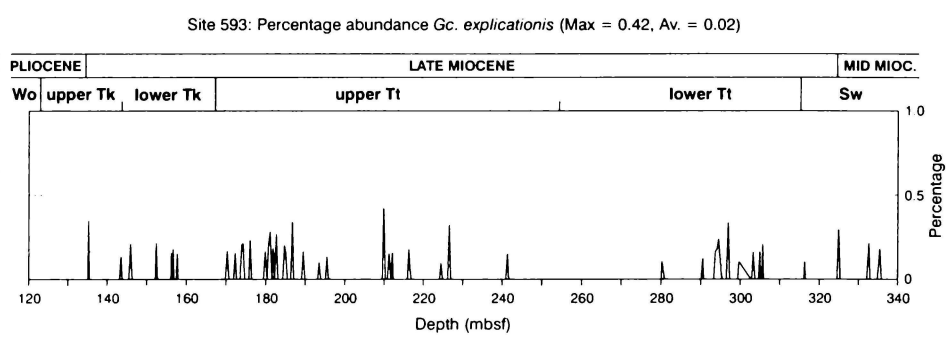
Distribution: The wide range of morphotypes that are collectively included in *Gc. conomiozea* s.s. constitute a major and sometimes dominant component of lower Kapitean assemblages, and abundances are only exceeded by *Zeaglobigerina.*

Typical morphotypes with less than four and one-half chambers in the outer whorl are noted below the lowest occurrence of *Gc. conomiozea* s.s., but they are assigned to *Gc. miotumida s.s.* Typical crust-free and lightly crusted morphotypes of *Gc. conomiozea* are also noted in assemblages above the highest occurrence of *Gc. conomiozea* s.s., up to 593-14X-4, 111-114 cm (125.91 mbsf) – they are assigned to *Gc. conomiozea* s.l.

Globoconella explicationis (Jenkins)

1967 *Globorotalia miotumida explicationis* Jenkins, p. 1073, figs. 4/14-17.





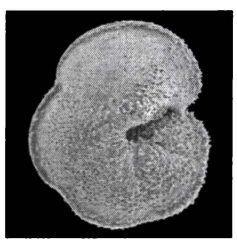
Plates: 1.6/13, 1.12/9, 1.21/8, 1.30/13–15, 1.36/13–15.

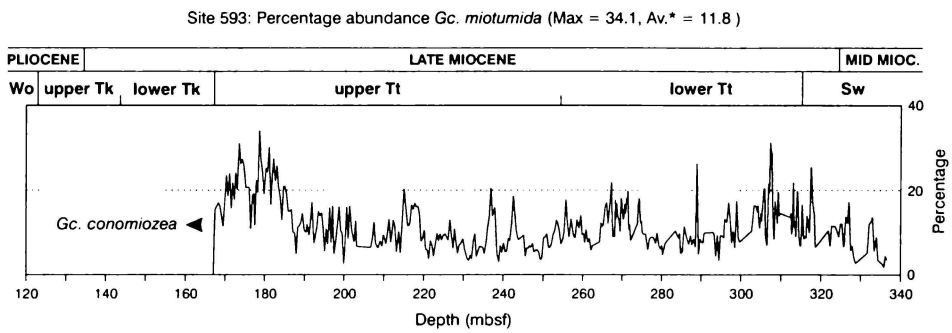
Remarks: Scott et al. (1990) consider *Gc. explicationis* to be a late ontogenetic variant peripheral to the main *Gc. miotumida* bioseries. It was separated in the census on the basis of its distinctive morphology where late-formed chambers are progressively offset due to a higher rate of whorl translation in late ontogeny. Specimens are generally crust-free and have four to five chambers in the outer whorl, a lobate spiral outline, and a distinctive peripheral keel covered with pustules.

Distribution: *Globoconella explicationis* is relatively rare, but occurs sporadically throughout the late Miocene.

Globoconella miotumida (Jenkins)

1960 *Globorotalia menardii* (d'Orbigny) subsp. *miotumida* Jenkins, p. 362, pl. 4, figs. 9a-c.





Plates: 1.9/10–12, 1.12/4–8 and 10–15, 1.15/7–15, 1.18/7–15, 1.21/9–15, 1.24/8–15, 1.27/5–15, 1.30/7–12, 1.33/10–15, 1.36/4–12.

Remarks: *Globoconella miotumida* embodies a wide range of morphotypic variation centred on strongly keeled, biconvex to ventroconical forms with a high-arched aperture and four and one-half to five chambers in the outer whorl. Typical specimens of *Gc. miotumida* have a crescentic spiral chamber shape with poorly differentiated leading and trailing sections (Cifelli & Scott 1986, p. 9) and an interiomarginal umbilical-extraumbilical aperture bordered by a distinct rim. The accepted range of morphological variation extends to moderately elevated biconvex specimens with weakly inflated chamber walls (Plates 1.21/10–12 and 1.27/7–9), ventroconical specimens with relatively flat spiral sides (Plate 1.27/10–12, 15), and strongly compressed biconvex specimens (Plate 1.15/13–15).

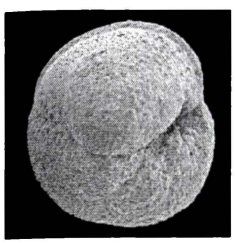
Globoconella miotumida s.s. and *Gc. conomiozea* s.s. are separated biostratigraphically at the level where at least 10% of specimens in the *Gc. miotumida* bioseries have less than four and one-half chambers in the outer whorl. Typical crust-free and lightly crusted morphotypes that occur above the highest occurrence of *Gc. miotumida* s.s. and have more than four and one-half chambers in the outer whorl are included in *Gc. miotumida* s.l.

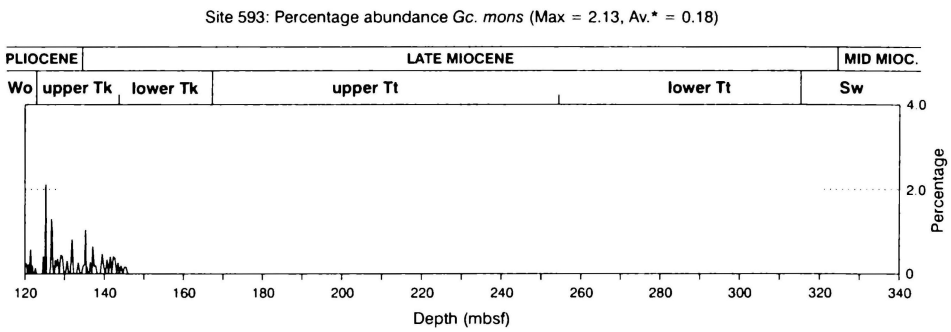
Distribution: *Globoconella miotumida* constitutes an important and long ranging component of late Miocene assemblages and is ranked second in overall abundance, next to

Zeaglobigerina. Abundances remain relatively constant through much of the late Miocene, but increase in the uppermost Tongaporutuan, just prior to the entry of *Gc. conomiozea* s.s.

Globoconella mons (Hornibrook)

1982 *Globorotalia conomiozea* Kennett subsp. *mons* Hornibrook, p. 91, figs. 3a-g; 4a-i.





Plates: 1.3/13–15, 1.9/13–15.

Remarks: *Globoconella mons* is used here for tightly coiled four-chambered forms that have a reduced umbilicus, a low-arched aperture, and distinctly ventroconical axial profile. The species evolved from *Gc. conomiozea* in the lower Kapitean. In describing the subspecies, Hornibrook (1982) included strongly ventroconical quasitruncatuline morphotypes with a prominent angular peak on the umbilical side. Scott et al. (1990) adopted a broader morphologic concept and also included compact heavily encrusted morphotypes with less prominent ventroconical profiles – the unifying factors being the four chambers in the outer whorl, the narrow or closed umbilicus, and the low-arched aperture. The range of variation tolerated by Scott et al. (1990) is followed here, although it partially overlaps the variation field that is assigned to *Gc. conomiozea.*

Distribution: The species constitutes a minor part of most upper Kapitean and lower Opoitian assemblages above 593-16X-5, 0-3 cm (145.50 mbsf). Rare tightly coiled, strongly ventroconical specimens were noted down to 593-18X-1, 65-68 cm (159.35 mbsf) but they generally have high-arched apertures.

Globoconella pliozea (Hornibrook)

1982 *Globorotalia pliozea* Hornibrook, p. 95, figs. 7a-g.

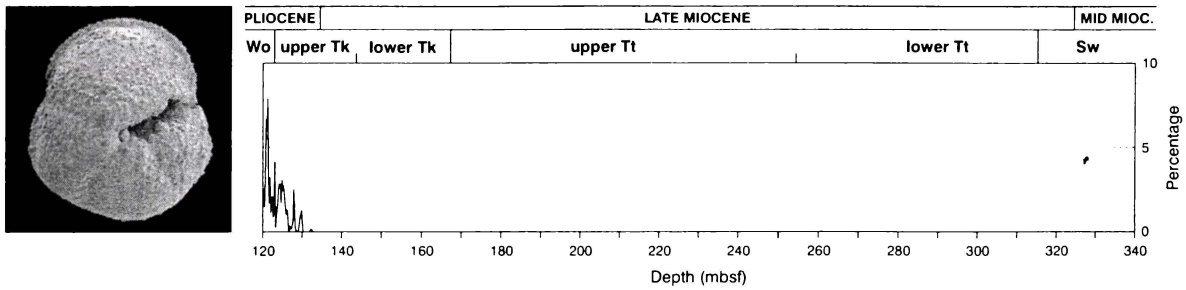


Plate: 1.3/7–9.

Remarks: The name *Globoconella pliozea* is applied here to relatively compressed, compactly coiled biconvex forms in the *Gc. miotumida* plexus that have less than four and one-half chambers in the outer whorl, and a symmetrically arched or slightly asymmetrical crescentic chamber outline in spiral view. They are considered here to be part of a group that is divergent from the *Gc. miotumida* bioseries. Crust-free specimens within early populations have less embracing chambers, similar to those noted by Hornibrook (1982) in core 284-9X, and tend to have less well developed biconvex axial profiles. Due to a significant overlap with the variation field associated with moderately compressed morphotypes of *Gc. conomiozea,* only morphotypes with biconvex axial profiles are included *Gc. pliozea.*

Distribution: *Globoconella pliozea* species first occurs in the upper Kapitean, in 593-15X-2, 93-96 (132.33 mbsf), although significant numbers of specimens only begin to appear in the lower Opoitian.

Globoconella puncticulata (Deshayes)

1832 *Globigerina puncticulata* Deshayes, p. 170; Banner & Blow (1960), p. 15, pl. 5, figs. 7a-c (lectotype).

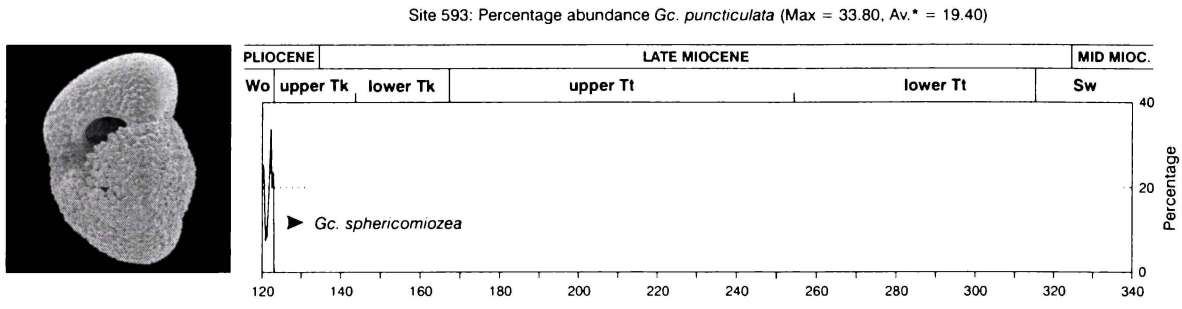


Plate: 1.3/1–6.

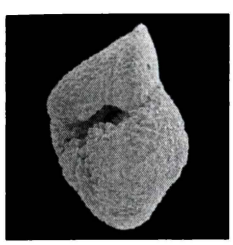
Remarks: The lowest occurrence of *Globoconella puncticulata* s.s. as employed in this study corresponds to the level where more than 95% of adult specimens in the *Gc.*

sphericomiozea - *Gc. puncticulata* morphoseries lack keels – see remarks concerning *Gc. sphericomiozea.*

Distribution: *Globoconella puncticulata* constitutes a major part of lower Opoitian assemblages. Unkeeled morphotypes of *Gc. puncticulata* s.l. are also noted in populations of *Gc. sphericomiozea* s.s. and *Gc. conomiozea* s.s. down to 593-17X-6, 77-79 cm (157.37 mbsf).

***Globoconella sphericomiozea* (Walters)**

1965 *Globorotalia miozea* Finlay subsp. *sphericomiozea* Walters, p. 126, figs. 8n-s.



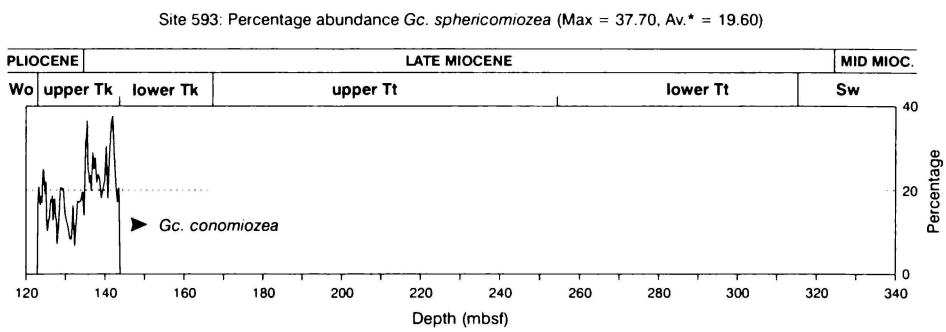


Plate: 1.6/1–9.

Remarks: Scott (1980) refined the biostratigraphic application of *Globoconella sphericomiozea* s.s and defined the species in terms of two overlapping morphotypic concepts – keeled *Gc. conomiozea* and unkeeled *Gc. sphericomiozea.* Stratigraphic space was allocated to *Gc. sphericomiozea* s.s. on the basis of the progressive increase in the number of weakly keeled and unkeeled morphotypes. The appearance of the species is arbitrarily defined as the level where 5% of adult specimens lack a keel, and its disappearance has been placed at a level immediately preceding the lowest occurrence of *Gc. puncticulata* s.s. – the level where all specimens lack a keel.

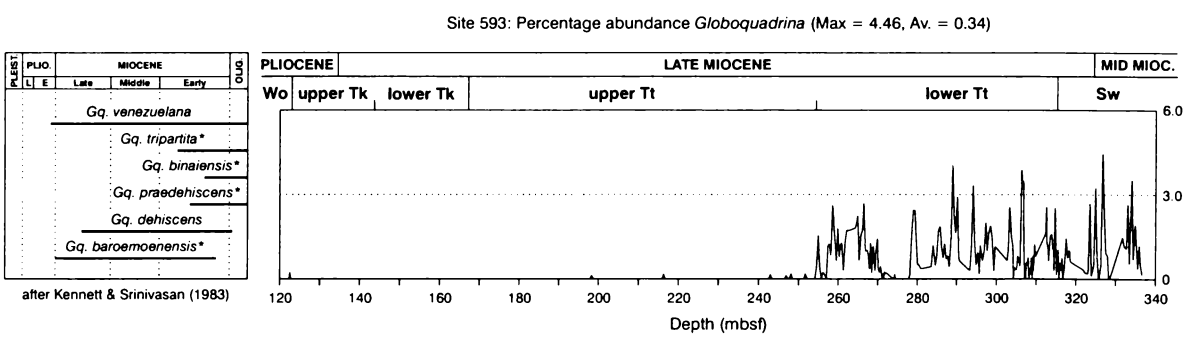
Based on these criteria, the lowest occurrence of *Gc. sphericomiozea* is well defined at Site 593 and the species highest occurrence is very poorly defined. In the uppermost part of the species range, very rare, weakly keeled specimens that are a part of the overlapping morphological variation fields of *Gc. conomiozea* and *Gc. puncticulata* occur sporadically over a stratigraphic interval of at least 4.6 m. The situation is further complicated by the presence of rare weakly keeled specimens of *Truncorotalia* cf. *crassaconica,* which can easily be mistaken for weakly-keeled *Gc. sphericomiozea.* To improve the biostratigraphic application of *Gc. sphericomiozea,* the zero threshold for keeled morphotypes that was

proposed by Scott (1980) as marking the entry of *Gc. puncticulata* s.s. – contiguous with the exit of *G. sphericomiozea* s.s. – is redefined here as the level where more than 95% of adult specimens in the *Gc. sphericomiozea - Gc. puncticulata* series lack keels.

Distribution: In terms of the emended species definition, *Gc. sphericomiozea* is confined to assemblages between 593-16X-3, 103-106 cm (143.53 mbsf) and 593-14X-5, 0-3 cm (126.30 mbsf). *Globoconella sphericomiozea* constitutes a major component of upper Kapitean assemblages, but the abundance of the species decreases markedly in the vicinity of the Miocene-Pliocene boundary – from a high of 36.7% just below the boundary, to a low of 7.3% just above the boundary.

GLOBOQUADRINA

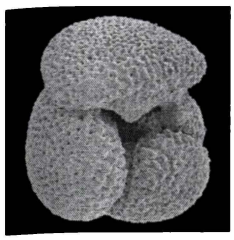
Finlay (1947a) erected the genus *Globoquadrina* for trochospiral species with cancellate tests, quadrate to subquadrate equatorial profiles, and interiomarginal, umbilical-extraumbilical apertures with one or more tooth-like projections into the umbilicus. Use of *Globoquadrina* in this study follows Kennett & Srinivasan (1983) and is confined to species of the *Gq. tripartita – Gq. dehiscens* lineage.

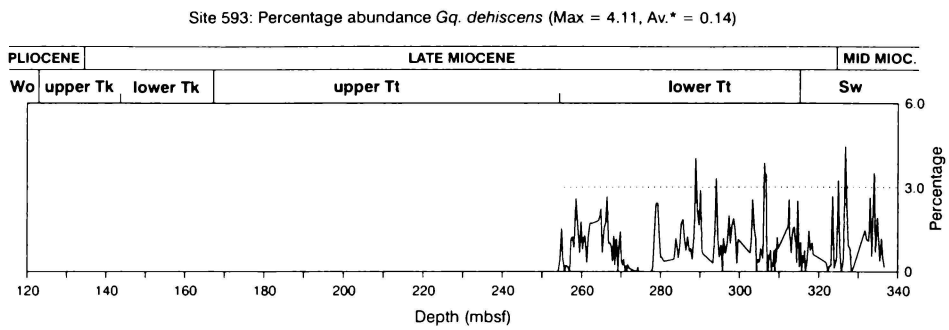


The genus *Globoquadrina* is almost exclusively confined to the Waiauan and lower Tongaporutuan, although very rare specimens that may be *Globoquadrina*, including at least one individual that resembles *Gq. venezuelana,* are noted in the younger part of the late Miocene and earliest Pliocene section.

Globoquadrina dehiscens (Chapman, Parr, and Collins)

1934 *Globorotalia dehiscens* Chapman, Parr, and Collins, p. 569, pl. 11, figs. 36a-c.





Plates: 1.26/8–9, 1.29/11–12, 1.32/7–8, 1.35/1–3.

Remarks: Typical quadrate forms of *Gq. dehiscens* and kummerforms that superficially resemble *Gq. tripartita* (e.g. Scott 1992, p. 504 fig. 2) are included in the acceptable range of morphological variation. Quadrate specimens without a kummerform chamber have a very distinctive oblique apertural face with a single tooth-like projection that extends into the umbilicus. Small specimens have four chambers in the outer whorl and are somewhat globorotaliid-like in appearance, while large specimens have three and one-half to four, slightly embracing, and inflated chambers in the outer whorl.

Small specimens that are assigned to *Globoquadrina* sp.? have cancellate test surfaces and quadrate equatorial profiles, but lack well developed umbilical tooth-like projections.

Distribution: *Globoquadrina dehiscens* forms a small and persistent part of assemblages up to 593-27CC, 10-12 cm (254.49 mbsf), except for a narrow interval in the vicinity of 593-30X-2 (276 mbsf) where it is missing. The highest recorded specimens of *Gq. dehiscens* are comparable in shape and size to those from lower in the section, and there is no obvious reduction in the species abundance immediately prior to its disappearance. Despite a comprehensive search of bulk residues, the species was not found higher in the section, but a single specimen of *Gq.* cf. *venezuelana* (Hedberg) was noted at 593-22X-1, 122-124 cm (198.32 mbsf).

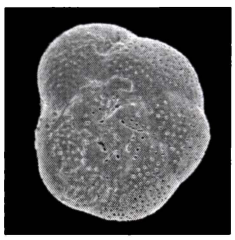
GLOBOROTALIA

Bandy (1972) proposed the subgenus *Globorotalia* for species related to the *Gr. lengauensis – Gr. tumida* lineage. It is raised here to the status of a genus.

Globorotalia is very poorly represented in the late Miocene at Site 593, although at least one species (*Gr. lenguaensis*) is noted in the lower Tongaporutuan.

Globorotalia lenguaensis Bolli

1957 *Globorotalia lenguaensis* Bolli, p. 120, pl. 29, figs. 5a-c.



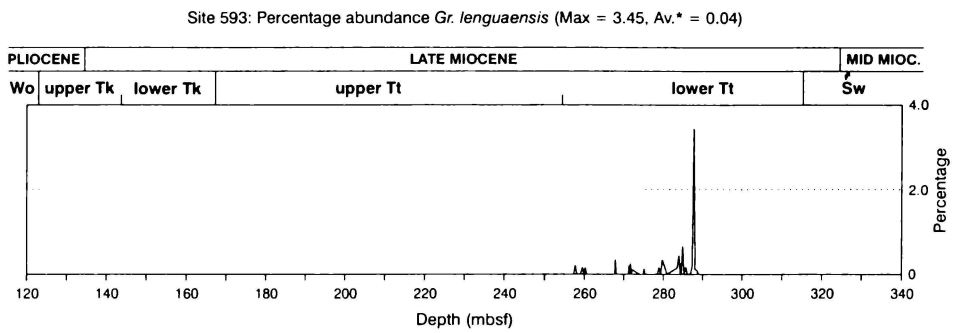


Plate: 1.37/13–15.

Remarks: *Globorotalia lenguaensis* includes small, low trochospiral forms with a compressed biconvex test, six to seven chambers in the outer whorl, a subcircular equatorial profile, and a smooth coarsely perforate surface ultrastructure. Typical specimens have asymmetrical crescentic chamber outlines in spiral view, with well developed trailing sections, although morphological variation extends to some specimens that have chambers with elevated, almost linear trailing sections in spiral view.

Distribution: *Globorotalia lenguaensis* is rare and is confined to the upper part of the lower Tongaporutuan. Scott (1992) assigned similar forms in the early late Miocene of Site 593 to *Gr.* cf. *lenguaensis.*

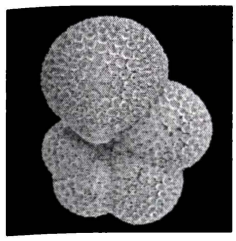
GLOBOROTALOIDES

Bolli (1957) erected the genus *Globorotaloides* for low trochospiral forms with a well developed cancellate surface ultrastructure. The genus is noted by Kennett & Srinivasan (1983) to combine at various stages in its growth characteristic features of at least four generic forms: an early stage *Globorotalia*-like interiomarginal, umbilical-extraumbilical aperture, followed by a late stage *Globigerina*-like umbilical aperture, a *Catapsydrax*-like bulla-like final chamber, and *Globoquadrina*-like apertural plates and cancellate surface ultrastructure.

Globorotaloides is extremely rare in the late Miocene of Site 593, only one species being noted.

Globorotaloides hexagonus (Natland)

1938 *Globigerina hexagona* Natland, p. 149, pl. 7, figs. 1a-c.



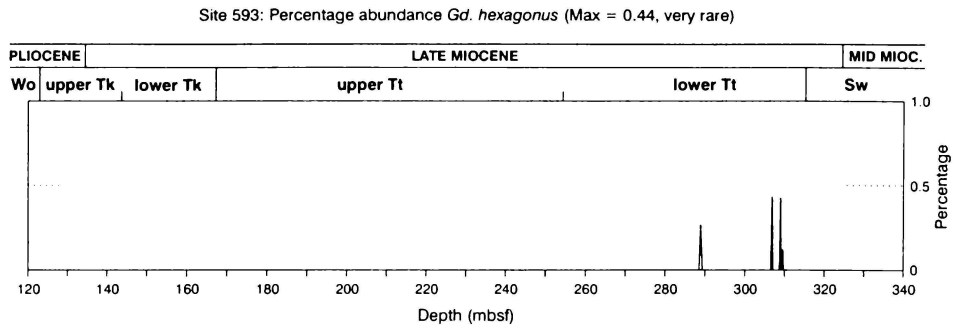


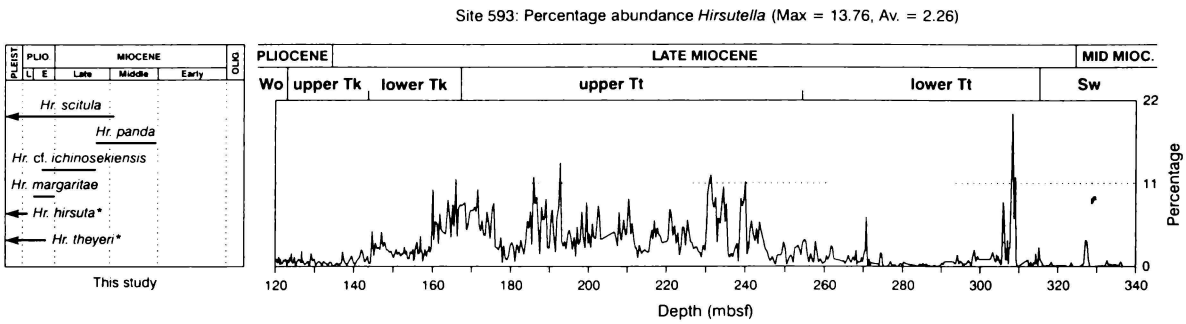
Plate: 1.37/7–11

Remarks: *Globorotaloides hexagonus* is a very distinctive low trochospiral species with a depressed umbilical region, linear sutures, lobate periphery, and well developed cancellate surface ultrastructure with large pores and deep hexagonal pore pits surrounded by interpore ridges. The species exhibits a wide range of variation in the number, size, shape, and inflation of chambers. Most specimens have four to five globular chambers in the outer whorl compared to the characteristic five or six chambers of warm subtropical to tropical specimens. Interpore ridges are commonly affected by dissolution.

Distribution: *Globorotaloides hexagonus* is rare at Site 593 and was found in only five census samples from the lower Tongaporutuan. A more comprehensive search of the >150 µm fraction suggests *Gd. hexagonus* is moderately persistent in the interval 593-33X-2 to 593-33X-5, but is extremely rare outside this interval.

HIRSUTELLA

The concept of *Hirsutella* employed here is based on the subgenus proposed by Bandy (1972) for species of the *Globorotalia (Turborotalia) scitula – margaritae – praehirsuta – hirsuta* series, although the subgenus is raised here to the status of a genus. Use of the genus is restricted to densely perforate smooth-walled, four and one-half to five-chambered forms, with compressed peripheries and asymmetrical crescentic chamber outlines in spiral view. It includes unkeeled species of the *Hr. scitula – Hr. hirsuta* lineage and the keeled spiroconical species *Hr. panda* and *Hr.* cf. *ichinosekiensis,* which are considered here to be part of the same lineage. Coarsely perforate, non-quadrate forms, that were assigned to *Hirsutella* by Kennett & Srinivasan (1983), including *"Globorotalia" bermudez* and *"Globorotalia" challengeri,* are reassigned on the basis of their surface ultrastructure to *Globorotalia,* and finely perforate, pustulose forms with inflated tests, including *"Globorotalia" juanai* and *"Globorotalia" cibaoensis,* are reassigned to *Truncorotalia.* Changes to the genus *Hirsutella* are discussed in more detail in Study 2.



The genus *Hirsutella* constitutes a small but important part of late Miocene assemblages, particularly in the upper Tongaporutuan and lower Kapitean. A significant short-lived influx of the keeled species *Hr. panda* is also noted in the lowermost Tongaporutuan.

Hirsutella cf. *ichinosekiensis* (Takayanagi & Oda)

1976 *Globorotalia (Globorotalia) ichinosekiensis* Takayanagi and Oda, p. 374, pl. 2, figs. 1a-c.

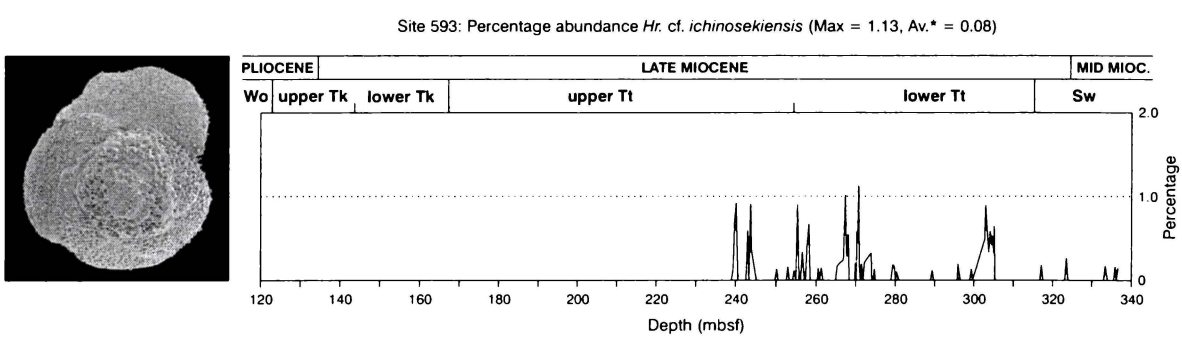


Plate: 1.38/7.

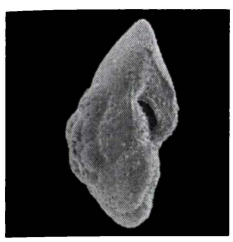
Remarks: *Hirsutella ichinosekiensis* was introduced by Takayanagi and Oda, in Takayanagi et al. (1976), for late Miocene spiroconical forms, with concave umbilical sides, smooth finely perforate walls, and four and one-half to five chambers in the outer whorl – a species that they considered to be the ancestor to *Hr. margaritae.* Specimens of *Hr.* cf. *ichinosekiensis* are very similar to the illustrated holotype, but are distinguished in having a very weakly developed peripheral keel or an acutely-angled peripheral margin with no keel. Most specimens at Site 593 coil sinistrally, whereas *Hr. ichinosekiensis* is noted by Takayanagi & Oda (1976) to have a strong preference for dextral coiling.

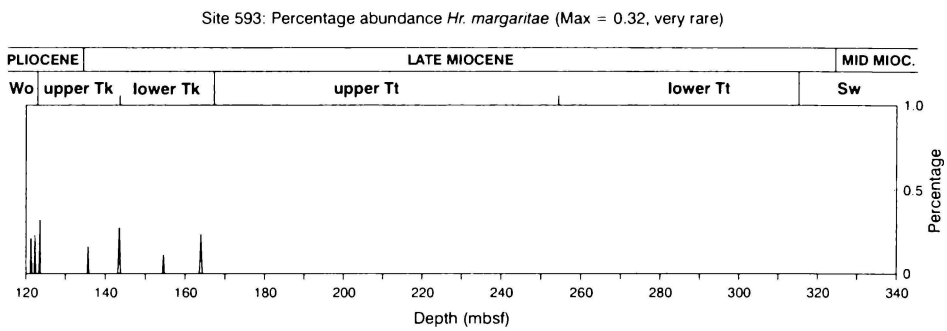
Weakly keeled specimens of *Hr.* cf. *ichinosekiensis* intergrade morphologically with strongly keeled specimens of *Hr. panda* in the lower Tongaporutuan and they are considered here to be part of the same evolutionary stock.

Distribution: *Hirsutella ichinosekiensis* is a relatively minor species in upper Waiauan and Tongaporutuan assemblages and abundances rarely exceed 1%. The lower part of its range overlaps with *Hr. panda.*

Hirsutella margaritae (Bolli and Bermudez)

1965 *Globorotalia margaritae* Bolli and Bermudez, p. 139, pl. 1, figs. 16-18; Neotypified. Bolli & Bermudez (1978), p. 138, pl. 1, figs. 1-9.





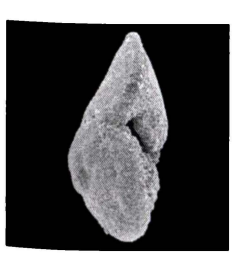
Plates: 1.5/5, 1.38/10.

Remarks: Very rare spiroconical specimens of *Hirsutella margaritae* with concave umbilical sides and weakly developed peripheral keels occur in the Kapitean and Opoitian. They are morphologically similar to Tongaporutuan specimens of *Hr.* cf. *ichinosekiensis* and spiral conical forms of *H.* scitula, and are clearly related in terms of their phylogeny. All specimens of *Hr. margaritae* are dextrally coiled.

Distribution: Typical spiroconical morphotypes of *Hr. margaritae* are relatively rare and are confined to the upper part of the sequence above 593-18X-4, 73-76 (163.93 mbsf). The species is used as an index species for the Pliocene in tropical to warm subtropical regions, although its very poorly defined entry at Site 593 places a caveat on its use in temperate regions.

Hirsutella panda (Jenkins)

1960 *Globorotalia menardii* (d'Orbigny) subsp. *panda* Jenkins, p. 364, pl. 4, figs. 10a-c.



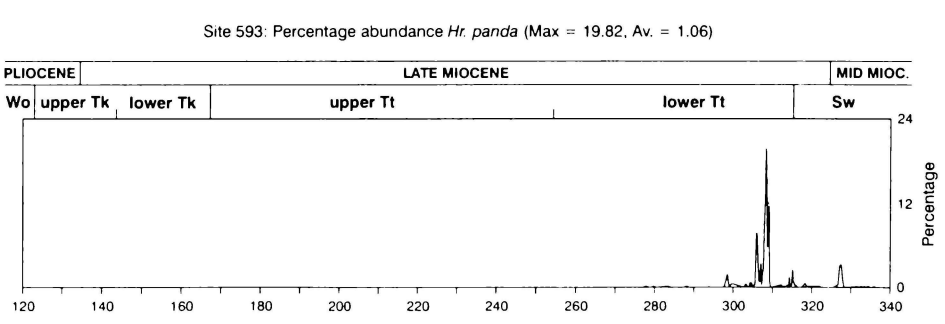


Plate: 1.33/7–9.

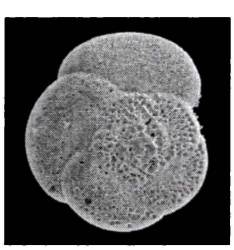
Remarks: Kennett & Srinivasan (1983) included *"Globorotalia" panda* in the genus *Globoconella*, but it is reassigned here to the genus *Hirsutella* on the basis of its densely perforate, smooth surface ultrastructure. The spiroconical test, concave umbilical side, acutely angled peripheral margin, and asymmetrical crescentic outline of chambers in spiral view, suggest it is of the same lineage as *Hr.* cf. *ichinosekiensis* and *Hr. margaritae.* It is distinguished from these species in having a strongly developed keel.

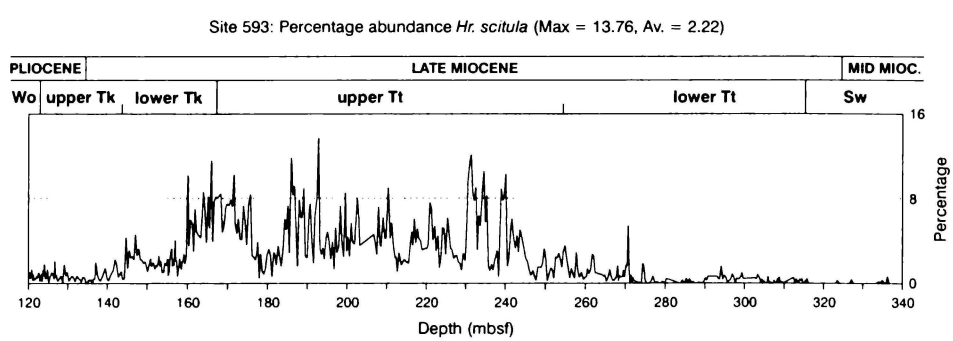
Distribution: *Hirsutella panda* is restricted to the lower part of the sequence below 593-32X-4, 48-50 cm (298.08 mbsf). It constitutes a relatively minor part of upper Waiauan and lower Tongaporutuan assemblages, except for a short-lived influx in the lowermost Tongaporutuan, where it reaches a maximum abundance of 19.82%.

In the lower Tongaporutuan, strongly keeled specimens of *Hr. panda* intergrade with spiroconical specimens of *Hr.* cf. *ichinosekiensis* that have reduced keels or acutely angled peripheries with no keel. The latter species is predominantly sinistral-coiled and extends up to 593-28X-1, 103-105 cm (255.28 mbsf), whereas *Hr. panda* is largely dextral-coiled and is restricted to the lower part of the sequence below the highest occurrence of *Globoquadrina dehiscens.*

Hirsutella scitula (Brady)

1882 *Pulvinulina scitula* Brady, p.716 (Figures in Brady, *Rep. Voy. Challenger*, Zool., pl. 103, figs. 7a-c, 1882); Banner & Blow (1960), p. 27, pl. 5, fig. 5 (lectotype).

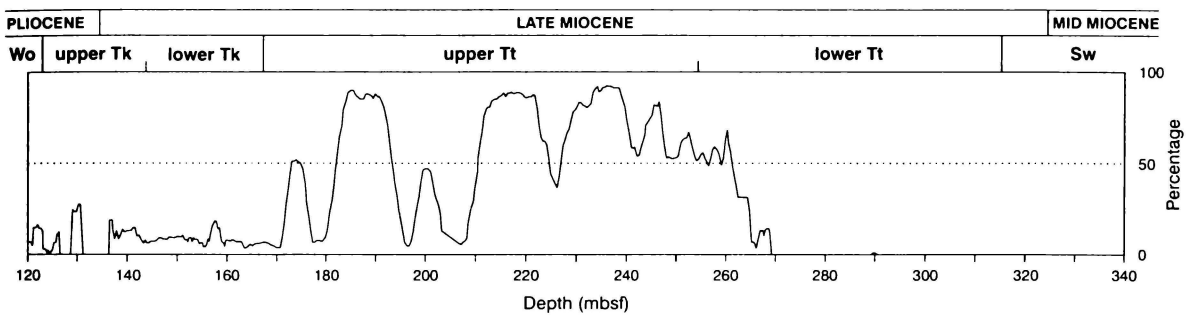




Plates: 1.2/7–11, 1.5/6–8, 1.9/3–5, 1.11/13–15, 1.14/15, 1.15/1–3, 1.17/13–15, 1.18/1–3, 1.21/1–7, 1.24/3–7, 1.27/1–4, 1.30/4–6, (spiroconical form) 1.38/4–6 and 9, (cf.) 1.12/1–3, 1.18/4–6, 1.26/13–15, 1.36/1–3, 1.38/1.

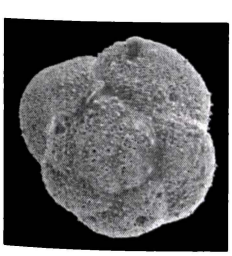
Remarks: The morphotypic concept of *Hirsutella scitula* that is employed in this study is based on compressed low trochospiral forms with smooth, densely perforate test walls, four and one-half to five chambers in the outer whorl, and asymmetrical crescentic chamber outlines in spiral view, with well developed trailing sections. It is distinguished from most other species of *Hirsutella* in having a more inflated non-carinate chamber margin as opposed to an acutely rounded or keeled periphery. Accepted morphological variation extends to biconvex and spiroconical forms, and rare specimens with distinctly lobate equatorial outlines. Forms that have chambers with elevated, almost linear trailing sections in spiral view (Plates 1.12/1–3 and 1.36/1–3), and those with a low rate of radial chamber expansion (Plate 1.18/4–6), are assigned to *Hr.* cf. *scitula.*

Site 593: Coiling data *Hirsutella scitula* (Percentage sinistral-coiled shells, 11-point moving average)



Distribution: *Hirsutella scitula* is a persistent late Miocene species, although it constitutes a relatively minor part of assemblages, except in the upper Tongaporutuan and lowermost Kapitean where it maintains an average abundance of 4.8%. Jenkins (1971) noted *Hirsutella scitula* to have a strong preference for dextral coiling, but in the interval where it is more common the majority of shells are sinistral-coiled.

Hirsutella sp.



Site 593: Percentage abundance *Hirsutella* sp. (Max = 1.13, Av.* = 0.09)

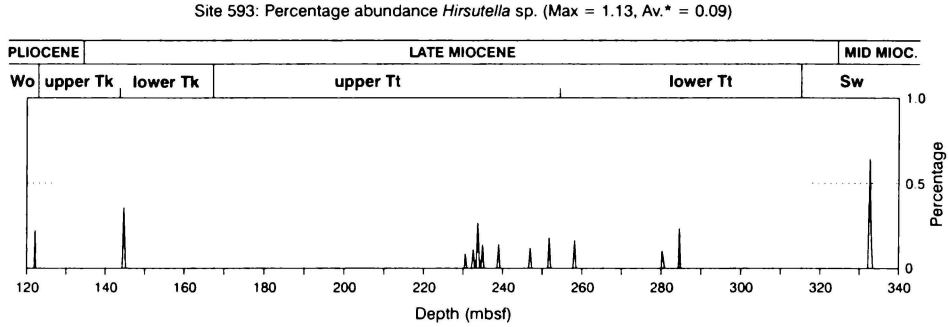
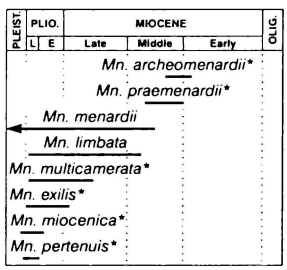


Plate: 1.38/2–3.

Remarks: Only a few poorly preserved hirsutellids, mainly juveniles of uncertain affiliation, are included in this miscellaneous collective.

MENARDELLA

The subgenus *Menardella* was proposed by Bandy (1972) for sharp-edged to keeled species of the *Globorotalia archeomenardii – Globorotalia menardii* lineage, and it is raised here to the status of a genus. Species of *Menardella* are characterized by low trochospiral tests, with five or more chambers in the outer whorl, smooth densely perforate surfaces, and a prominent peripheral keel. In spiral view, the trailing sections of chamber outlines tend to be radially extended, particularly in tropical and warm-subtropical forms.



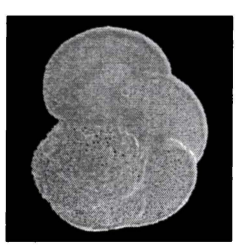
after Kennett & Srinivasan (1983)

Distribution and abundance - see *Mn.* cf. *limbata* (below)

The genus *Menardella* is very uncommon in the late Miocene and it was only found in the lower part of the sequence, below 593-23X-4, 112-114 cm (212.32 mbsf).

Menardella cf. *limbata* (Fornasini)

1902 *Rotalia limbata* Fornasini, Parker, Jones, and Brady; enumerated by d'Orbigny (1826), p. 20, pl. 3, fig. 81.



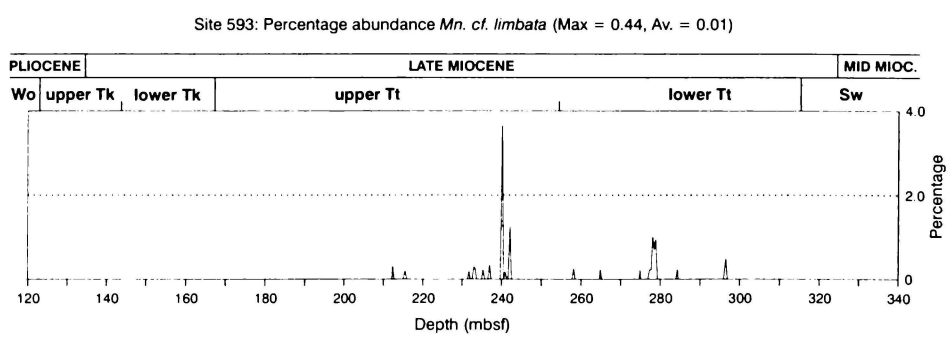


Plate: 1.38/11–12.

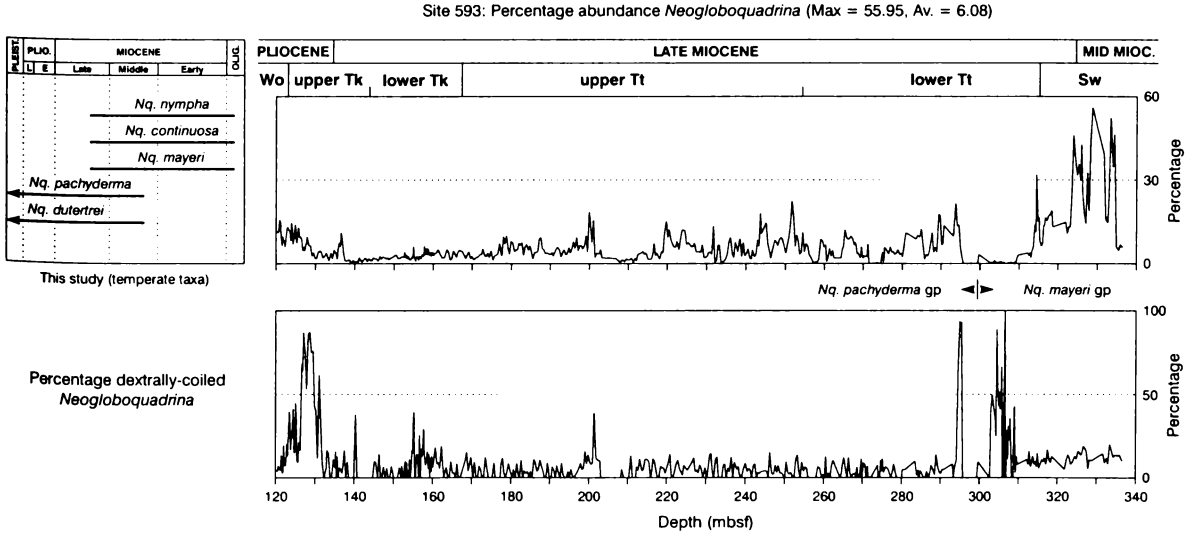
Remarks: The genus *Menardella* is represented at Site 593 by compressed trochospiral forms with well developed peripheral keels and strongly asymmetrical crescentic spiral chamber outlines that have deeply concave trailing sections. The detail of chamber outlines closely resembles *Mn. limbata*, but the specimens have only five to six chambers in the outer whorl, whereas typical *Mn. limbata* has six to eight chambers.

Jenkins & Srinivasan (1986) did not find species of *Menardella* in the late Miocene, but Scott (1992) noted *Mn. menardii* in a lower Tongaporutuan sample 593-30X-3, 122 cm (278.12 mbsf). The specimens picked by Scott have strongly developed asymmetrical crescentic chamber outlines, similar to *Mn.* cf. *limbata,* and there are no typical specimens of *Mn. menardii* on the faunal slide, with radially extended wedge-shaped chamber outlines.

Distribution: *Menardella* cf. *limbata* is uncommon in the late Miocene and is confined to the lower part of the sequence below 593-23X-4, 112-114 cm (212.32 mbsf). Although specimen numbers are very low, it is a moderately persistent species in the vicinity of core 593-26X-4 (c. 240 mbsf).

NEOGLOBOQUADRINA

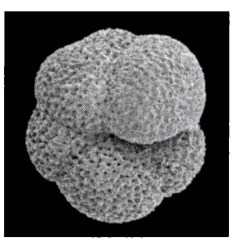
The genus *Neogloboquadrina* was introduced by Bandy et al. (1967) and it has been widely used for species that evolved from *Nq. continuosa* in the late Middle Miocene (Kennett & Srinivasan 1983). Early Neogene forms that are closely related have been variously assigned to different genera – *Globorotalia* (*Turborotalia*) (Jenkins 1971), *Jenkinsella* (Kennett & Srinivasan 1983), *Paragloborotalia* (Cifelli 1982), and *Neogloboquadrina* (Jenkins 1993). The use of different generic assignments for closely related forms is totally artificial and obscures phylogenic relationships. For this reason, the genus *Neogloboquadrina* is employed in this study for all cancellate Neogene species that have globular to subglobular chambers arranged in a compact, low trochospiral geometry, and an umbilical-extraumbilical aperture bordered by a rim.

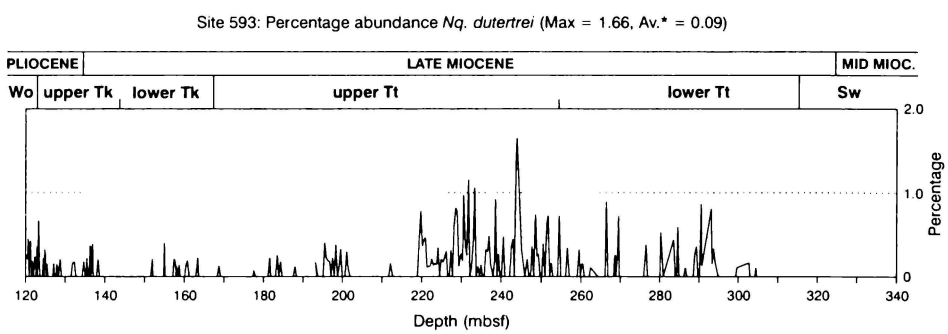


The genus *Neogloboquadrina* constitutes a major part of upper Waiauan assemblages, but abundances decrease markedly in the vicinity of the middle-late Miocene boundary. The transition from elements of the *Nq. mayeri* s.l. group to *Nq. pachyderma* occurs just above the middle-late Miocene boundary in a short interval where *Neogloboquadrina* is extremely rare. This interval includes populations with a significant contribution of dextral shells, whereas populations above and below this interval are predominantly sinistral, except for a short interval in the upper Kapitean near the Miocene-Pliocene boundary.

Neogloboquadrina dutertrei (d'Orbigny)

1839 *Globigerina dutertrei* d'Orbigny, p. 84, pl. 4, figs. 19-21; Banner and Blow (1960), p. 4, pl. 2, fig. 1 (lectotype).





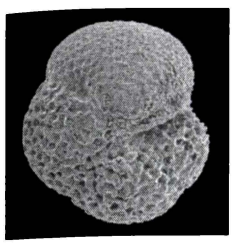
Plates: 1.2/6, 1.5/4, 1.11/7–8, 1.14/14, 1.24/1–2.

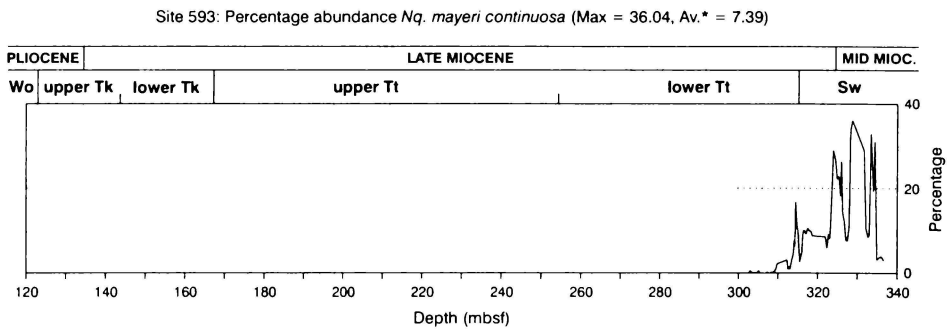
Remarks: The use of *Neogloboquadrina dutertrei* is confined to forms of *Neogloboquadrina* that have more than four and one-half globose or subglobose chambers in the outer whorl (see remarks concerning *Nq. pachyderma*). Kummerforms that have more than four and one-half chambers in the whorl preceding the kummerform chamber are assigned to *Nq. dutertrei,* and those with less than four and one-half chambers are assigned to *Nq. pachyderma.*

Distribution: Typical tropical and warm-subtropical forms of *Neogloboquadrina dutertrei* with five or more chambers in the outer whorl are relatively uncommon, although forms with more than four and one-half chambers in the outer whorl constitute a small and relatively persistent part of late Miocene assemblages. *Neogloboquadrina dutertrei* seldom exceeds abundances of 1%, but it is generally more common in the lower part of the sequence below 593-24X-3, 1-3 cm (219.31 mbsf). It is also more common in the upper Kapitean and lower Opoitian.

Neogloboquadrina mayeri continuosa (Blow)

1959 *Globorotalia opima* Bolli subsp. *continuosa* Blow, p. 218, pl. 19, figs. 125a-c.





Plates: 1.33/1–4, 1.35/4–9, (aberrant) 1.39/13.

Remarks: Compact, low trochospiral forms of *Neogloboquadrina* with four to four and one-half chambers in the outer whorl, and a subquadrate slightly lobate equatorial chamber outline are assigned to *Nq. mayeri continuosa*. Bolli & Saunders (1982) consider such specimens to be four-chambered variants of *Nq. mayeri* s.s., but they are separated in the census as a subspecies, along with *Nq. mayeri nympha*. The three subspecies, which are collectively referred to in this study as *Nq. mayeri s.l.*, intergrade morphologically and are nearly always found in the same samples, although *Nq. mayeri continuosa* is generally more common in the lower Tongaporutuan following the decrease in the abundance of *Neogloboquadrina*.

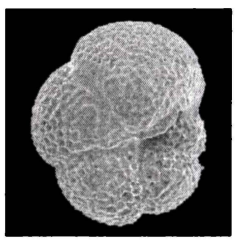
Acceptable morphological variation extends to relatively rare forms that have spiral chamber outlines and high-arched looped-shaped apertures like *Nq. acrostoma partimlabiata* (Ruggieri and Sprovieri). *Neogloboquadrina mayeri continuosa* is distinguished from *N. pachyderma* in being slightly more compact in its coiling and having less globose chambers. The position of the aperture is also slightly less interiomarginal (compare Plates 1.33/1–3 and 1.29/13–15).

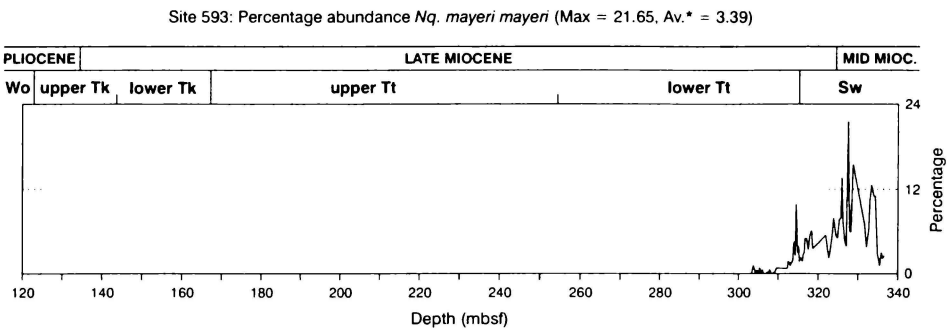
Distribution: The subspecies *Nq. mayeri continuosa* is very abundant in the upper Waiauan, but abundances decrease markedly in the vicinity of the Waiauan-Tongaporutuan boundary, and it is extremely rare in the interval leading up to its disappearance at 593-33X-1, 27-29 cm (302.97 mbsf). *Neogloboquadrina mayeri continuosa* has a strong preference for sinistral coiling, except for a short interval immediately prior to the subspecies highest occurrence where there is a significant increase in the contribution of dextral-coiled shells. This change in coiling corresponds to the interval where

Neogloboquadrina is extremely rare and is the same as for other subspecies of *N. mayeri* s.l.

Neogloboquadrina mayeri mayeri (Cushman and Ellisor)

1939 *Globorotalia mayeri* Cushman and Ellisor, p.11, pl. 2, figs. 4a-c.





Plates: 1.32/10–12, 1.33/5, 1.35/10–13.

Remarks: Compact, low trochospiral forms of *Neogloboquadrina* with more than four and one-half chambers in the outer whorl are assigned to *Nq. mayeri mayeri* (see remarks concerning *Nq. mayeri continuosa*). Kummerform specimens with more than four and one-half in the whorl preceding the kummerform chamber are also included in the subspecies.

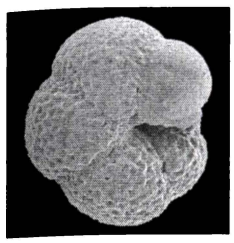
Neogloboquadrina mayeri mayeri is distinguished from *Nq. dutertrei* in having less globose chambers, and a slightly more interiomarginal, umbilical-extraumbilical aperture.

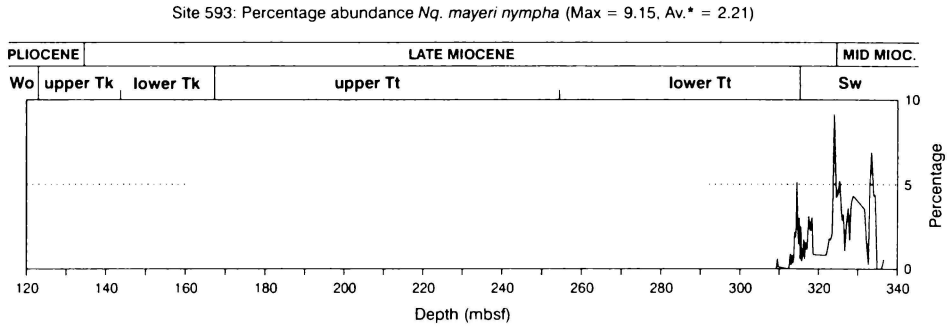
Distribution: Typical five-chambered forms of *Nq. mayeri mayeri* are relatively rare and most specimens have four and one-half to five chambers in the outer whorl. *Neogloboquadrina mayeri mayeri* is confined to the lower part of the sequence below 593-33X-1, 107-109 cm (303.77 mbsf). It is found in the same samples as *Nq. mayeri continuosa,* but is less common. The subspecies constitutes an important part of upper Waiauan assemblages, but its abundance decreases markedly in the vicinity of the Waiauan-Tongaporutuan boundary and it is extremely rare in the interval leading up to its disappearance.

Changes in coiling follow the same pattern as for *Nq. mayeri continuosa* – upper Waiauan and basal Tongaporutuan populations show a strong preference for sinistral coiling and there is a significant increase in the contribution of dextral shells in the interval leading up to the species disappearance.

Neogloboquadrina mayeri nympha (Jenkins)

1967 *Globorotalia mayeri* (Jenkins) subsp. *nympha*, p. 1072, figs. 3/7-13.





Plates: 1.32/13–15, 1.35/14–15.

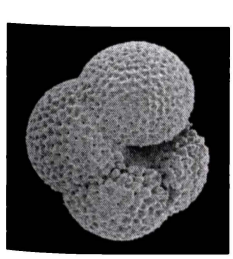
Remarks: Compact, low trochospiral forms of *Neogloboquadrina* that have a kummerform final chamber and less than four and one-half chambers in the preceding whorl are assigned to *Nq. mayeri nympha* (see remarks concerning *Nq. mayeri continuosa*). Forms that have more than four and one-half chambers in the whorl preceding the kummerform chamber are assigned to *Nq. mayeri mayeri.*

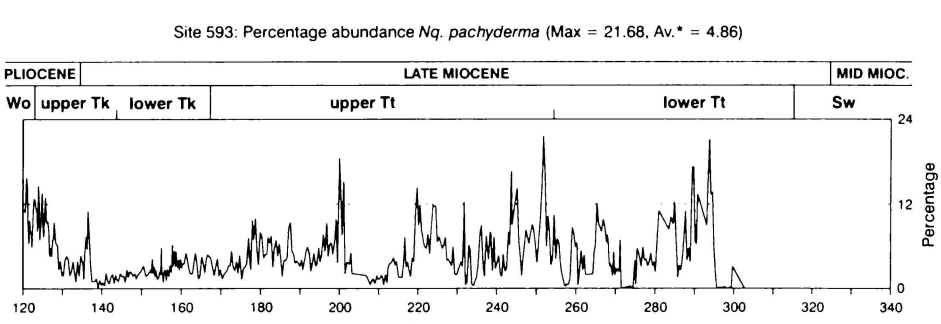
Distribution: *Neogloboquadrina mayeri nympha* is found in the same samples as *Nq. mayeri mayeri* and *Nq. mayeri continuosa,* but is less common. In the census, it is confined to the lower part of the sequence below 593-33X-1, 84-86 cm (309.54 mbsf), but very rare specimens are noted in supplementary picks, up to 593-33X-1, 107-109 cm (303.77 cm).

The coiling signature for *Nq. mayeri nympha* is the same as for other subspecies of *Nq. mayeri* s.l. – it shows a strong preference for sinistral coiling, except for a short interval immediately prior to the subspecies highest occurrence.

Neogloboquadrina pachyderma (Ehrenberg)

1861 *Aristospira pachyderma* Ehrenberg, pp. 276, 277, and 303; Banner & Blow (1960), p. 4, pl. 3, figs. 4a-c (lectotype).





Plates: 1.2/1–5, 1.5/1–3, 1.8/13–15, 1.11/9–12, 1.14/10–13, 1.17/10–12, 1.20/13–15, 1.23/12–15, 1.26/10–11, 1.29/13–15, 1.30/1–3, (aberrant) 1.39/14.

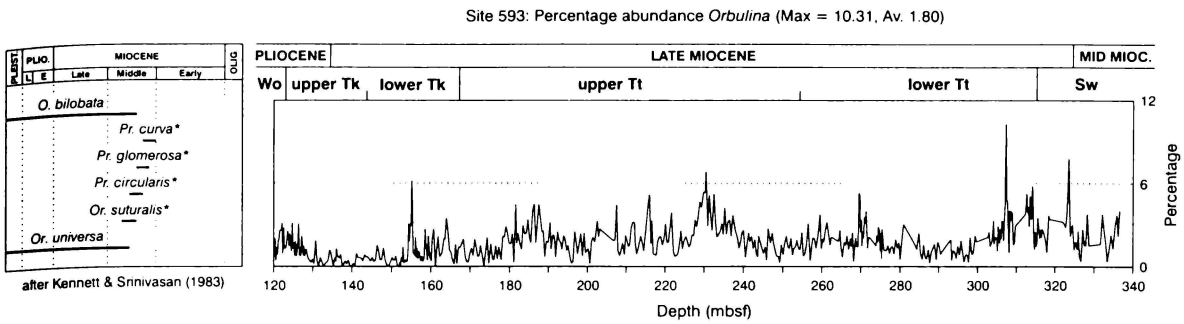
Remarks: Compactly coiled, low trochospiral forms with slightly lobate subquadrate profiles and four to four and one-half chambers in the outer whorl are included in *Neogloboquadrina pachyderma*. The range of accepted morphological variation extends to kummerforms that have less than four and one-half chambers in the outer whorl, prior to the kummerform chamber being added. *Neogloboquadrina pachyderma* is distinguished from *Nq. mayeri continuosa* in having more globular chambers and a slightly more interiomarginal, umbilical-extraumbilical aperture.

Distribution: *Neogloboquadrina pachyderma* constitutes a small but important part of most late Miocene assemblages, although abundances are highly variable.

Most late Miocene populations of *Nq. pachyderma* are dominated by sinistrally coiled shells, but there are at least two short intervals with significant contributions of dextral shells (see earlier discussion of *Neogloboquadrina*). The lower interval corresponds to the basal part of the species range, where *Nq. pachyderma* is extremely rare, and the other occurs in the vicinity of the Miocene-Pliocene boundary. The lower interval has not been recognized before, but an interval of dextrally coiled *Nq. pachyderma* has been recognized at Site 284 in the vicinity of the Miocene-Pliocene boundary (Kennett & Vella 1975).
Crusted and crust-free forms occur in most late Miocene populations of *Nq. pachyderma*, but there is a marked increase in the number of heavily encrusted forms in the Kapitean and lower Opoitian.

ORBULINA

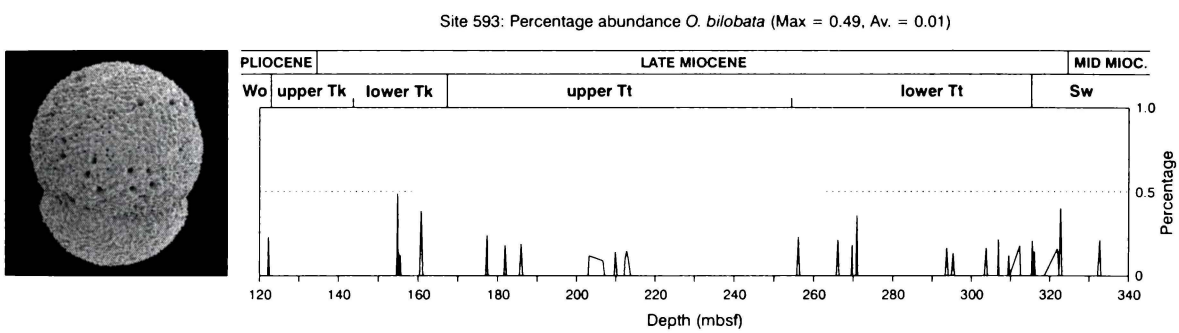
The genus *Orbulina* evolved from *Praeorbulina* at the base of the middle Miocene, and is important for the biostratigraphic subdivision of the middle Miocene (Finlay 1947b; Fleming et al. 1969). The extant species *Orbulina universa* and *Orbulina bilobata* that are found in late Miocene sequences first appear at the base of the upper Lillburnian (Hornibrook et al. 1989).



Orbulina constitutes a small but persistent part of late Miocene assemblages, but abundances rarely exceed 6%. Most late Miocene orbulines are very small and have encrusted tests, with a thick layer of secondary calcite and a small number of large sutural pores, similar to *Praeorbulina* (see remarks concerning *Orbulina* sp. "juvenile").

Orbulina bilobata (d'Orbigny)

1846 *Globigerina bilobata* d'Orbigny, p. 164, pl. 9, figs. 11-14.



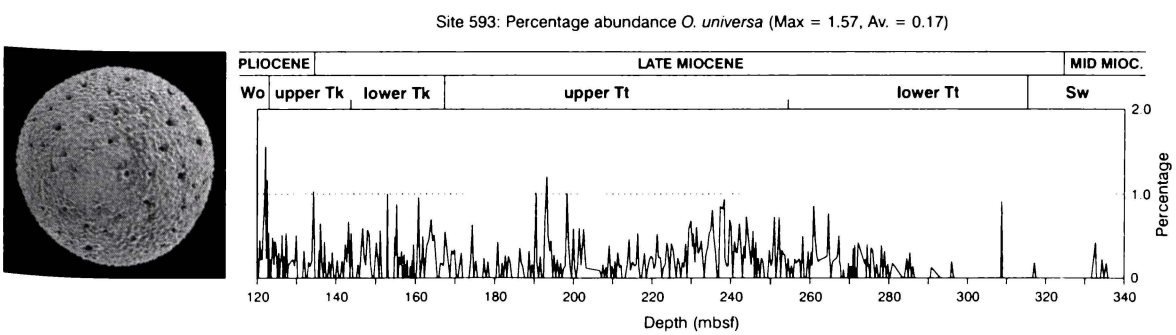
Plates: 1.1/10, 1.8/2, 1.14/2, 1.17/2, 1.20/3, 1.22/14, 1.25/13, 1.31/12, 1.34/11.

Remarks: Forms of *Orbulina* that are distinctly bilobate and have small pores outside of the sutures are assigned to *Orbulina bilobata*.

Distribution: The species is very rare and occurs sporadically throughout the late Miocene.

Orbulina universa d'Orbigny

1839 *Orbulina universa* d'Orbigny, p. 3, pl. 1, fig. 1.

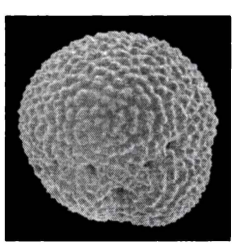


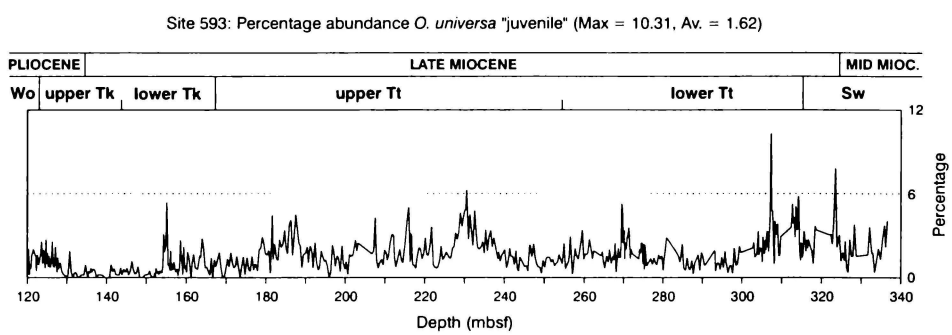
Plates: 1.1/9, 1.4/10, 1.8/1, 1.11/1, 1.14/1, 1.17/1, 1.20/1–2, 1.22/13, 1.25/11, 1.34/10.

Remarks: Use of the name *Orbulina universa* is restricted to large spherical specimens with a fully enveloping final chamber and small, pore-like apertures over most of the test. Some specimens are noted to be intermediate in character between *O. universa* and *O. suturalis* and to have small, pore-like apertures confined to less than 50% of the test. Such forms are only included in *O. universa* if the final chamber is fully enveloping.

Distribution: Large spherical specimens of *Orbulina universa* constitute a very small part of most late Miocene assemblages, but are relatively rare in the upper Waiauan and lowermost Tongaporutuan.

Orbulina universa "juvenile"





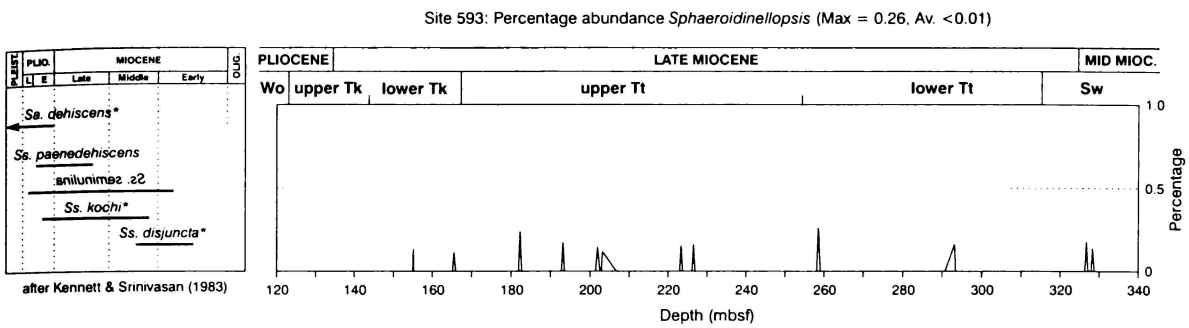
Plates: 1.1/11, 1.4/11, 1.8/3–6, 1.11/2–3, 1.14/3–4, 1.17/3–4, 1.20/4–6, 1.22/15, 1.25/12, 1.29/2, 1.31/13–15, 1.34/12–13.

Remarks: Small encrusted specimens that lack a fully enveloping final chamber and have large sutural pores similar to *Praeorbulina* are considered to be juveniles of *O. universa* and are included in the informal taxon *Orbulina* sp. "juvenile". In previous studies of Sites 284 and 593, such specimens have been assigned to *O. universa* (Jenkins 1975; Kennett & Vella 1975; Scott 1992), and possibly *O. suturalis* (Jenkins & Srinivasan 1986).

Distribution: Specimens that are assigned to the informal taxon *Orbulina* sp. "juvenile" constitute an important part of all late Miocene assemblages. The abundance of such orbulines is about ten-times greater than for typical large specimens of *O. universa.*

SPHAEROIDINELLOPSIS

Banner & Blow (1959) erected the genus *Sphaeroidinellopsis* for globigerine-like forms with a very distinctive, thick cortex covered test. The addition of thick secondary calcite material restricts pores and provides a smooth glassy appearance to the test. *Sphaeroidinellopsis* resembles the genus *Sphaeroidinella,* but the latter is distinguished by its supplementary sutural apertures in large adult specimens.



Sphaeroidinellopsis is very rare in the late Miocene, but at least two species are noted.

Sphaeroidinellopsis paenedehiscens Blow

1969 *Sphaeroidinellopsis subdehiscens* (Blow) subsp. *paenedehiscens* Blow, p. 386, pl. 30, figs. 4, 5, 9.

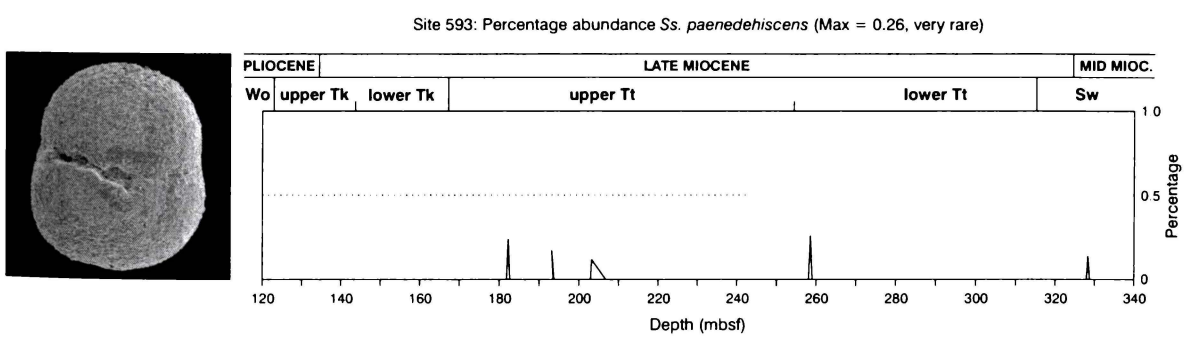


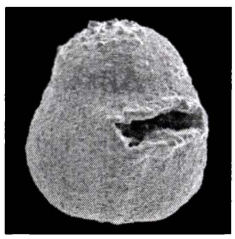
Plate: 1.37/5.

Remarks: *Sphaeroidinellopsis paenedehiscens* includes forms with a compactly coiled, thick cortex covered, sparsely perforate test, and elongate umbilical aperture bordered by a crenulated lip, which is developed as an extension of the cortex. It is distinguished from *Ss. seminulina* in having only three chambers in the outer whorl, a large, moderately embracing final chamber, and a less lobate test outline.

Distribution: The species is extremely rare in the late Miocene.

Sphaeroidinellopsis seminulina (Schwager)

1866 *Globigerina seminulina* Schwager, p. 256, pl. 7, fig. 112.



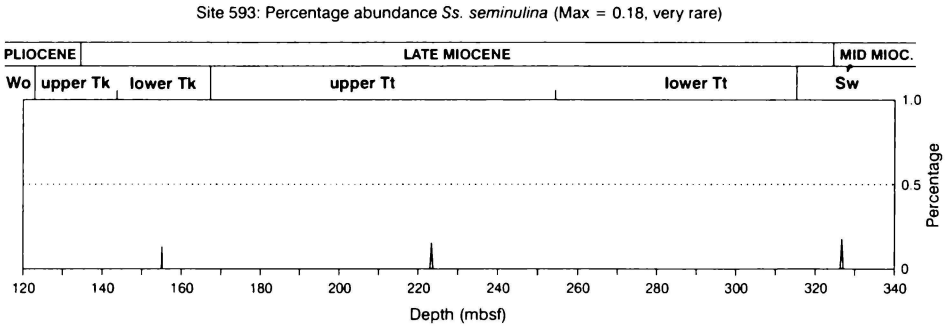


Plate: 1.37/6.

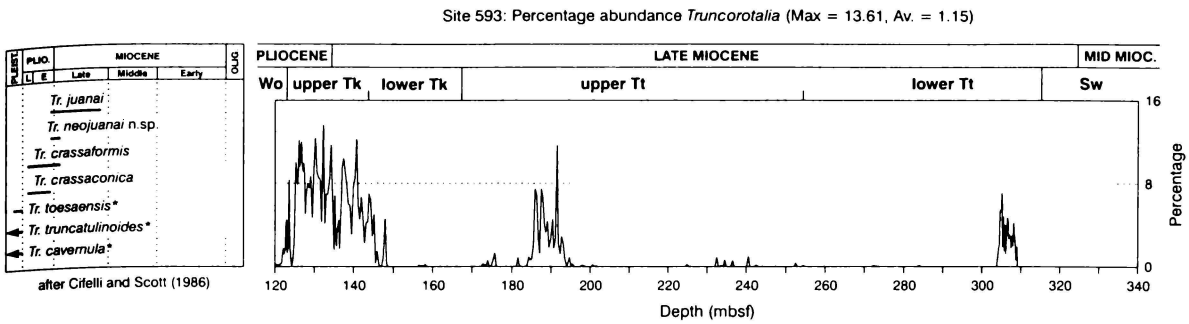
Remarks: *Sphaeroidinellopsis seminulina* has three to four chambers in the outer whorl, a weakly lobate chamber outline, a perforate test covered with a thick cortex, and an elongate umbilical aperture with a crenulated lip. The cortex is generally thinner on the final chamber, and pores and conical pustules are often well developed. It is distinguished from *Ss. paenedehiscens* in having more chambers in the outer whorl, a smaller less embracing final chamber, and a slightly more lobate test outline.

Distribution: The species is extremely rare in the late Miocene.

TRUNCOROTALIA

Cushman & Bermudez (1949) introduced the subgenus *Truncorotalia* and it was subsequently employed by Kennett & Srinivasan (1983) for keeled and non-keeled conicotruncate forms with low arched apertures that evolved from the late Miocene temperate-subantarctic species *Globorotalia* (*Hirsutella*) *cibaoensis*. Use here is based on Kennett & Srinivasan (1983), except that the status of the subgenus is raised to that of a genus. The lineage is also considered here to have evolved from *Truncorotalia juanai* as opposed to *"Globorotalia" cibaoensis* – see comments in Study 2 regarding *Tr. juanai*.

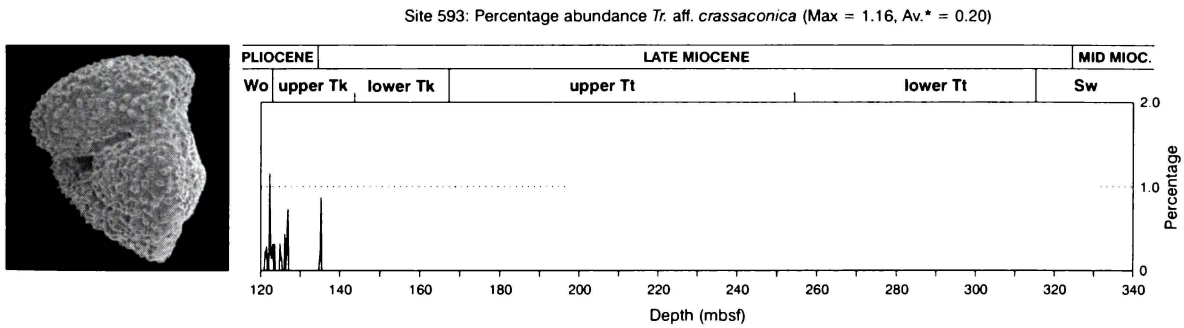
Truncorotalia is distinguished by its densely perforate, pustulate surface ultrastructure. Late Miocene and early Pliocene species have four chambers in the outer whorl and are distinctly quadrate, while five- to six-chambered forms with subcircular equatorial outlines evolve in the late Pliocene.



The genus *Truncorotalia* is largely, but not exclusively, confined to three short intervals in the late Miocene: a lowermost Tongaporutuan interval; an uppermost Tongaporutuan interval; and an upper Kapitean interval in the vicinity of the Miocene-Pliocene boundary. In each of these intervals *Truncorotalia* constitutes a small but persistent part of the planktic foraminiferal assemblage, and average abundances range from 2.8-5.7%.

Truncorotalia aff. *crassaconica* (Hornibrook)

1981 *Globorotalia crassaconica* Hornibrook, p. 271, figs. 5g-i, 9a-c.



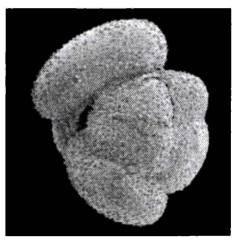
Plates: 1.5/9, 1.38/15, 1.39/1–3.

Remarks: Forms of *Truncorotalia* that have four chambers in the outer whorl, a subquadrate equatorial outline, and an inflated ventroconical axial-profile with an open umbilicus, are included in *Tr.* aff. *crassaconica.* Such forms are distinguished from *Tr. crassaformis* in having an angular peripheral margin, with an irregular imperforate pustulate rim-like ridge. These features attest to a close affinity with the keeled species *T. crassaconica.* Similar forms have previously been assigned to *Globorotalia crassaformis* (Cifelli & Scott 1986, p. 50, fig. 20/d-e) and *Globorotalia crassaconica* – early form (Scott et al. 1990, p. 107).

Distribution: Specimens of *Tr.* aff. *crassaconica* are extremely rare but are first noted in the vicinity of the Miocene-Pliocene boundary, in 593-15X-4, 90-93 cm (135.30 mbsf).

This occurs just prior to the entry of typical *Tr. crassaformis,* and well below the entry of *Tr. crassaconica* as noted by Hoskins (1990), in 593A-11H-1, 40 cm (94.50 mbsf).

Truncorotalia cf. *crassaformis* (Galloway and Wissler)



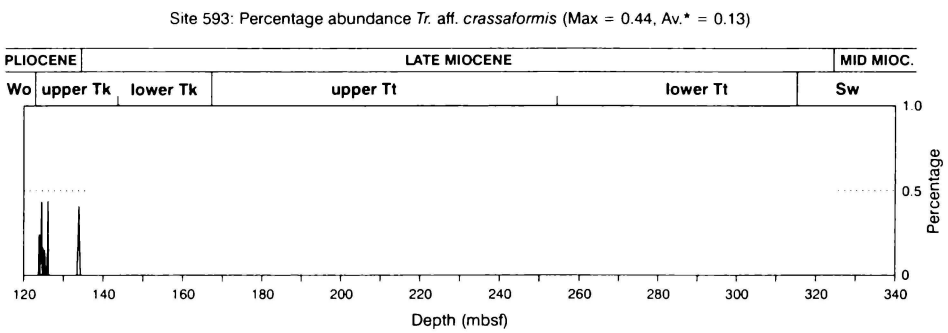


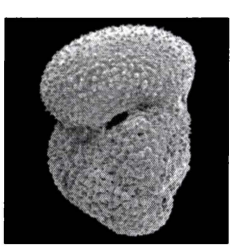
Plate: 1.2/12–13.

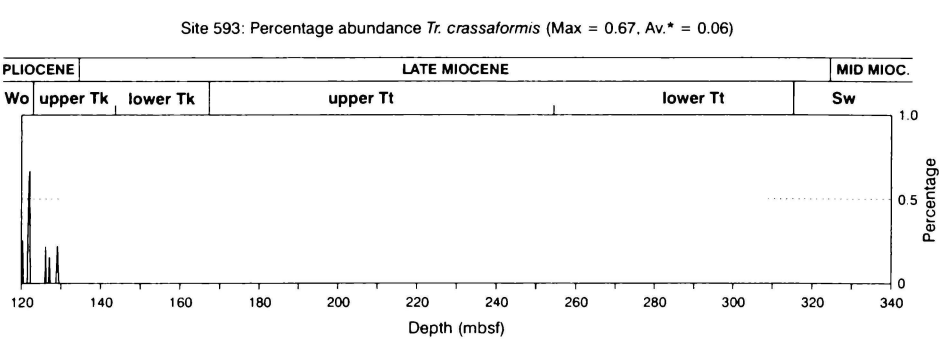
Remarks: Variants of *Truncorotalia crassaformis* in which late-formed chambers are offset due to a higher rate of whorl translation in late ontogeny, as in *Globoconella kingmai* (Scott) and *Globoconella explicationis* (Jenkins), are assigned to *Tr.* cf. *crassaformis.*

Distribution: Such forms are very rare and confined to the uppermost part of the sequence with *Tr. crassaformis.*

Truncorotalia crassaformis (Galloway and Wissler)

1927 *Globigerina crassaformis* Galloway and Wissler, p. 41, pl. 7, fig. 12.





Plates: 1.2/14–15, 1.39/4–5, (aberrant) 1.39/6.

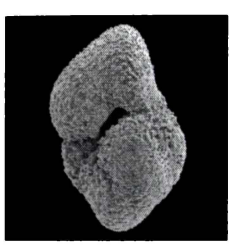
Remarks: There is currently little consensus on the phylogenetic origin of *Truncorotalia crassaformis* and this has been compounded by nomenclatural confusion involving potential ancestral species (Cifelli & Scott 1986). *Truncorotalia crassaformis* is considered here to evolve from *Tr. juanai* – see remarks concerning this species in Study 2.

The morphotypic concept of *Tr. crassaformis* that is employed in this study is based on forms that have a densely perforate and pustulate surface ultrastructure, four chambers in the outer whorl, a rounded periphery, an open umbilicus, and a low slit-like umbilical-extraumbilical aperture. It is distinguished from earlier species of *Truncorotalia* in having a distinctly ventroconical axial profile and a low slit-like aperture, and from later species in having a rounded peripheral margin and an inflated subquadrate spiral profile.

Distribution: The first typical specimens of *Tr. crassaformis* occur in the upper Kapitean as very rare variants in populations of ventrally extended *Tr. juanai*.

***Truncorotalia juanai* (Bermudez and Bolli)**

1969 *Globorotalia juanai* Bermudez and Bolli, pp.171-172, pl.14, figs. 1-6.



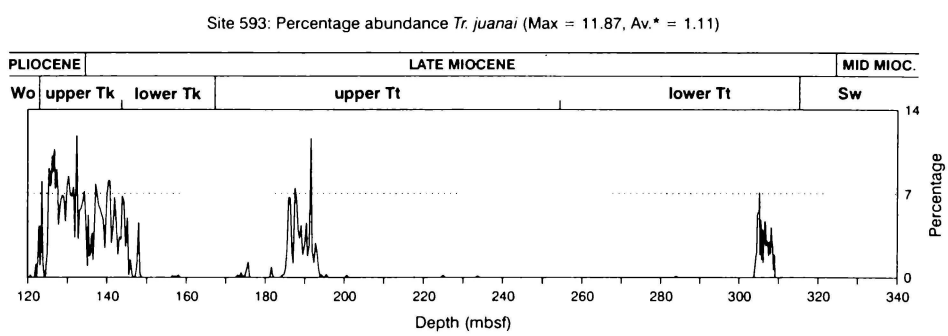
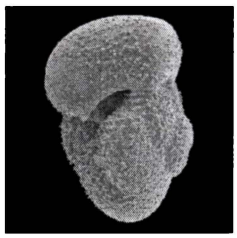


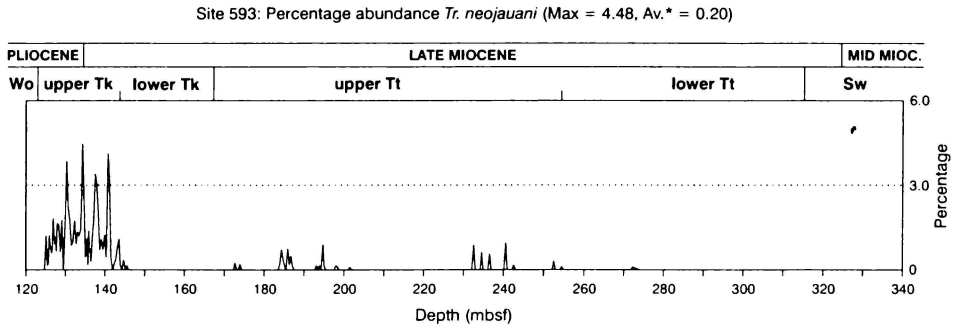
Plate: 1.5/13–15.

Remarks: Late Miocene forms of *Truncorotalia* with biconvex axial profiles and rounded, acutely angled peripheries, are assigned to *Tr. juanai*. Acceptable morphological variation extends to forms with spirally domed biconvex axial profiles and ventrally extended forms that maintain an acutely angled periphery.

Distribution: *Truncorotalia juanai* is largely, but not exclusively, confined to three short intervals in the late Miocene. The interval in the lowermost Tongaporutuan is dominated by spirally-domed, biconvex forms; the interval in the uppermost Tongaporutuan is dominated by equally biconvex forms; and the interval in the upper Kapitean, in the vicinity of the Miocene-Pliocene boundary, includes forms with biconvex and ventrally extended axial profiles. *Truncorotalia juanai* constitutes a persistent part of assemblages in each of these intervals, but is otherwise very rare or absent.

Truncorotalia neojuanai Crundwell





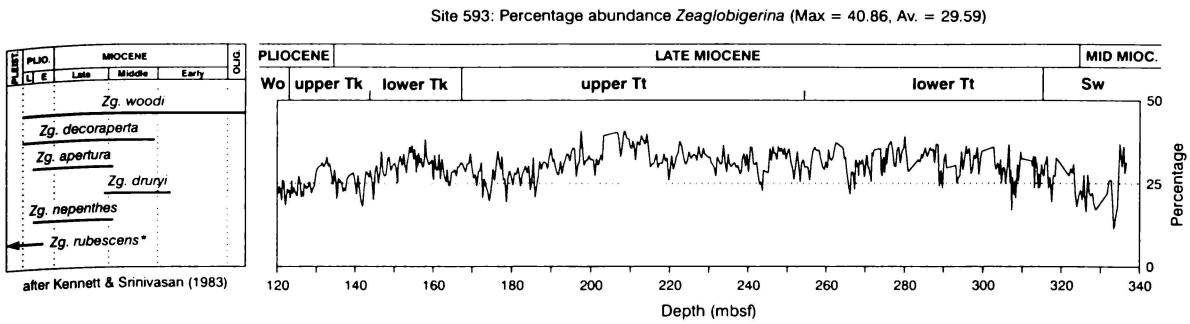
Plates: 1.5/10–12, (aberrant) 1.39/15.

Remarks: Forms of *Truncorotalia* that have ventrally-inflated chambers and axial profiles that are neither biconvex as in *Tr. juanai*, or ventroconical as in *Tr. crassaformis*, are here included in the new species *Tr. neojuanai*. *Truncorotalia neojuanai* is distinguished from *Tr. juanai* in having a high-angled rounded periphery as opposed to an acutely-angled periphery, and is distinguished from *Tr. crassaformis* in having chambers with a lower rate of ventral inflation. Forms where the ratio of axial height (H) versus spiral diameter (D) is less than 0.75 are assigned to *Tr. juanai*, and those where the (H/D) ratio is greater or equal to 0.75 are assigned to *Tr. crassaformis*. These criteria have been applied here on the basis of visual inspection only, and detailed morphometric study is needed to refine and improve the reliability of such biostratigraphic concepts.

Distribution: Ventrally-inflated forms of *Tr. neojuanai* occur as very rare variants in uppermost Miocene populations of *Tr. juanai*, but there is a marked increase in such forms in the upper Kapitean – in the vicinity of the Miocene-Pliocene boundary. This is taken to be the lowest occurrence of *Tr. neojuanai*.

ZEAGLOBIGERINA

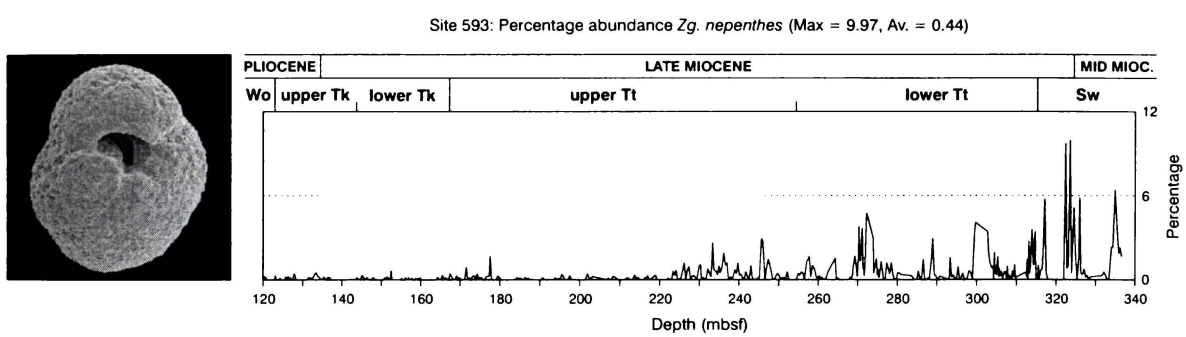
Kennett & Srinivasan (1983) erected the subgenus *Zeaglobigerina* for globigerine-like forms with a perforate, cancellate surface ultrastructure. Such forms are similar to *Globigerinoides*, but lack supplementary sutural apertures. The status of the subgenus *Zeaglobigerina* is raised here to that of a genus.



The genus *Zeaglobigerina* constitutes a very major and often dominant part of late Miocene assemblages. In terms of overall abundance, it tends to be slightly more common in the Tongaporutuan and lower Kapitean, and abundances decrease in the vicinity of the middle-late Miocene boundary, and the Miocene-Pliocene boundary.

Zeaglobigerina nepenthes (Todd)

1957 *Globigerina nepenthes* Todd, p. 301, figs. 7a-b.

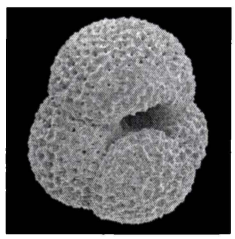


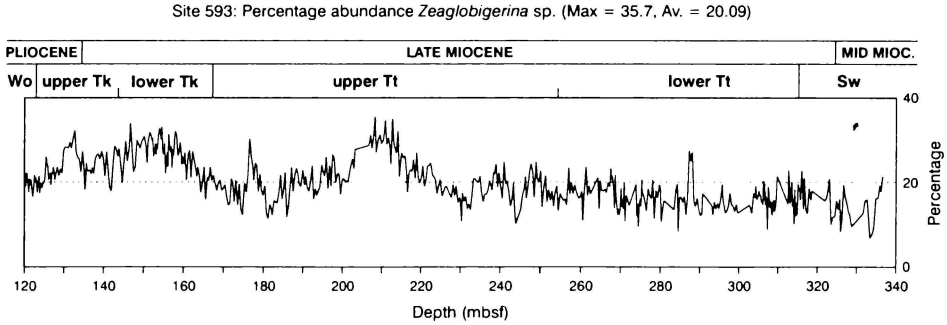
Plates: 1.4/14–15, 1.8/11–12, 1.14/9, 1.23/9–10, 1.26/6–7, 1.29/9–10, 1.32/4, 1.34/15, 1.39/11–12, (compact) 1.20/12, 1.32/5.

Remarks: Typical specimens of *Zeaglobigerina nepenthes* with a finger-like final chamber and a small umbilical aperture with a distinct lip are relatively rare. The majority of specimens that are assigned to *Zg. nepenthes* have compact heavily encrusted tests with a final chamber that is only slightly extended. Because it was not possible in the census to consistently distinguish between *Zg. druryi* and *Zg. nepenthes,* forms with a low, partially embracing final chamber have been included in *Zg. nepenthes*?

Distribution: *Zeaglobigerina nepenthes* is a moderately persistent late Miocene species, particularly in the lower part of the sequence below 593-24X-5, 103-105 cm (223.33 mbsf) where it is more common.

Zeaglobigerina sp.





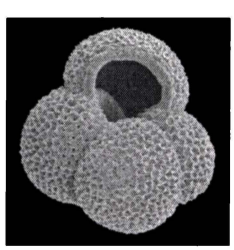
Plates: 1.1/15, 1.4/12, 1.8/10, 1.11/6, 1.14/7, 1.17/7–9, 1.20/9, 1.23/11, 1.29/8, 1.32/6, 1.37/4, (aberrant) 1.39/7–9.

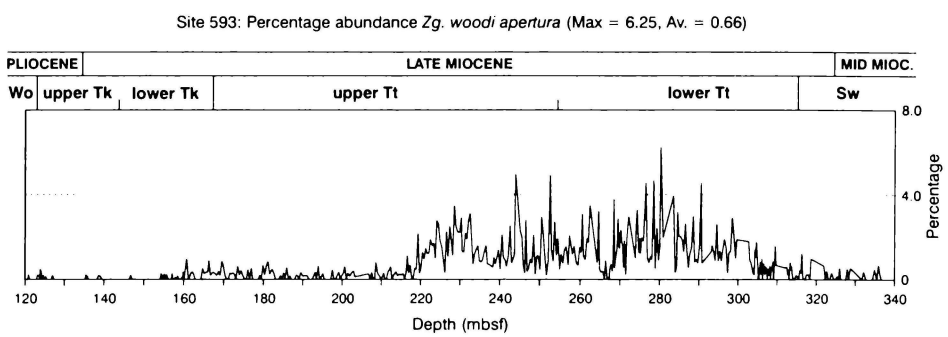
Remarks: All cancellate globigerine-like forms without supplementary apertures that are not included in *Zeaglobigerina nepenthes, Zg. woodi apertura, Zg. woodi decoraperta,* and *Z. woodi woodi* are assigned to the miscellaneous collective *Zeaglobigerina* sp. The group principally includes juveniles that lack diagnostic adult characteristics. The most common forms include individuals with a small subcircular umbilical aperture – they are distinguished from *Zg. woodi woodi* in that maximum diameter of the aperture is less than 25% of the maximum dimension of the final chamber. Also included are four-chambered forms with a low-arched umbilical-extraumbilical aperture and a distinct imperforate rim (Plates 1.4/12 and 1.20/9), a well as three-chambered forms (Plate 1.23/11).

Distribution: The miscellaneous collective *Zeaglobigerina* sp. constitutes a very important part of all late Miocene assemblages, especially in the middle upper Tongaporutuan and Kapitean, where they make up almost one-third of the planktic foraminiferal assemblage.

Zeaglobigerina woodi apertura (Cushman)

1918 *Globigerina apertura* Cushman, p. 57, pl. 12, figs. 8a-c.





Plates: 1.1/14, 1.8/8, 1.11/5, 1.14/6, 1.17/10–11, 1.20/8, 1.23/5, 1.26/6, 1.29/2.

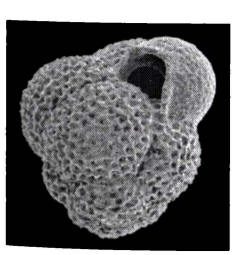
Remarks: *Zeaglobigerina woodi apertura* is distinguished from other elements of the *Zg. woodi* plexus by its low-spired test and very large, semicircular, umbilical aperture, with a distinct imperforate rim. To facilitate census counts, only specimens where the maximum diameter of the aperture (A) is more than half the maximum dimension of the final chamber (C) are assigned to *Z. woodi apertura.* Specimens with A/C ratios of 0.25-0.50 are assigned to *Zg. woodi woodi,* and those with A/C ratios less than 0.25 are included in *Zeaglobigerina* sp.

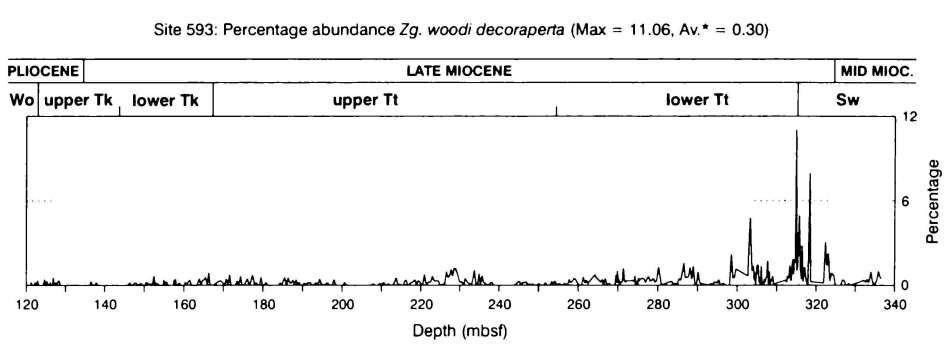
Typical specimens of *Zg. woodi apertura* have a subcircular umbilical aperture that is aligned with the antepenultimate chamber (Plate 1.20/7), but the accepted range of morphological variation extends to forms with high-arched umbilical-extraumbilical apertures (Plate 1.26/5), and kummerforms with obliquely aligned apertures (Plate 1.20/10). Very rare specimens were also noted with at least one supplementary sutural aperture, similar to *Globigerinoides bollii* Blow.

Distribution: *Zeaglobigerina woodi apertura* is a relatively persistent late Miocene subspecies, but is most common in the lower Tongaporutuan and lower upper Tongaporutuan, where it maintains an average abundance of 1.3%.

***Zeaglobigerina woodi decoraperta* (Takayanagi and Saito)**

1962 *Globigerina druryi* Akers subsp. *decoraperta* Takayanagai and Saito, p. 85, pl. 28, figs. 10a-c.





Plates: 1.8/9, 1.14/8, 1.23/3, 1.26/7, 1.29/3.

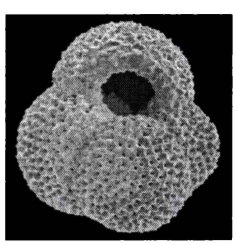
Remarks: The use of *Zeaglobigerina woodi decoraperta* in this study is restricted to high-spired forms in the *Zg. woodi* plexus, with a semicircular to low-arched rimmed aperture. The majority of such specimens have a kummerform final chamber.

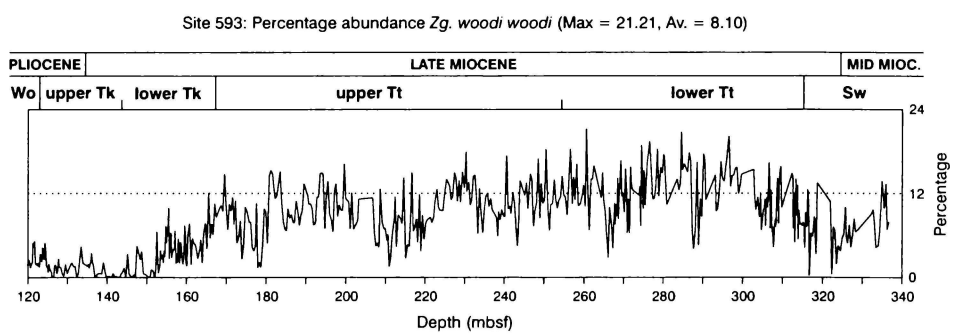
Distribution: *Zeaglobigerina woodi decoraperta* is a relatively rare, but moderately persistent, late Miocene subspecies. It is most common in the vicinity of the Waiauan-Tongaporutuan boundary.

In the lower part of the section, compact high-spired specimens of *Zg. woodi decoraperta* intergrade with *Zg. nepenthes* and incorrect identifications may have contributed to the elevated abundances of the subspecies in the lowermost Tongaporutuan. Jenkins (1971) noted a similar gradation between thick-walled *Globigerina nepenthes* and thin-walled *Globigerina decoraperta* in at least one onland section in New Zealand. More work is needed to clarify the morphological relationship between these species.

Zeaglobigerina woodi woodi (Jenkins)

1960 *Globigerina woodi* Jenkins, p. 352, pl. 2, figs. 2a-c.





Plates: 1.1/13, 1.4/13, 1.8/7, 1.11/4, 1.14/5, 1.17/7–8, 1.20/7, 1.23/4, 1.26/5, 1.29/1, 1.31/14.

Remarks: Use of the name *Zeaglobigerina woodi woodi* is restricted in this study to low-spired elements in the *Zg. woodi* plexus that have a subcircular umbilical aperture, with a maximum diameter ranging from one-quarter to one-half of the maximum dimension of the final chamber. Specimens with larger apertures are assigned to *Zg. woodi apertura,* and those with smaller apertures are included in *Zeaglobigerina* sp.

The gross morphology of *Zg. woodi woodi* remains relatively stable throughout the late Miocene although the size and obliquity of the aperture is moderately varied. Very rare specimens were noted with at least one supplementary sutural aperture, similar to *Globigerinoides bollii* Blow, but they are otherwise indistinguishable from *Zg. woodi woodi.*

Distribution: *Zeaglobigerina woodi woodi* constitutes the most common element of the *Zg. woodi* plexus in the late Miocene, particularly in the Tongaporutuan where it maintains an average abundance of 10.6%. The abundance of the species decreases markedly in the upper part of the lower Kapitean, and abundances remain low through the Kapitean and lower Opoitian.

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Key to Plates 1.1–1.39: The following plates provide a visual guide to morphological variation and faunal change in late Miocene temperate planktic foraminiferal assemblages. The illustrated specimens for each assemblage are arranged with particular reference to surface ultrastructure and gross morphological features. There are three plates for each of the 12 horizons shown in Figure 1.4 (Plates 1.1–1.36), and three plates of miscellaneous taxa (Plates 1.37–1.39).

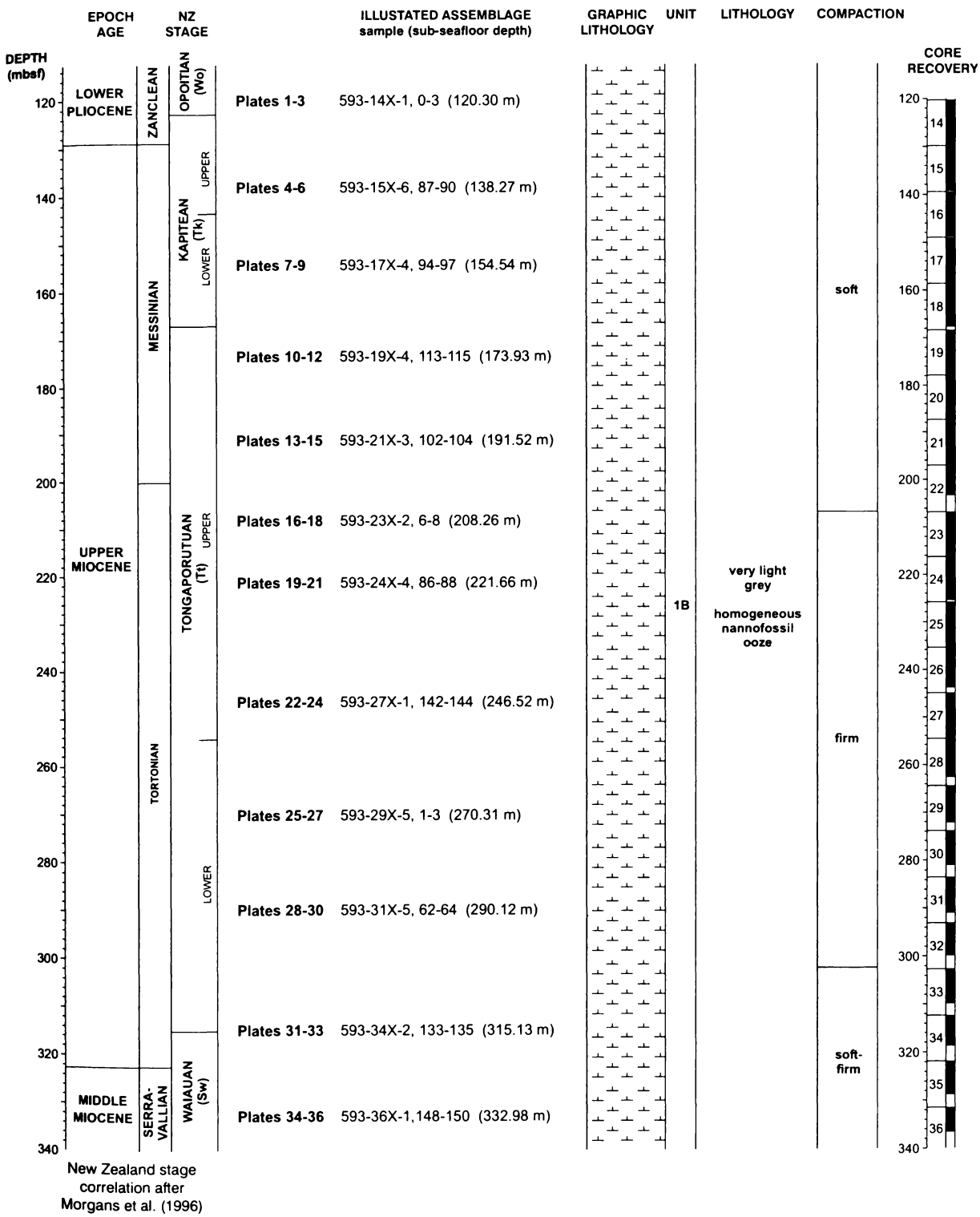


Figure 1.4 – Stratigraphic distribution of illustrated planktic foraminiferal assemblages (Plates 1.1–1.36) from DSDP Site 593. Lithostratigraphic classification after Kennett et al. (1986).

Index to illustrated species, Plates 1.1–1.39 (*Globigerina – Hirsutella*)

Illustrated taxa	Plate/Figure
Globigerina bulloides d'Orbigny	1.1/1, 1.4/1, 1.7/1, 1.10/1, 1.13/1, 1.16/1-2, 1.19/1–2, 1.22/1, 1.25/1, 1.28/1, 1.31/1, 1.34/1–2
Globigerina eamesi Blow	1.10/3, 1.28/3
Globigerina falconensis Blow	1.1/2, 1.4/2, 1.7/2–3, 1.10/2, 1.13/2, 1.16/3, 1.19/3–4, 1.22/2, 1.25/2, 1.28/2, 1.31/2, 1.34/3
Globigerina sp.	1.1/3–4, 1.4/3–5, 1.7/4–6, 1.10/4–5, 1.13/3–4, 1.16/4–6, 1.19/5–6, 1.22/3–4, 1.25/3, 1.28/4–6, 1.31/3–4, 1.34/4; (aberrant) 1.39/11
Globigerina cf. *angustiumbilicata* (Bolli)	1.4/7, 1.7/7, 1.13/7–8, 1.19/10–11, 1.22/5–6, 1.25/4–5, 1.28/7–9, 1.31/5–6, 1.34/5–7, 1.37/5–7
Globigerina quinqueloba (Natland)	1.1/5, 1.4/6, 1.7/8–9, 1.10/6–7, 1.13/5–6, 1.16/7–8, 1.19/7–9, 1.22/7
Globigerinella aequilateralis (Brady)	1.37/1
Globigerinita glutinata (Egger)	1.1/6–7, 1.4/8–9, 1.7/10–11, 1.10/8–9, 1.13/9–11, 1.16/9–11, 1.19/12, 1.22/8–9, 1.25/6, 1.28/10–11, 1.31/7–8, 1.34/8
Globigerinita uvula (Ehrenberg)	1.7/12, 1.10/10–11, 1.13/12, 1.28/12, 1.31/9, 1.34/9
Globigerinoides obliquus Bolli	1.1/12, 1.37/2–3
Globigerinoides quadrilobatus immaturus (Le Roy)	1.23/3–4, 1.29/4
Globigerinoides quadrilobatus quadrilobatus (d'Orbigny)	1.23/1–2, 1.25/14–15, 1.29/3
Globigerinoides quadrilobatus trilobus (Reuss)	1.23/5–6, 1.26/1–2
Globigerinoides sacculifer (Brady)	1.39/1
Globigerinopsis obesa (Bolli)	1.1/8, 1.7/13–15, 1.10/12–15, 1.13/13–15, 1.16/13–15, 1.19/13–15, 1.22/10–12, 1.25/7–10, 1.28/13–15, 1.29/1, 1.31/10–11
Globoconella conomiozea (Kennett)	1.6/10–12, 1.6/14–15, 1.9/6–9, (s.l.) 1.3/10–12
Globoconella explicationis (Jenkins)	1.6/13, 1.12/9, 1.21/8, 1.30/13–15, 1.36/13–15
Globoconella miotumida (Jenkins)	1.9/10–12, 1.12/4–8, 1.12/10–15, 1.15/7–15, 1.18/7–15, 1.21/9–15, 1.24/8–15, 1.27/5–15, 1.30/7–12, 1.33/10–15, 1.36/4–12
Globoconella mons (Hornibrook)	1.3/13–15, 1.9/13–15
Globoconella pliozea (Hornibrook)	1.3/7–9
Globoconella puncticulata (Deshayes)	1.3/1–6
Globoconella sphericomiozea (Walters)	1.6/1–9
Globoquadrina dehiscens (Chapman, Parr, and Collins)	1.26/8–9, 1.29/11–12, 1.32/7–8, 1.35/1–3
Globorotalia lenguaensis Bolli	1.37/13–15
Globorotaloides hexagonus (Natland)	1.37/7–10
Hirsutella cf. *ichinosekiensis* (Takayanagi and Oda)	1.38/7
Hirsutella margaritae (Bolli and Bermudez)	1.5/5, 1.38/10
Hirsutella panda (Jenkins)	1.33/7–9
Hirsutella scitula (Brady)	1.2/7–11, 1.5/6–8, 1.9/3–5, 1.11/13–15, 1.14/15, 1.15/1–3, 1.17/13–15, 1.18/1–3, 1.21/1–7, 1.24/3–7, 1.26/12, 1.27/1–3, 1.30/4–6; (spiroconical) 1.27/4, 1.38/4–6, 1.38/8–9; (cf.) 1.12/1–3, 1.18/4–6, 1.26/13–15, 1.36/1–3, 1.38/1
Hirsutella sp.	1.38/2–3

Index to illustrated species, Plates 1.1–1.39 (*Menardella – Zeaglobigerina*)

Illustrated taxa	Plate/Figure
Menardella cf. *limbata* (Fornasini)	1.38/11–12
Neogloboquadrina dutertrei (d'Orbigny)	1.2/6, 1.5/4, 1.9/1–2, 1.11/7–8, 1.14/14, 1.24/1–2
Neogloboquadrina mayeri continuosa (Blow)	1.33/1–5, 1.35/4–9; (aberrant) 1.39/13
Neogloboquadrina mayeri mayeri (Cushman and Ellisor)	1.32/9–12, 1.33/6, 1.35/10–15
Neogloboquadrina mayeri nympha (Jenkins)	1.32/13–15
Neogloboquadrina pachyderma (Ehrenberg)	1.2/1–5, 1.5/1–3, 1.8/13–15, 1.11/9–12, 1.14/10–13, 1.17/10–12, 1.20/13–15, 1.23/12–15, 1.26/10–11, 1.29/13–15, 1.30/1–3; (aberrant) 1.39/14
Orbulina bilobata (d'Orbigny)	1.1/10, 1.8/2, 1.14/2, 1.17/2, 1.20/3, 1.22/14, 1.25/13, 1.31/12, 1.34/11
Orbulina universa d'Orbigny	1.1/9, 1.4/10, 1.8/1, 1.11/1, 1.14/1, 1.17/1, 1.20/1–2, 1.22/13, 1.25/11, 1.34/10
Orbulina universa "juvenile"	1.1/11, 1.4/11, 1.8/3–6, 1.11/2–3, 1.14/3–4, 1.17/3–4, 1.20/4–6, 1.22/15, 1.25/12, 1.29/2, 1.31/13–15, 1.34/12–13
Sphaeroidinellopsis paenedehiscens Blow	1.37/5
Sphaeroidinellopsis seminulina (Schwager)	1.37/6
Truncorotalia aff. *crassaconica* (Hornibrook)	1.5/9, 1.38/15, 1.39/1–3
Truncorotalia cf. *crassaformis* (Galloway and Wissler)	1.2/12–13
Truncorotalia crassaformis (Galloway and Wissler)	1.2/14–15, 1.39/4–5; (aberrant) 1.39/6
Truncorotalia juanai (Bermudez and Bolli)	1.5/13–15, 1.15/4–6
Truncorotalia praecrassaformis n. sp.	1.5/10–12; (aberrant) 1.39/15
Truncorotalia sp.	1.38/14
Zeaglobigerina nepenthes (Todd)	1.4/15, 1.8/12, 1.14/9, 1.23/9–10, 1.26/7, 1.29/9, 1.32/4, 1.39/12
Zeaglobigerina nepenthes ? (Todd) - compact form	1.4/14, 1.8/11, 1.20/12, 1.26/6, 1.29/10, 1.32/5, 1.34/15
Zeaglobigerina sp.	1.1/15, 1.4/12, 1.8/10, 1.11/6, 1.14/7, 1.17/7–9, 1.20/9, 1.23/11, 1.29/8, 1.32/6, 1.37/4; (aberrant) 1.39/7–9
Zeaglobigerina woodi apertura (Cushman)	1.1/14, 1.8/8, 1.11/5, 1.14/6, 1.17/10–11, 1.20/10–11, 1.23/8, 1.26/5, 1.29/6, 1.32/2
Zeaglobigerina woodi decoraperta (Takayanagi and Saito)	1.8/9, 1.14/8, 1.26/3, 1.29/7, 1.32/3
Zeaglobigerina woodi woodi (Jenkins)	1.1/13, 1.4/13, 1.8/7, 1.11/4, 1.14/5, 1.17/5–6, 1.20/7–8, 1.23/7, 1.26/4, 1.29/5, 1.32/1, 1.34/14; (cf. *Gs. bollii*) *1.37/11–12*

Plate 1.1

Lower Opoitian (lower Pliocene) planktic foraminifers

DSDP Site 593-14X-1, 0-3 cm (120.30 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

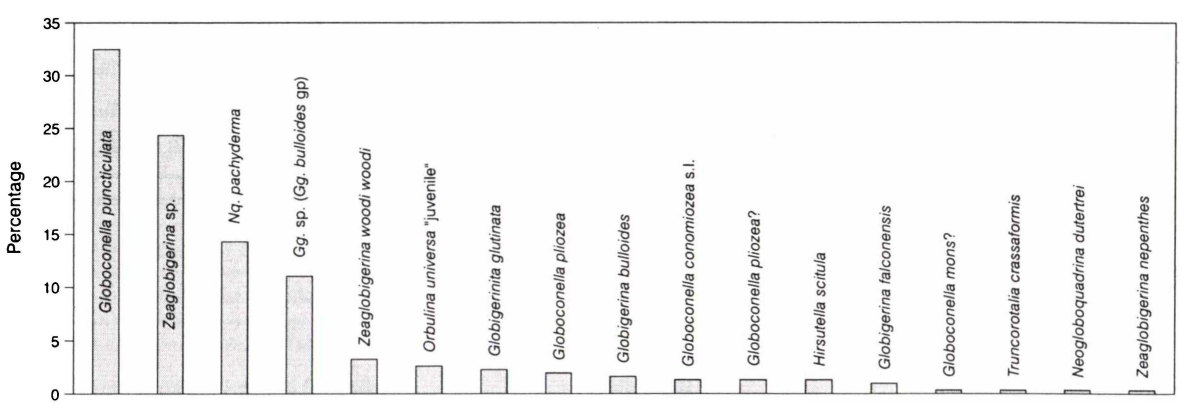
1) ***Globigerina bulloides*** **d'Orbigny**, 340 μm (Image 14463)
2) ***Globigerina falconensis*** **Blow**, 275 μm (Image 14465)
3) ***Globigerina*** **sp.** , *Gg. bulloides*-like juvenile, 300 μm (Image 14470)

4) ***Globigerina*** **sp.**, 150 μm (Image 14471)
5) ***Globigerina quinqueloba*** **(Natland)**, 190 μm (Image 14477)
6) ***Globigerinita glutinata*** **(Egger)**, non-bullate, 180 μm (Image 14485)

7) ***Globigerinita glutinata*** **(Egger)**, 140 μm (Image 14484)
8) ***Globigerinopsis obesa*** **(Bolli)**, 395 μm (Image 14489)
9) ***Orbulina universa*** **d'Orbigny**, 440 μm (Image 14536)

10) ***Orbulina bilobata*** **(d'Orbigny)**, 310 μm (Image 14532)
11) ***Orbulina universa*** **"juvenile"** 375 μm (Image 14540)
12) ***Globigerinoides obliquus*** **Bolli**, 305 μm (Image 14530)

13) ***Zeaglobigerina woodi woodi*** **(Jenkins)**, 200 μm (Image 14543)
14) ***Zeaglobigerina woodi apertura*** **(Cushman)**, 235 μm (Image 14544)
15) ***Zeaglobigerina*** **sp.**, 165 μm (Image 14547)



Faunal composition (120.30 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 308 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.1 – DSDP Site 593 (120.30 mbsf)

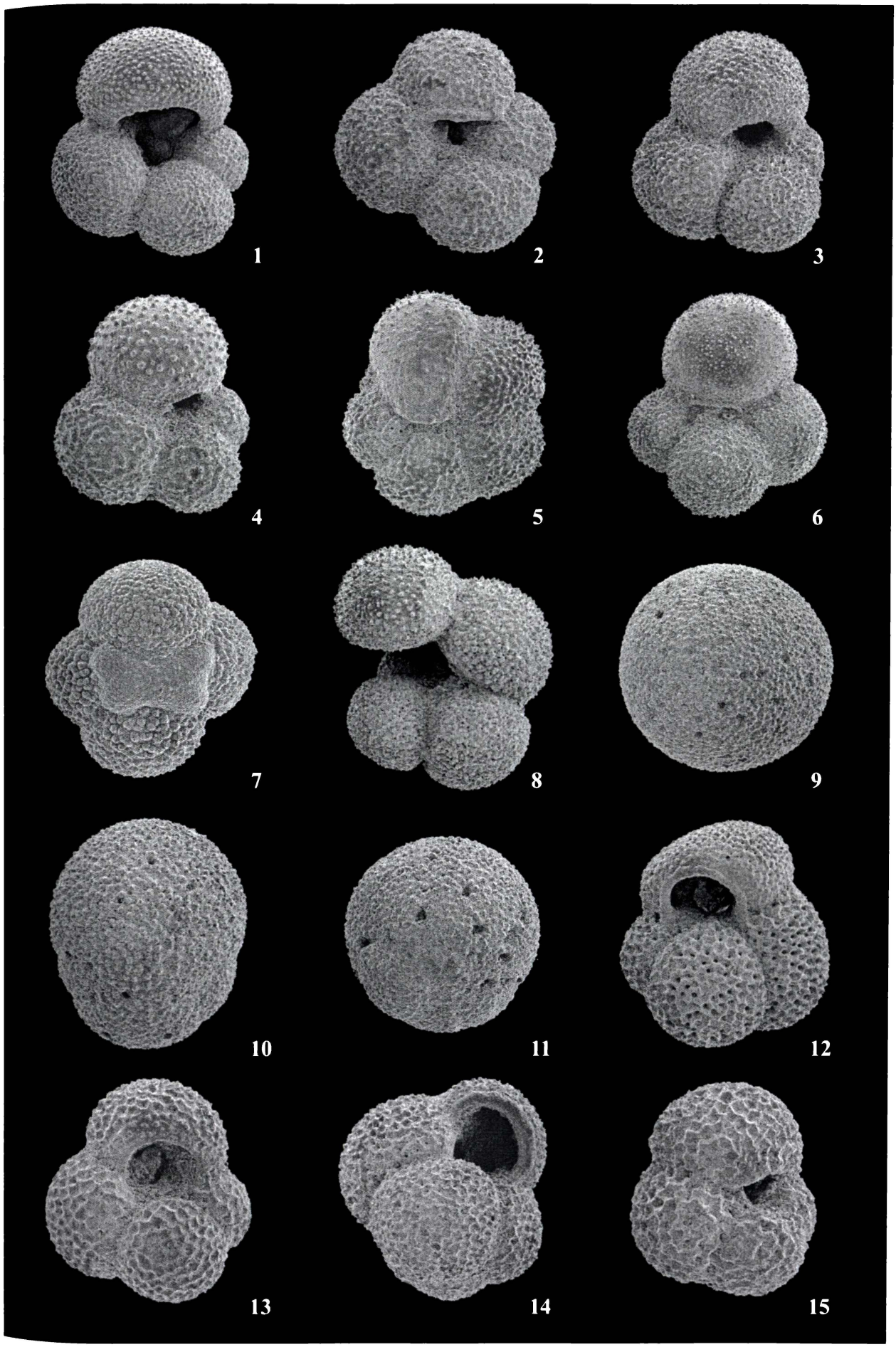


Plate 1.2

Lower Opoitian (lower Pliocene) planktic foraminifers

DSDP Site 593-14X-1, 0-3 cm (120.30 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

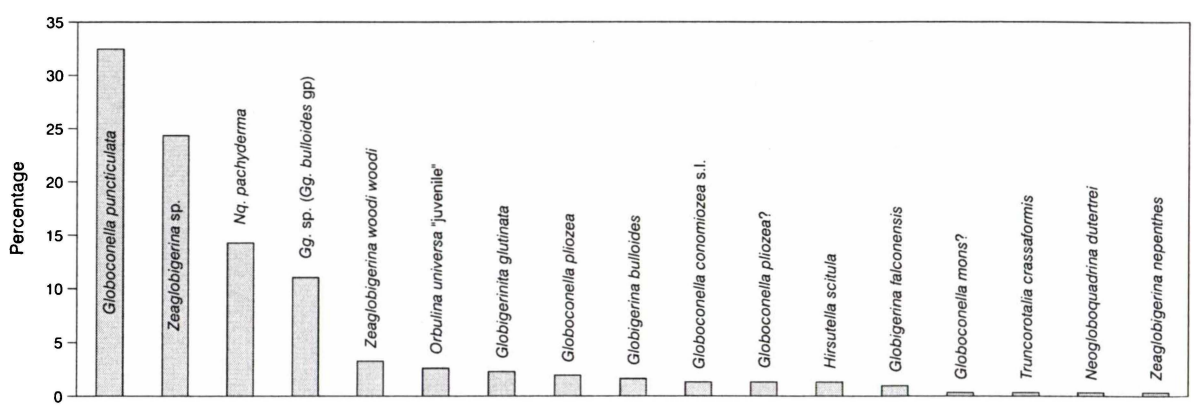
1) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 245 μm (Image 14509)
2) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 220 μm (Image 14512)
3) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 260 μm (Image 14510)

4) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 210 μm (Image 14513)
5) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 160 μm (Image 14514)
6) ***Neogloboquadrina dutertrei*? (d'Orbigny)**, 310 μm (Image 14515)

7) ***Hirsutella scitula* (Brady)**, 280 μm (Image 14523)
8) ***Hirsutella scitula* (Brady)**, 230 μm (Image 14524)
9) ***Hirsutella scitula* (Brady)**, 380 μm (Image 14522)

10) ***Hirsutella scitula* (Brady)**, 240 μm (Image 14525)
11) ***Hirsutella scitula* (Brady)**, 250 μm (Image 14526)
12) ***Truncorotalia* cf. *crassaformis* (Galloway and Wissler)**, 520 μm (Image 14521)

13) ***Truncorotalia* cf. *crassaformis* (Galloway and Wissler)**, 415 μm (Image 14519)
14) ***Truncorotalia crassaformis* (Galloway and Wissler)**, 280 μm (Image 14517)
15) ***Truncorotalia crassaformis* (Galloway and Wissler)**, 335 μm (Image 14516)



Faunal composition (120.30 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 308 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.2 – DSDP Site 593 (120.30 mbsf)

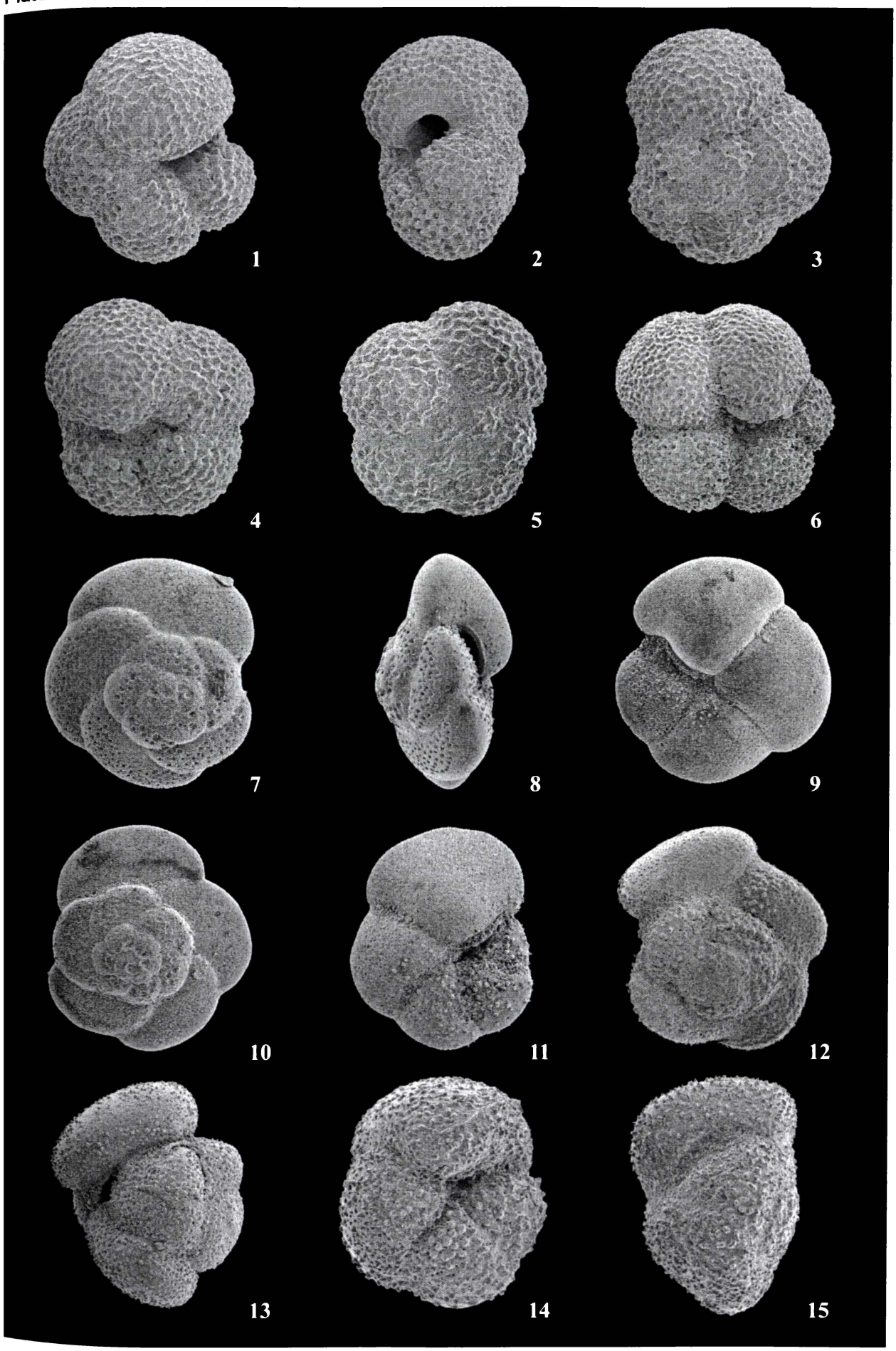


Plate 1.3

Lower Opoitian (lower Pliocene) planktic foraminifers

DSDP Site 593-14X-1, 0-3 cm (120.30 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

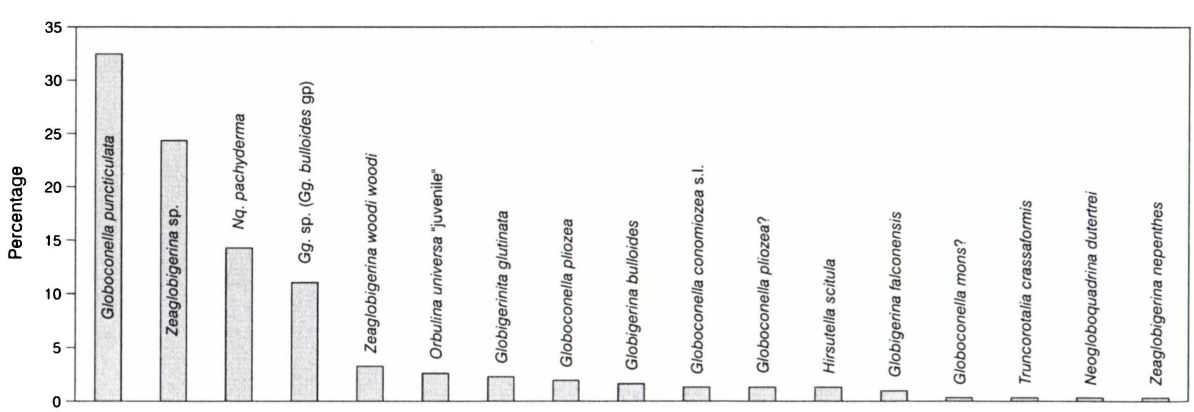
1) ***Globoconella puncticulata*** **(Deshayes)**, compressed, 290 μm (Image 14493)
2) ***Globoconella puncticulata*** **(Deshayes)**, compressed, 335 μm (Image 14491)
3) ***Globoconella puncticulata*** **(Deshayes)**, compressed, 360 μm (Image 14492)

4) ***Globoconella puncticulata*** **(Deshayes)**, inflated, 330 μm (Image 14496)
5) ***Globoconella puncticulata*** **(Deshayes)**, inflated, 345 μm (Image 14494)
6) ***Globoconella puncticulata*** **(Deshayes)**, inflated, 350 μm (Image 14495)

7) ***Globoconella pliozea*** **(Hornibrook)**, 525 μm (Image 14501)
8) ***Globoconella pliozea*** **(Hornibrook)**, 475 μm (Image 14502)
9) ***Globoconella pliozea*** **(Hornibrook)**, 485 μm (Image 14505)

10) ***Globoconella conomiozea*** **s.l. (Kennett)**, 390 μm (Image 14504)
11) ***Globoconella conomiozea*** **s.l. (Kennett)**, 395 μm (Image 14507)
12) ***Globoconella conomiozea*** **s.l. (Kennett)**, 430 μm (Image 14508)

13) ***Globoconella mons*** **(Hornibrook)**, encrusted, 415 μm (Image 14497)
14) ***Globoconella mons*** **(Hornibrook)**, encrusted, 325 μm (Image 14500)
15) ***Globoconella mons*** **(Hornibrook)**, encrusted, 350 μm (Image 14499)



Faunal composition (120.30 mbsf). Taxa ordered according to abundance. Percentage data, based on a pick of 308 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.3 – DSDP Site 593 (120.30 mbsf)

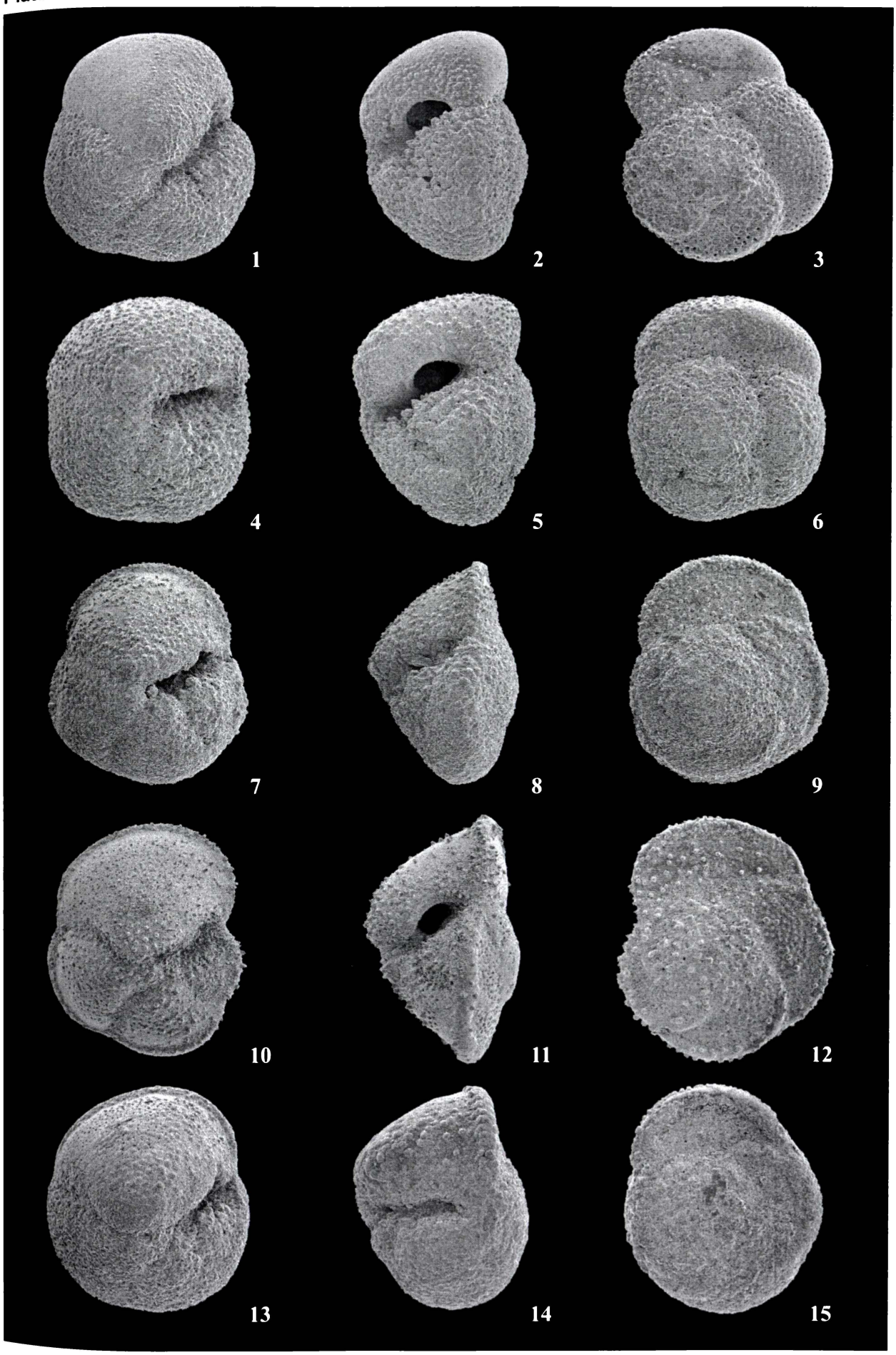


Plate 1.4

Upper Kapitean (early Pliocene) planktic foraminifers

DSDP Site 593-15X-6, 87-90 cm (138.27 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

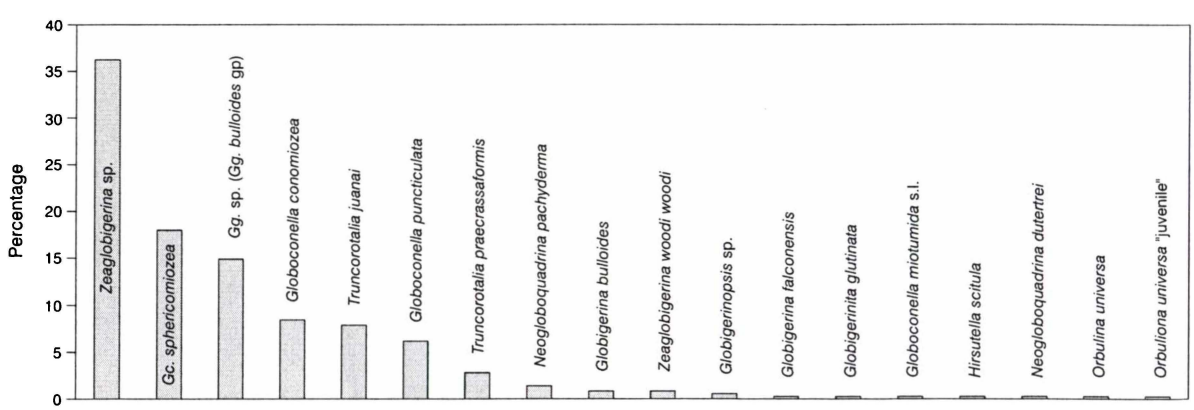
1) ***Globigerina bulloides*** **d'Orbigny**, 365 μm (Image 14550)
2) ***Globigerina falconensis*** **Blow**, 230 μm (Image 14552)
3) ***Globigerina*** **sp.**, *Gg.* cf. *foliata,* 165 μm (Image 14558)

4) ***Globigerina*** **sp.**, *Gg. bulloides*-like juvenile, 230 μm (Image 14555)
5) ***Globigerina*** **sp.**, 235 μm (Image 14557)
6) ***Globigerina quinqueloba*** **(Natland)**, 150 μm (Image 14559)

7) ***Globigerina*** **cf. *angustiumbilicata*? (Bolli)**, 170 μm (Image 14562)
8) ***Globigerinita glutinata*** **(Egger)**, 165 μm (Image 14563)
9) ***Globigerinita glutinata*** **(Egger)**, non-bullate, 155 μm (Image 14566)

10) ***Orbulina universa*** **d'Orbigny**, 500 μm (Image 14627)
11) ***Orbulina universa*** **"juvenile"** 200 μm (Image 14632)
12) ***Zeaglobigerina*** **sp.**, 210 μm (Image 14635)

13) ***Zeaglobigerina woodi woodi*** **(Jenkins)**, 235 μm (Image 14636)
14) ***Zeaglobigerina nepenthes*?** **(Cushman)**, compact, 175 μm (Image 14637)
15) ***Zeaglobigerina nepenthes*** **(Cushman)**, 185 μm (Image 14639)



Faunal composition (138.27 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 356 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.4 – DSDP Site 593 (138.27 mbsf)

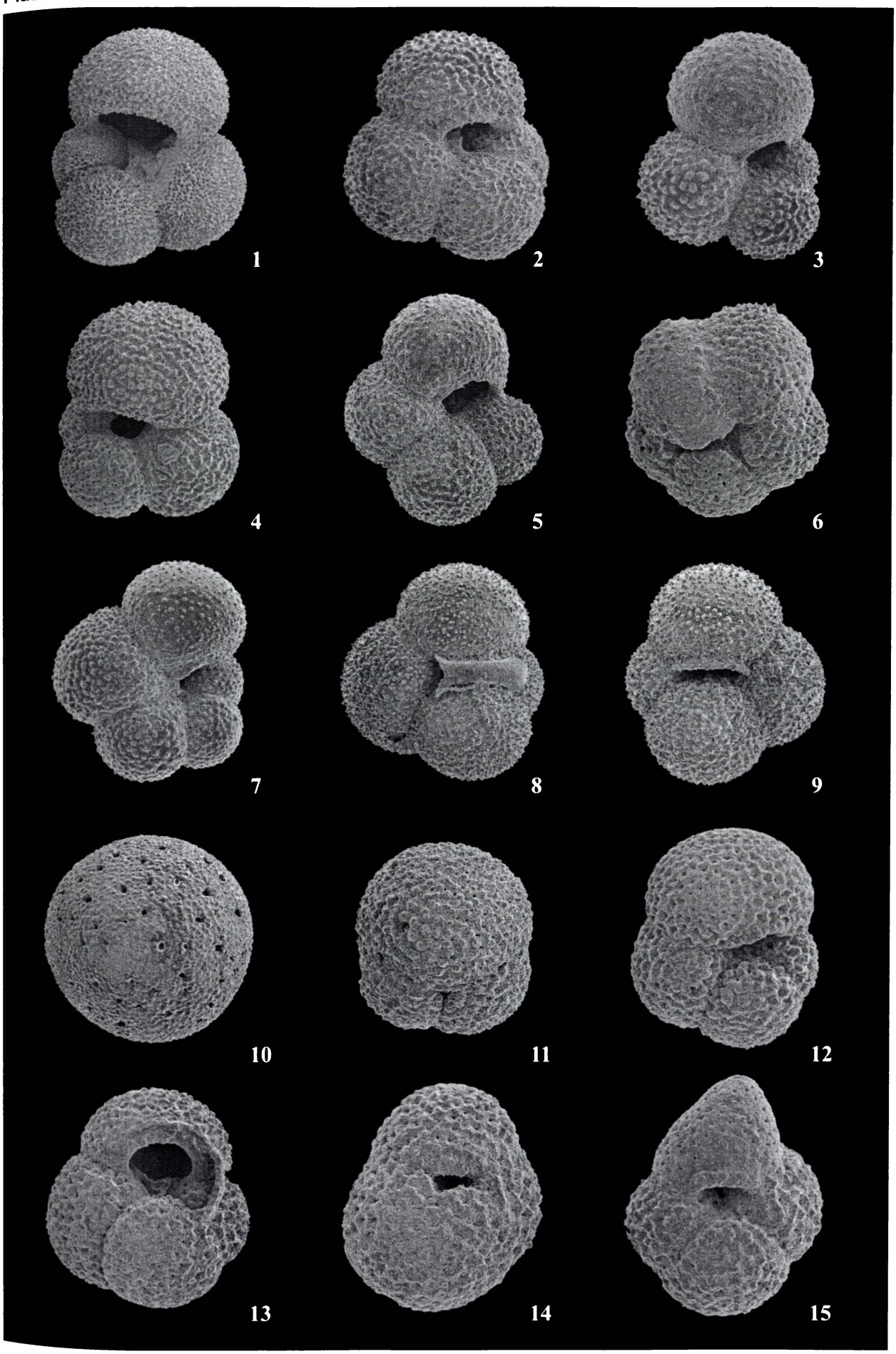


Plate 1.5

Upper Kapitean (early Pliocene) planktic foraminifers

DSDP Site 593-15X-6, 87-90 cm (138.27 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

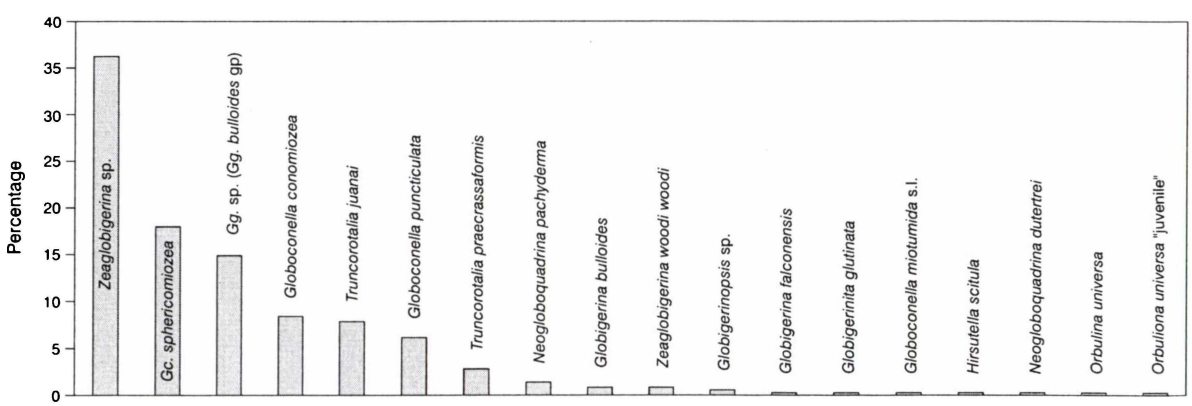
1) ***Neogloboquadrina pachyderma*** **(Ehrenberg)**, 185 μm (Image 14623)
2) ***Neogloboquadrina pachyderma*** **(Ehrenberg)**, 215 μm (Image 14622)
3) ***Neogloboquadrina pachyderma*** **(Ehrenberg)**, 240 μm (Image 14619)

4) ***Neogloboquadrina dutertrei*** **(d'Orbigny)**, 260 μm (Image 14625)
5) ***Hirsutella margaritae*** **(Bolli)**, 195 μm (Image 14608)
6) ***Hirsutella scitula*** **(Brady)**, 220 μm (Image 14614)

7) ***Hirsutella scitula*** **(Brady)**, 455 μm (Image 14613)
8) ***Hirsutella scitula*** **(Brady)**, 450 μm (Image 14609)
9) ***Truncorotalia*** **aff.** ***crassaconica*** **(Hornibrook**, 335 μm (Image 14582)

10) ***Truncorotalia praecrassaformis*** **n. sp.**, 380 μm (Image 14600)
11) ***Truncorotalia praecrassaformis*** **n. sp.**, 365 μm (Image 14601)
12) ***Truncorotalia praecrassaformis*** **n. sp.**, 340 μm (Image 14602)

13) ***Truncorotalia juanai*** **(Bermudez and Bolli)**, biconvex, 340 μm (Image 14604)
14) ***Truncorotalia juanai*** **(Bermudez and Bolli)**, biconvex, 290 μm (Image 14605)
15) ***Truncorotalia juanai*** **(Bermudez and Bolli)**, biconvex, 290 μm (Image 14606)



Faunal composition (138.27 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 356 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.5 - DSDP Site 593 (138.27 mbsf)

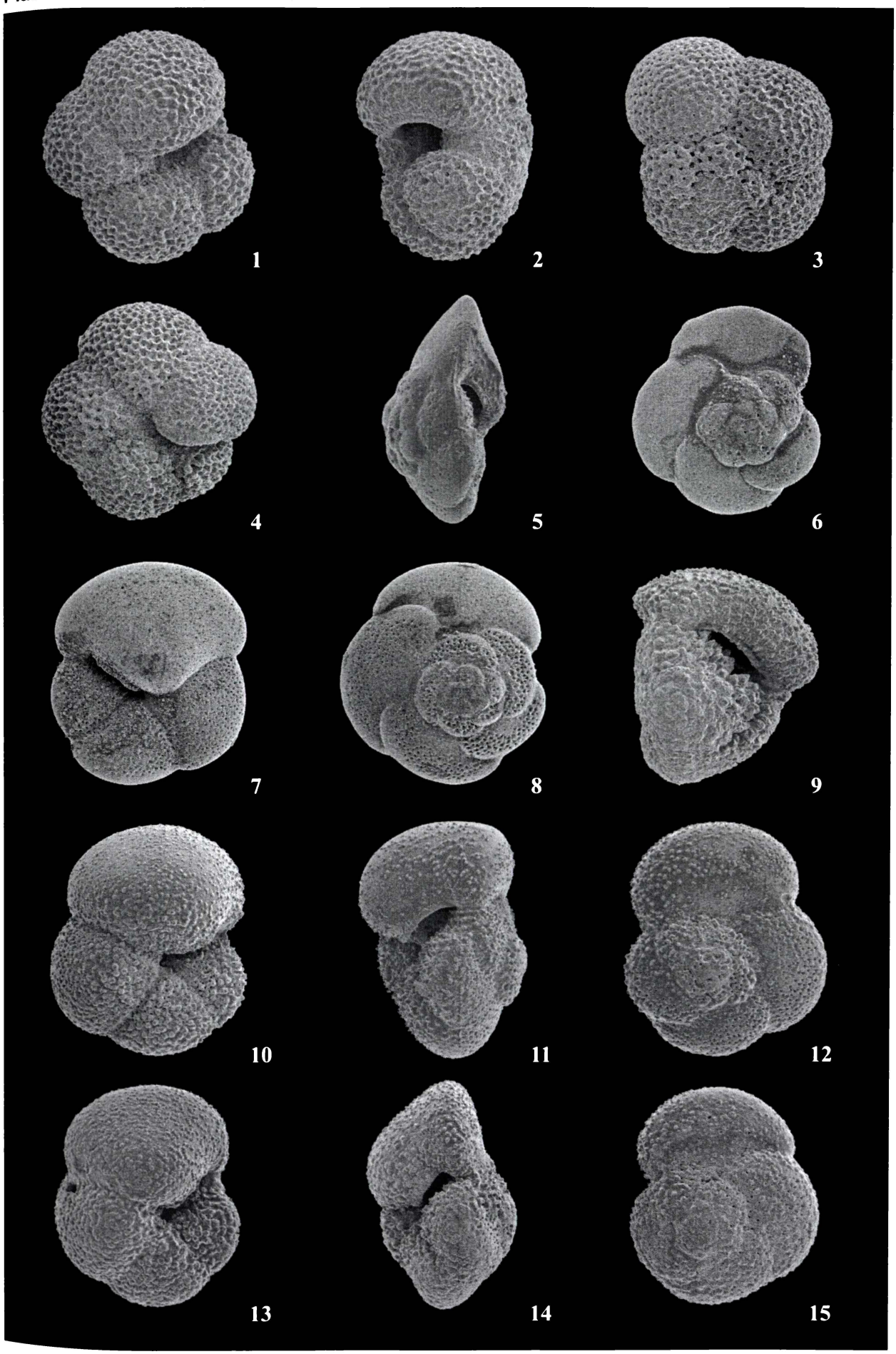


Plate 1.6

Upper Kapitean (early Pliocene) planktic foraminifers

DSDP Site 593-15X-6, 87-90 cm (138.27 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

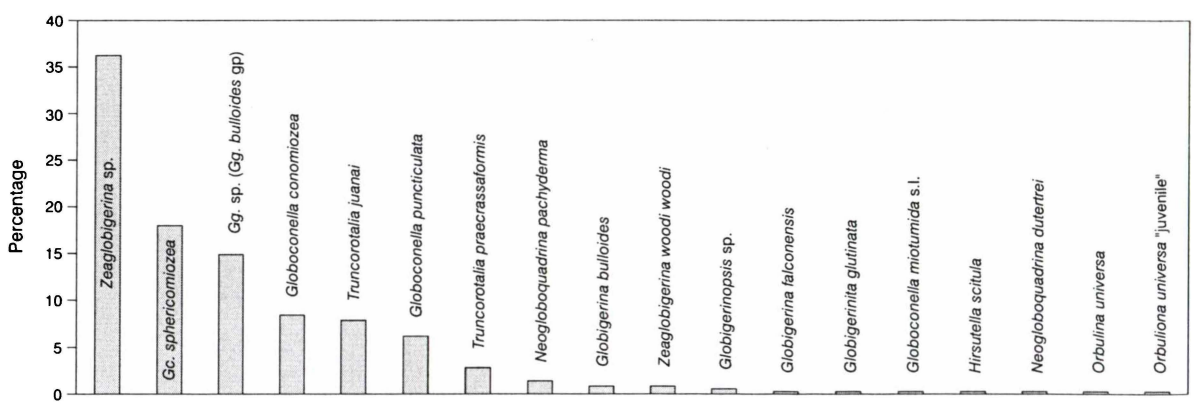
1) ***Globoconella sphericomiozea* (Walters)**, unkeeled, 250 μm (Image 14575)
2) ***Globoconella sphericomiozea* (Walters)**, unkeeled, 290 μm (Image 14577)
3) ***Globoconella sphericomiozea* (Walters)**, unkeeled, 310 μm (Image 14578)

4) ***Globoconella sphericomiozea* (Walters)**, unkeeled, 380 μm (Image 14569)
5) ***Globoconella sphericomiozea* (Walters)**, unkeeled, 415 μm (Image 14568)
6) ***Globoconella sphericomiozea* (Walters)**, unkeeled, 275 μm (Image 14567)

7) ***Globoconella sphericomiozea* (Walters)**, keeled, 435 μm (Image 14579)
8) ***Globoconella sphericomiozea* (Walters)**, keeled, 365 μm (Image 14581)
9) ***Globoconella sphericomiozea* (Walters)**, keeled, 440 μm (Image 14580)

10) ***Globoconella conomiozea* (Kennett)**, 355 μm (Image 14588)
11) ***Globoconella conomiozea* (Kennett)**, 370 μm (Image 14591)
12) ***Globoconella conomiozea* (Kennett)**, 415 μm (Image 14599)

13) ***Globoconella explicationis* (Jenkins)**, four chambered form, 255 μm (Image 14590)
14) ***Globoconella conomiozea* (Kennett)**, 330 μm (Image 14572)
15) ***Globoconella conomiozea* (Kennett)**, 260 μm (Image 14574)



Faunal composition (138.27 mbsf). Taxa ordered according to abundance. Percentage data, based on a pick of 356 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.6 – DSDP Site 593 (138.27 mbsf)

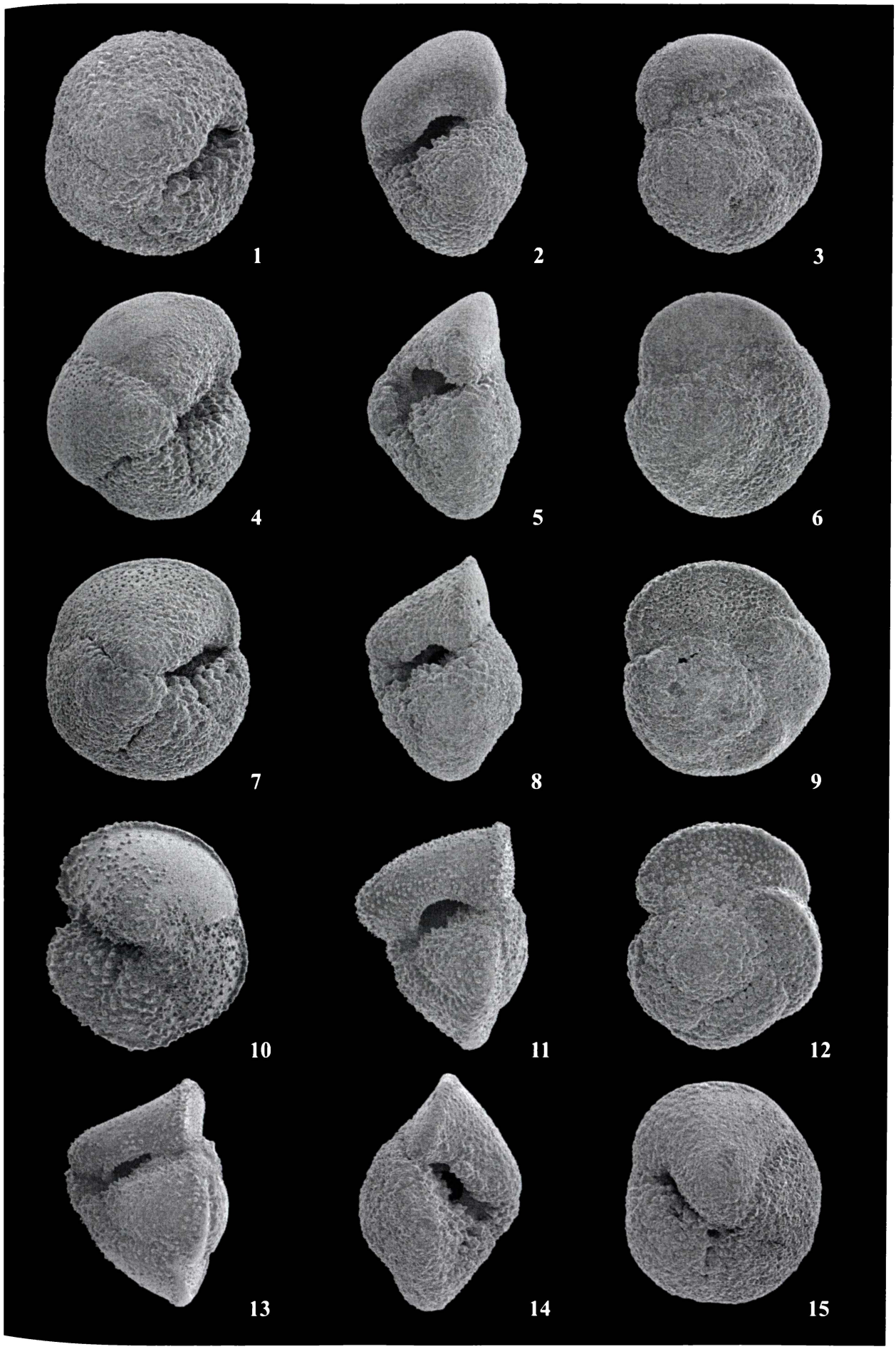


Plate 1.7

Lower Kapitean (latest Miocene) planktic foraminifers

DSDP Site 593-17X-4, 94-97 cm (154.54 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

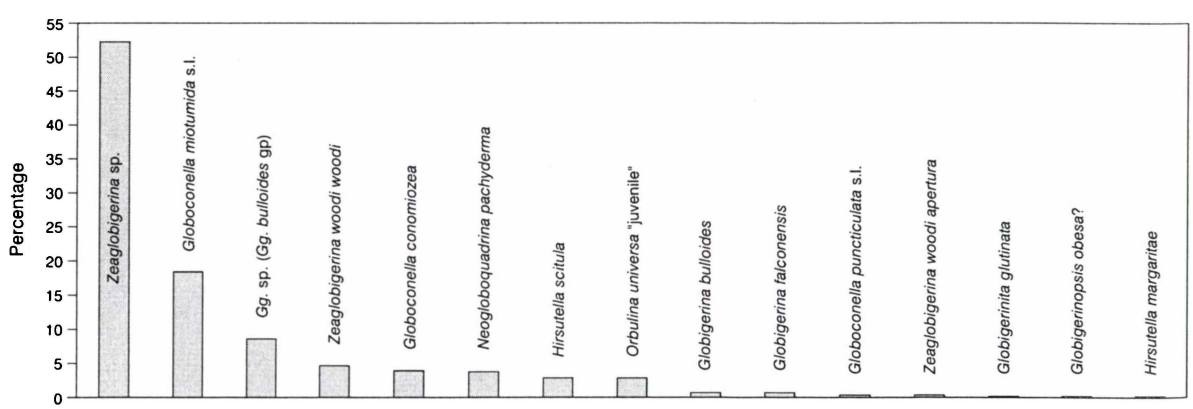
1) ***Globigerina bulloides*** **d'Orbigny**, 280 μm (Image 14641)
2) ***Globigerina falconensis*** **Blow**, 280 μm (Image 14643)
3) ***Globigerina falconensis*** **Blow**, 215 μm (Image 14644)

4) ***Globigerina*** **sp.**, 350 μm (Image 14645)
5) ***Globigerina*** **sp.**, *G. bulloides*-like juvenile, 260 μm (Image 14646)
6) ***Globigerina*** **sp.**, 190 (Image 14648)

7) ***Globigerina*** **cf. *angustiumbilicata*? (Bolli)**, 160 μm (Image 14652)
8) ***Globigerina quinqueloba*** **(Natland)**, 160 μm (Image 14650)
9) ***Globigerina quinqueloba*** **(Natland)**, 155 μm (Image 14651)

10) ***Globigerinita glutinata*** **(Egger)**, 160 μm (Image 14655)
11) ***Globigerinita glutinata*** **(Egger)**, non-bullate, 160 μm (Image 14656)
12) ***Globigerinita uvula*** **(Ehrenberg)**, 150 μm (Image 14657)

13) ***Globigerinopsis obesa*** **(Bolli)**, 560 μm (Image 14659)
14) ***Globigerinopsis obesa*** **(Bolli)**, 415 μm (Image 14661)
15) ***Globigerinopsis obesa*** **(Bolli)**, 420 μm (Image 14660)



Faunal composition (154.54 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 559 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.7 – DSDP Site 593 (154.54 mbsf)

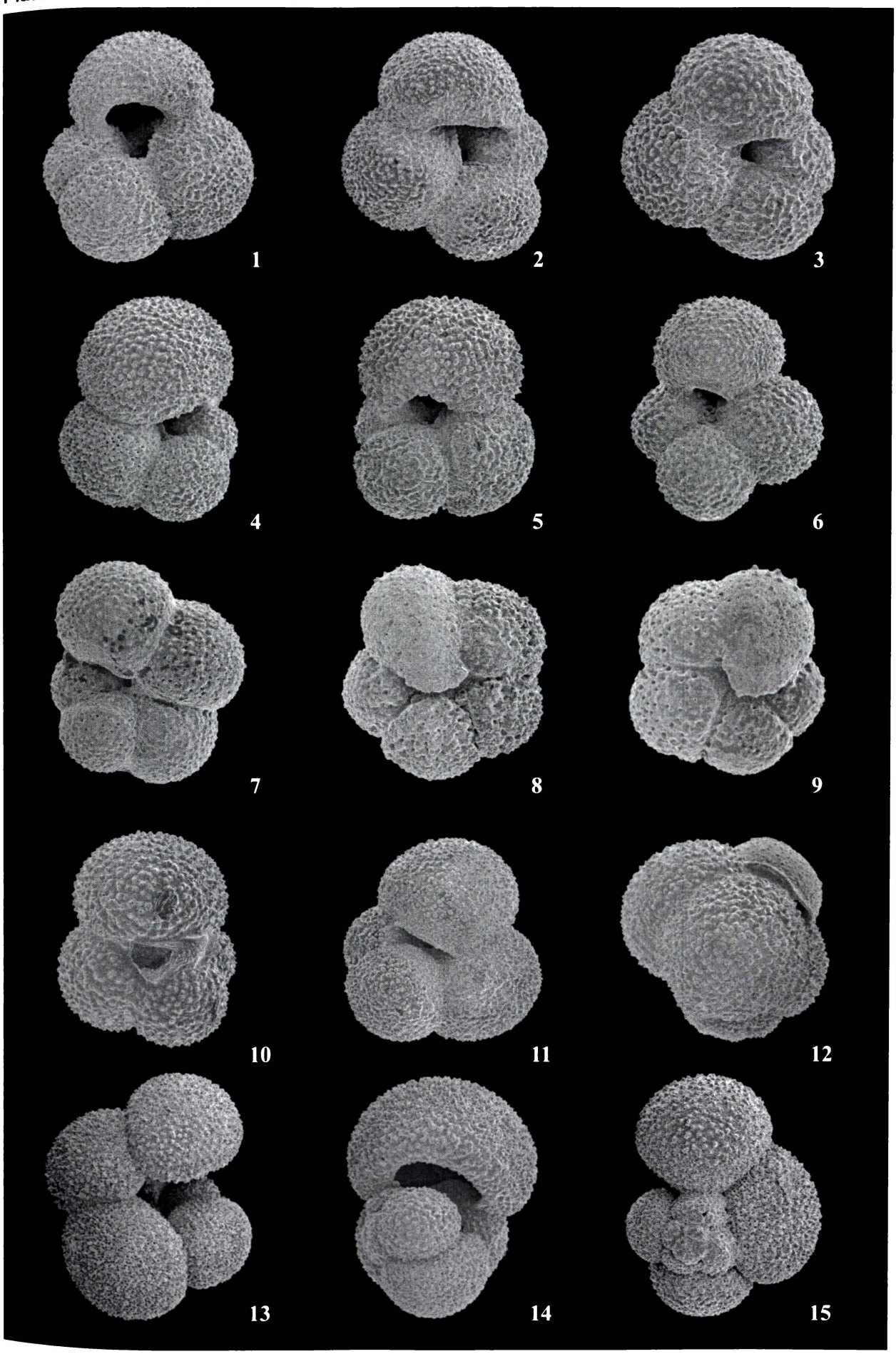


Plate 1.8

Lower Kapitean (latest Miocene) planktic foraminifers

DSDP Site 593-17X-4, 94-97 cm (154.54 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

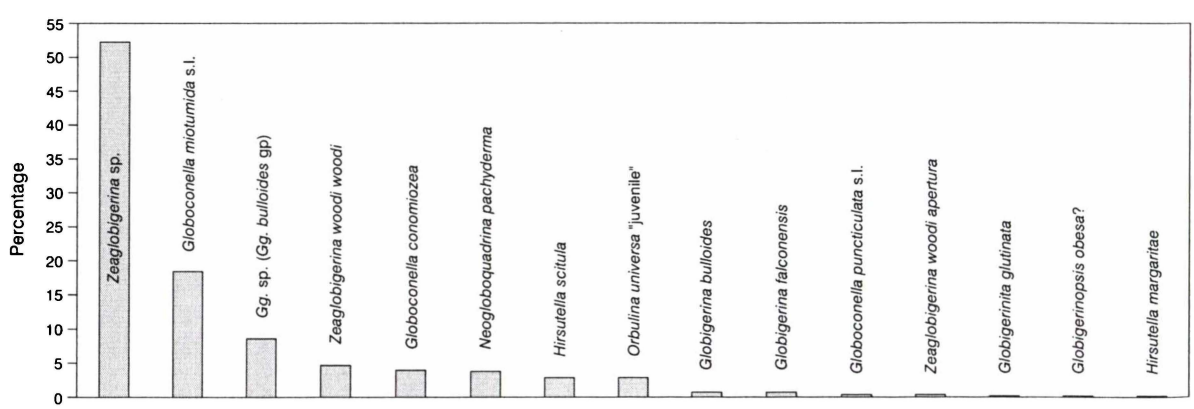
1) ***Orbulina universa* d'Orbigny**, 280 μm (Image 14689)
2) ***Orbulina bilobata* (d'Orbigny)**, 325 μm (Image 14691)
3) ***Orbulina universa* "juvenile"** 330 μm (Image 14690)

4) ***Orbulina universa* "juvenile"** 230 μm (Image 14692)
5) ***Orbulina universa* "juvenile"** 195 μm (Image 14693)
6) ***Orbulina universa* "juvenile"** 200 μm (Image 14695)

7) ***Zeaglobigerina woodi woodi* (Jenkins)**, 235 μm (Image 14696)
8) ***Zeaglobigerina woodi apertura* (Cushman)**, 325 μm (Image 14699)
9) ***Zeaglobigerina woodi decoraperta* (Takayanagi and Saito)**, 215 μm (Image 14700)

10) ***Zeaglobigerina* sp.**, 235 μm (Image 14701)
11) ***Zeaglobigerina nepenthes*? (Todd)**, compact, 160 μm (Image 14704)
12) ***Zeaglobigerina nepenthes* (Todd)**, 185 μm (Image 14705)

13) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 280 μm (Image 14685)
14) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 220 μm (Image 14687)
15) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 235 μm (Image 14686)



Faunal composition (154.54 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 559 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.8 – DSDP Site 593 (154.54 mbsf)

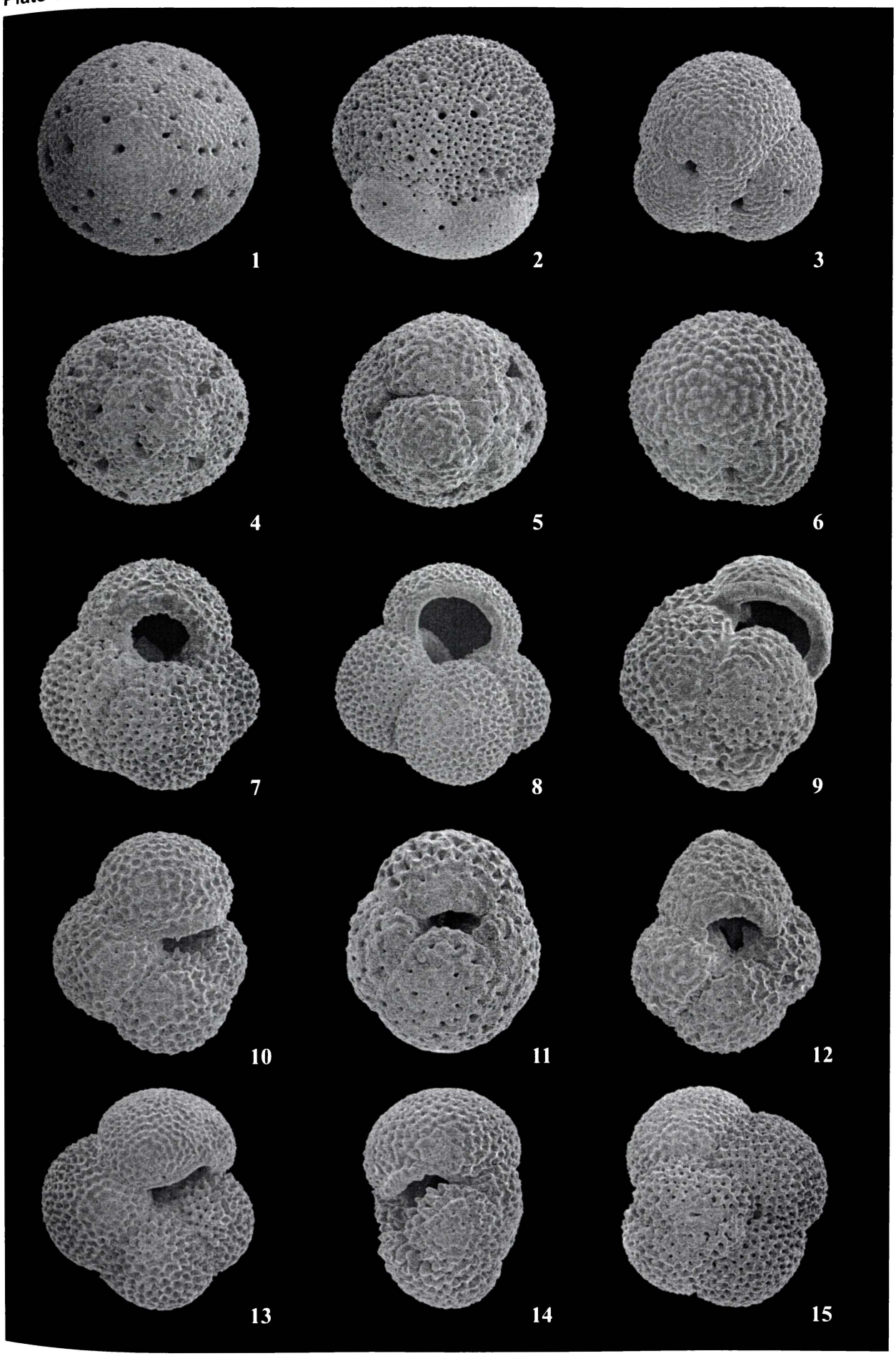


Plate 1.9

Lower Kapitean (latest Miocene) planktic foraminifers

DSDP Site 593-17X-4, 94-97 cm (154.54 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

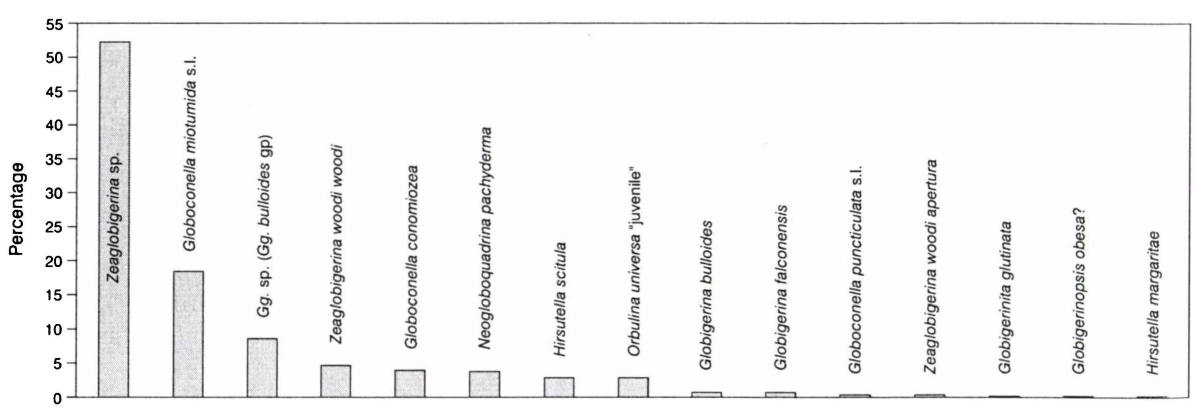
1) ***Neogloboquadrina dutertrei* (d'Orbigny)**, 290 μm (Image 14688)
2) ***Neogloboquadrina dutertrei* (d'Orbigny)**, 265 μm (Image 16819)
3) ***Hirsutella scitula* (Brady)**, 400 μm (Image 14677)

4) ***Hirsutella scitula* (Brady)**, 420 μm (Image 14676)
5) ***Hirsutella scitula* (Brady)**, 315 μm (Image 14678)
6) ***Globoconella conomiozea* (Kennett)**, unkeeled, 320 μm (Image 14666)

7) ***Globoconella conomiozea* (Kennett)**, 310 μm (Image 17044)
8) ***Globoconella conomiozea* (Kennett)**, 365 μm (Image 14670)
9) ***Globoconella conomiozea* (Kennett)**, 310 μm (Image 17045)

10) ***Globoconella miotumida* (Jenkins)**, ventroconical, 420 μm (Image 14668)
11) ***Globoconella miotumida* (Jenkins)**, ventroconical, 460 μm (Image 16808)
12) ***Globoconella miotumida* (Jenkins)**, ventroconical, 355 μm (Image 14665)

13) ***Globoconella mons* (Hornibrook)**, 295 μm (Image 14675)
14) ***Globoconella mons* (Hornibrook)**, encrusted, 445 μm (Image 14673)
15) ***Globoconella mons* (Hornibrook)**, 365 μm (Image 14674)



Faunal composition (154.54 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 559 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.9 – DSDP Site 593 (154.54 mbsf)

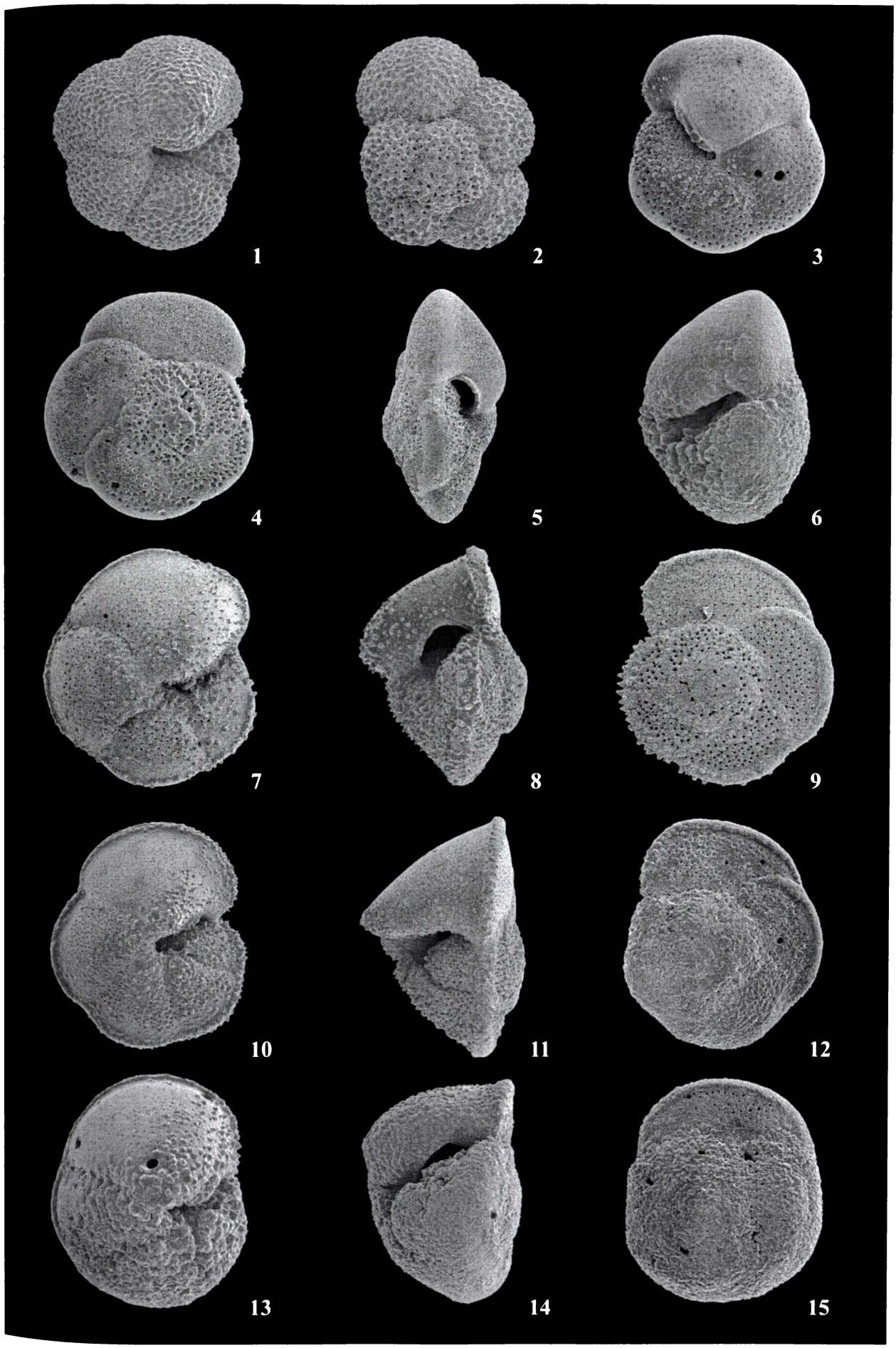


Plate 1.10

Upper Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593-19X-4, 113-115 cm (173.93 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

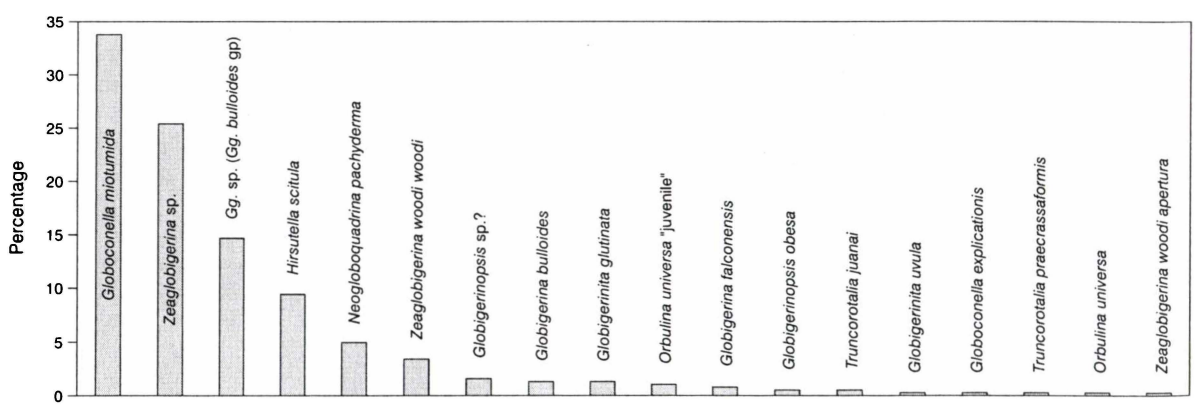
1) ***Globigerina bulloides*** **d'Orbigny**, 300 μm (Image 14723)
2) ***Globigerina falconensis*** **Blow**, 285 μm (Image 14725)
3) ***Globigerina eamesi*** **Blow**, 185 μm (Image 14813)

4) ***Globigerina*** **sp.**, 235 μm (Image 14726)
5) ***Globigerina*** **sp.**, 215 μm (Image 14811)
6) ***Globigerina quinqueloba*** **(Natland)**, 180 μm (Image 14816)

7) ***Globigerina quinqueloba*** **(Natland)**, 170 μm (Image 14817)
8) ***Globigerinita glutinata*** **(Egger)**, non-bullate, 170 μm (Image 14820)
9) ***Globigerinita glutinata*** **(Egger)**, 165 μm (Image 14746)

10) ***Globigerinita uvula*** **(Ehrenberg)**, 150 μm (Image 14747)
11) ***Globigerinita uvula*** **(Ehrenberg)**, 145 μm (Image 14748)
12) ***Globigerinopsis obesa*** **(Bolli)**, juvenile, 245 μm (Image 14749)

13) ***Globigerinopsis obesa*** **(Bolli)**, 235 μm (Image 14754)
14) ***Globigerinopsis obesa*** **(Bolli)**, 230 μm (Image 14751)
15) ***Globigerinopsis obesa*** **(Bolli)**, 600 μm (Image 14753)



Faunal composition (173.93 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 382 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.10 – DSDP Site 593 (173.93 mbsf)

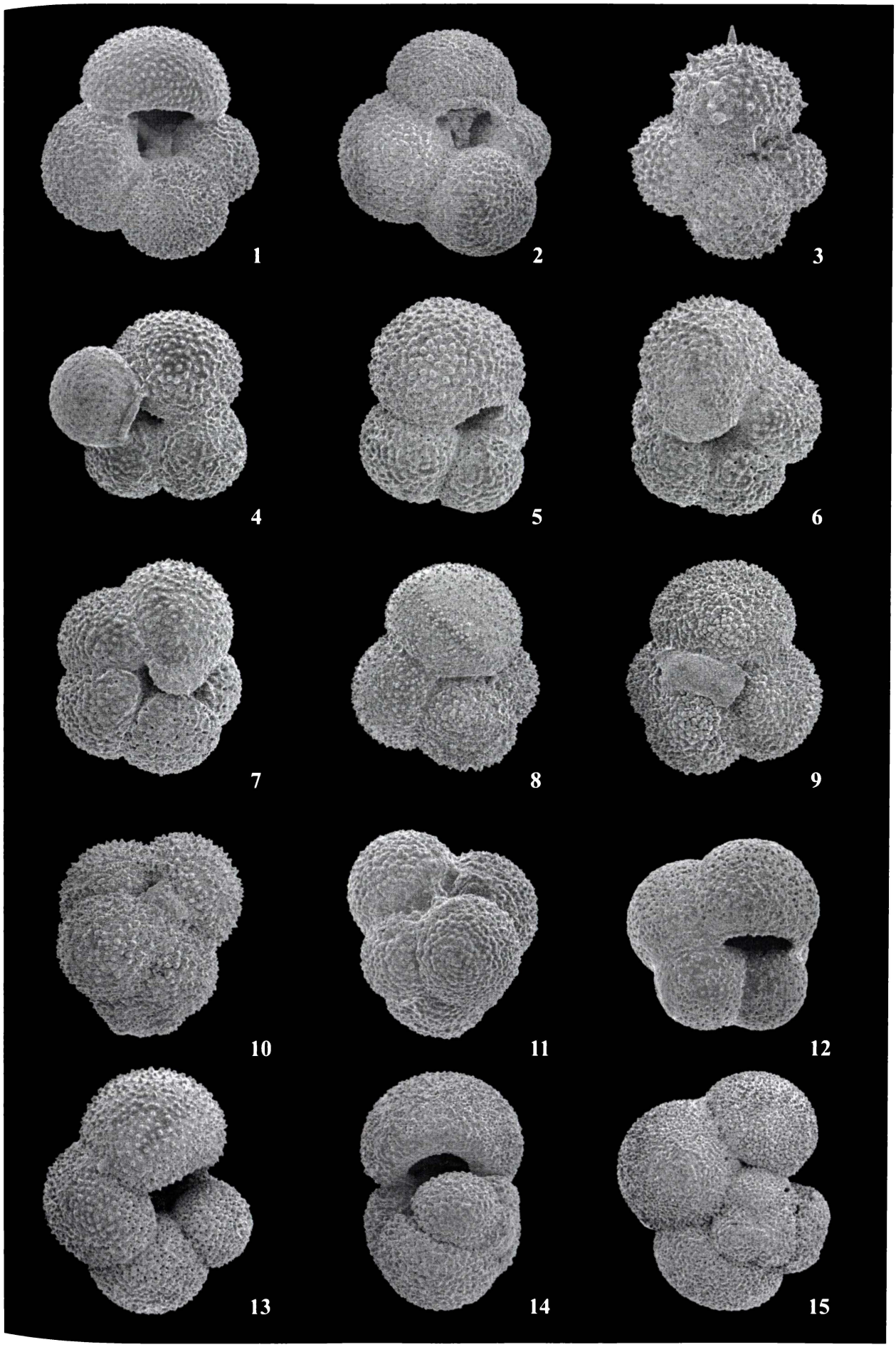


Plate 1.11

Upper Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593-19X-4, 113-115 cm (173.93 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

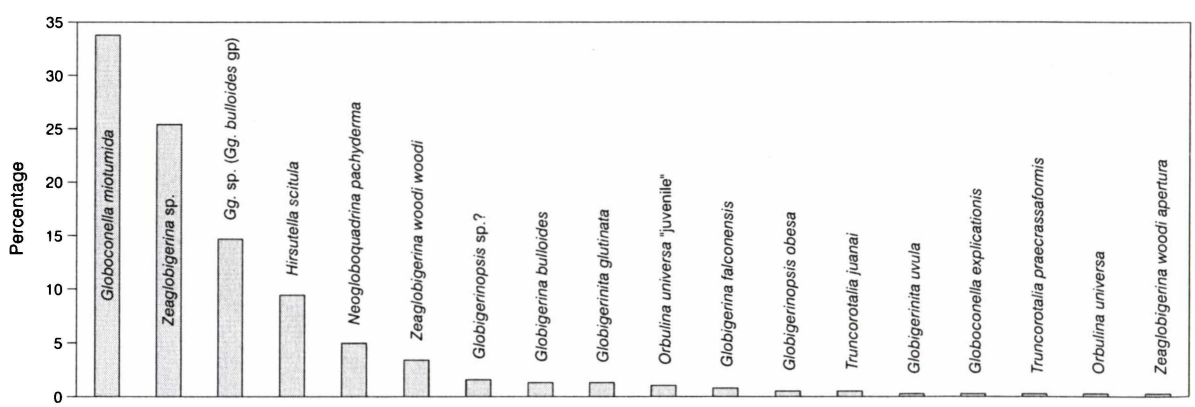
1) ***Orbulina universa*** **d'Orbigny**, 335 μm (Image 14784)
2) ***Orbulina universa*** **"juvenile"** 230 μm (Image 14786)
3) ***Orbulina universa*** **"juvenile"** 190 μm (Image 14787)

4) ***Zeaglobigerina woodi woodi*** **(Jenkins)**, 195 μm (Image 14788)
5) ***Zeaglobigerina woodi apertura*** **(Cushman)**, 335 μm (Image 14790)
6) ***Zeaglobigerina*** **sp.**, 230 μm (Image 14792)

7) ***Neogloboquadrina dutertrei*** **(d'Orbigny)**, 205 μm (Image 14780)
8) ***Neogloboquadrina dutertrei*** **(d'Orbigny)**, 220 μm (Image 14781)
9) ***Neogloboquadrina pachyderma*** **(Ehrenberg)**, 190 μm (Image 14779)

10) ***Neogloboquadrina pachyderma*** **(Ehrenberg)**, 215 μm (Image 14777)
11) ***Neogloboquadrina pachyderma*** **(Ehrenberg)**, 215 μm (Image 14778)
12) ***Neogloboquadrina pachyderma*** **(Ehrenberg)**, 210 μm (Image 14776)

13) ***Hirsutella scitula*** **(Brady)**, 330 μm (Image 14770)
14) ***Hirsutella scitula*** **(Brady)**, 340 μm (Image 14772)
15) ***Hirsutella scitula*** **(Brady)**, 320 μm (Image 14771)



Faunal composition (173.93 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 382 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.11 – DSDP Site 593 (173.93 mbsf)

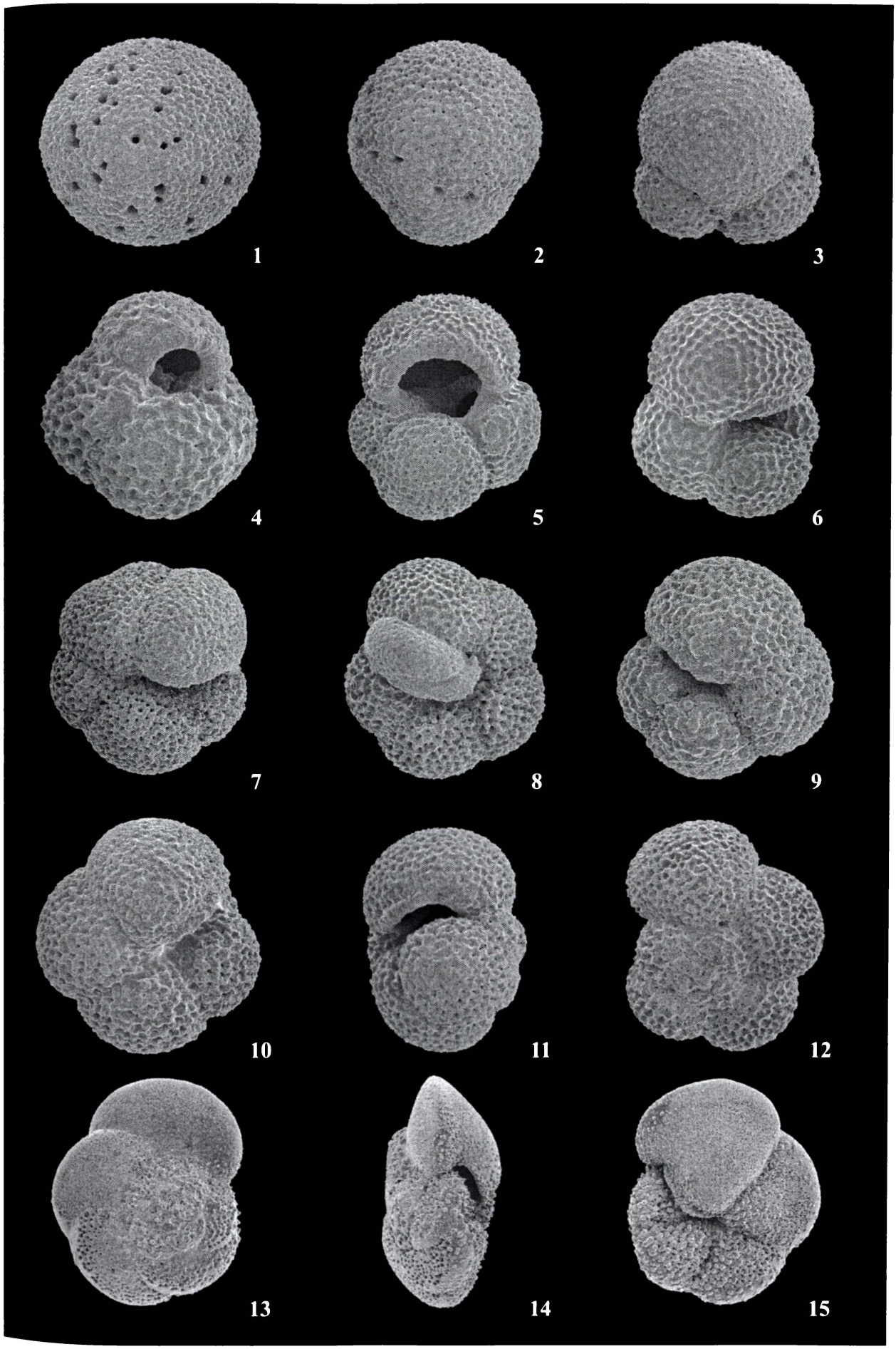


Plate 1.12

Upper Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593-19X-4, 113-115 cm (173.93 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

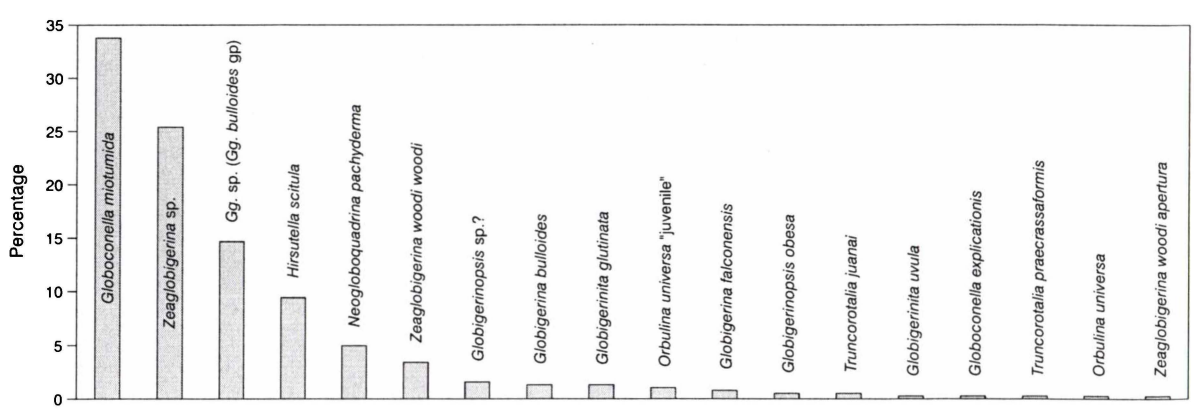
1) ***Hirsutella scitula*? (Brady)**, inflated, 315 μm (Image 14774)
2) ***Hirsutella scitula*? (Brady)**, inflated, 340 μm (Image 14775)
3) ***Hirsutella scitula*? (Brady)**, inflated, 245 μm (Image 14773)

4) ***Globoconella miotumida* (Jenkins)**, biconvex, 475 μm (Image 14757)
5) ***Globoconella miotumida* (Jenkins)**, biconvex, 375 μm (Image 14758)
6) ***Globoconella miotumida* (Jenkins)**, biconvex, 400 μm (Image 14756)

7) ***Globoconella miotumida* (Jenkins)**, 305 μm (Image 14764)
8) ***Globoconella miotumida* (Jenkins)**, 305 μm (Image 14765)
9) ***Globoconella explicationis* (Jenkins)**, four-chambered, 320 μm (Image 14769)

10) ***Globoconella miotumida* (Jenkins)**, encrusted, four-chambered, 415 μm (Image 14760)
11) ***Globoconella miotumida* (Jenkins)**, encrusted, four-chambered, 405 μm (Image 14761)
12) ***Globoconella miotumida* (Jenkins)**, 415 μm (Image 14759)

13) ***Globoconella miotumida* (Jenkins)**, crust-free, four-chambered, 475 μm (Image 14767)
14) ***Globoconella miotumida* (Jenkins)**, crust-free, four-chambered, 395 μm (Image 14768)
15) ***Globoconella miotumida* (Jenkins)**, crust-free, four-chambered, 390 μm (Image 14766)



Faunal composition (173.93 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 382 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.12 – DSDP Site 593 (173.93 mbsf)

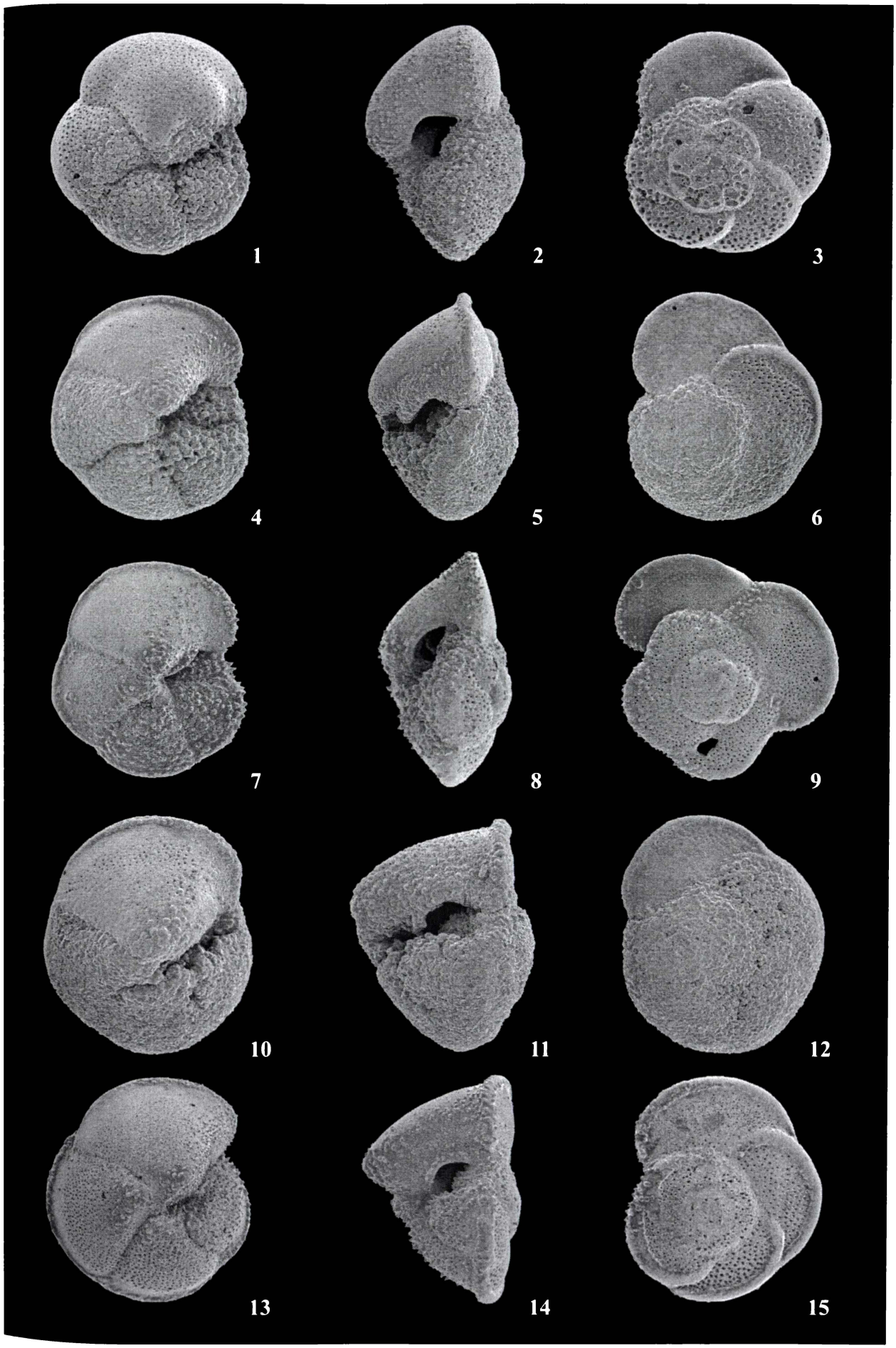


Plate 1.13

Upper Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593-21-3, 102-104 cm (191.52 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

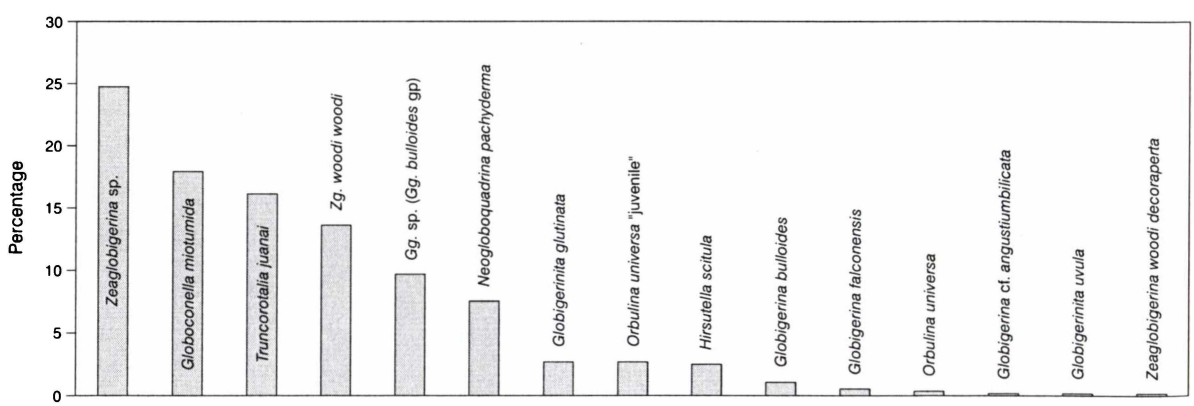
1) ***Globigerina bulloides*** **d'Orbigny**, 325 μm (Image 14823)
2) ***Globigerina falconensis*** **Blow**, 215 μm (Image 14824)
3) ***Globigerina*** **sp.**, 250 μm (Image 14826)

4) ***Globigerina*** **sp.**, *Gg. falconensis*-like juvenile, 170 μm (Image 14829)
5) ***Globigerina quinqueloba*** **(Natland)**, 160 μm (Image 14832)
6) ***Globigerina quinqueloba*** **(Natland)**, 180 μm (Image 14833)

7) ***Globigerina*** **cf.** ***angustiumbilicata*** **(Bolli)**, 180 μm (Image 14834)
8) ***Globigerina*** **cf.** ***angustiumbilicata*** **(Bolli)**, 165 μm (Image 14836)
9) ***Globigerinita glutinata*** **(Egger)**, 155 μm (Image 14839)

10) ***Globigerinita glutinata*** **(Egger)**, 175 μm (Image 14838)
11) ***Globigerinita glutinata*** **(Egger)**, encrusted, 230 μm (Image 14837)
12) ***Globigerinita uvula*** **(Ehrenberg)**, 150 μm (Image 14840)

13) ***Globigerinopsis obesa*** **(Bolli)**, 445 μm (Image 14842)
14) ***Globigerinopsis obesa*** **(Bolli)**, 405 μm (Image 14843)
15) ***Globigerinopsis obesa*** **(Bolli)**, 495 μm (Image 14844)



Faunal composition (191.52 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 558 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.13 – DSDP Site 593 (191.52 mbsf)

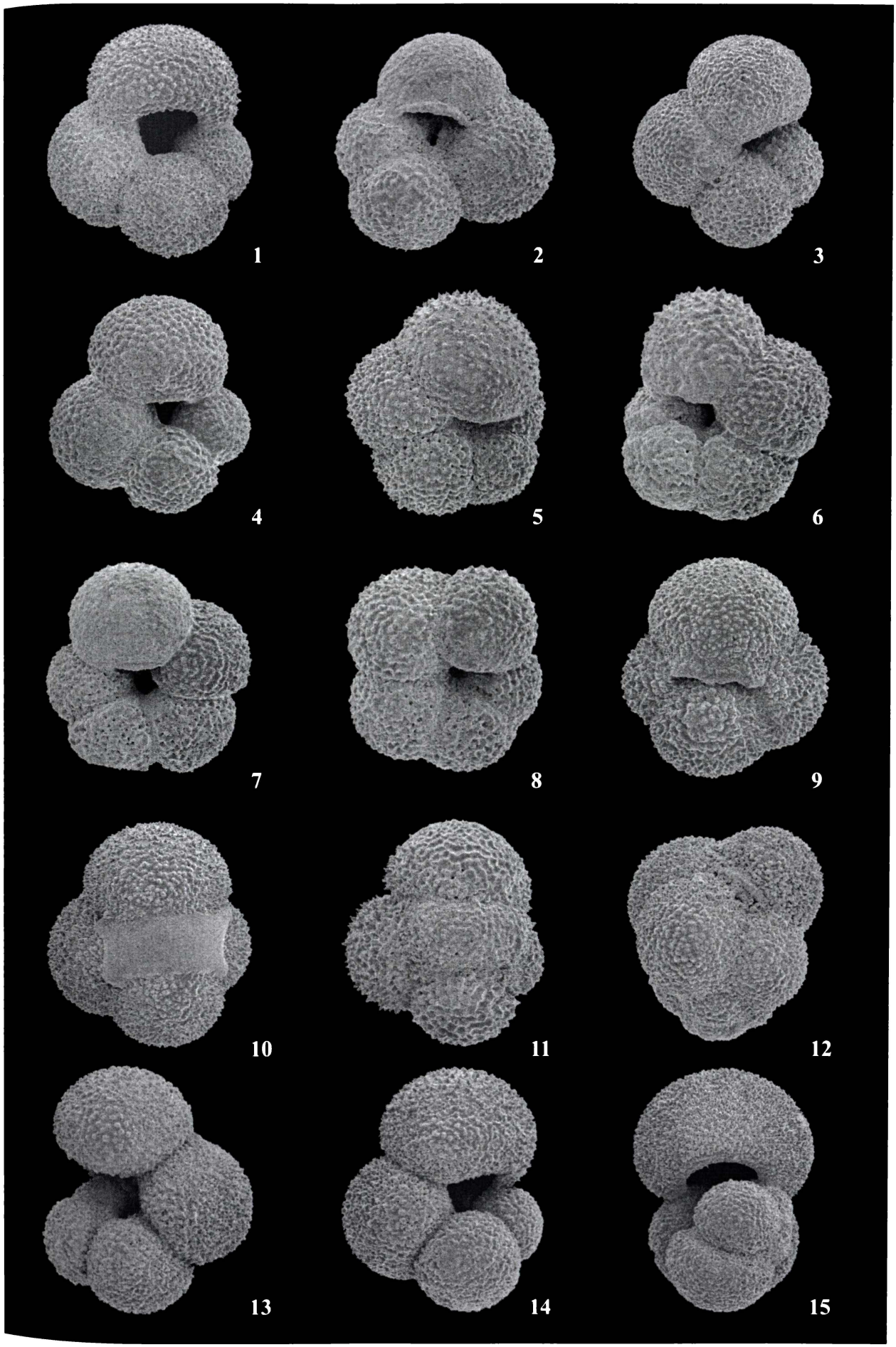


Plate 1.14

Upper Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593-21-3, 102-104 cm (191.52 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

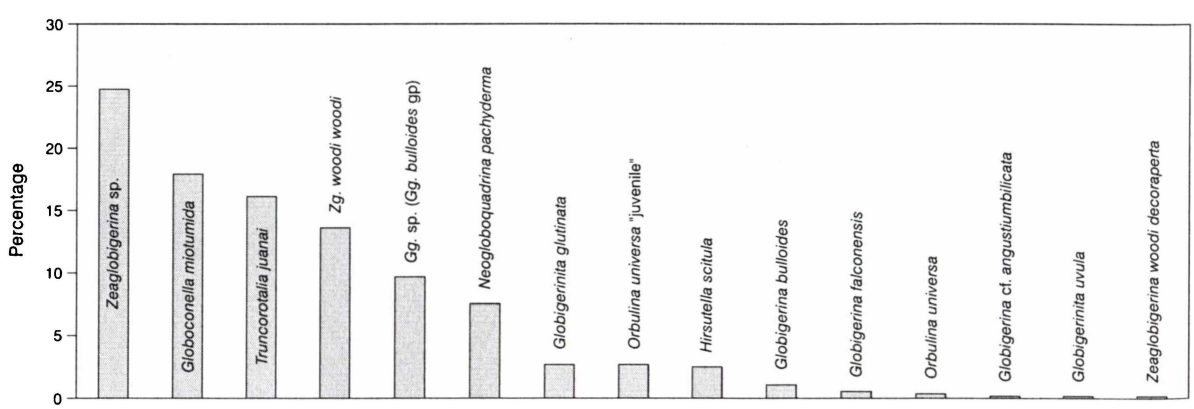
1) ***Orbulina universa*** **d'Orbigny**, 405 μm (Image 14871)
2) ***Orbulina bilobata*** **(d'Orbigny)**, 380 μm (Image 14874)
3) ***Orbulina universa*** **"juvenile"** 305 μm (Image 14878)

4) ***Orbulina universa*** **"juvenile"** 240 μm (Image 14877)
5) ***Zeaglobigerina woodi woodi*** **(Jenkins)**, 240 μm (Image 14881)
6) ***Zeaglobigerina woodi apertura*** **(Jenkins)**, 280 μm (Image 14882)

7) ***Zeaglobigerina*** **sp.**, 210 μm (Image 14880)
8) ***Zeaglobigerina woodi decoraperta*** **(Takayanagi and Saito)**, 200 μm (Image 14886)
9) ***Zeaglobigerina nepenthes?*** **(Todd)**, 175 μm (Image 14885)

10) ***Neogloboquadrina pachyderma*** **(Ehrenberg)**, 240 μm (Image 14864)
11) ***Neogloboquadrina pachyderma*** **(Ehrenberg)**, 480 μm (Image 14866)
12) ***Neogloboquadrina pachyderma*** **(Ehrenberg)**, 220 μm (Image 14865)

13) ***Neogloboquadrina pachyderma*** **(Ehrenberg)**, 255 μm (Image 14867)
14) ***Neogloboquadrina dutertrei*** **(d'Orbigny)**, 255 μm (Image 14870)
15) ***Hirsutella scitula*** **(Brady)**, 320 μm (Image 14860)



Faunal composition (191.52 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 558 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.14 – DSDP Site 593 (191.52 mbsf)

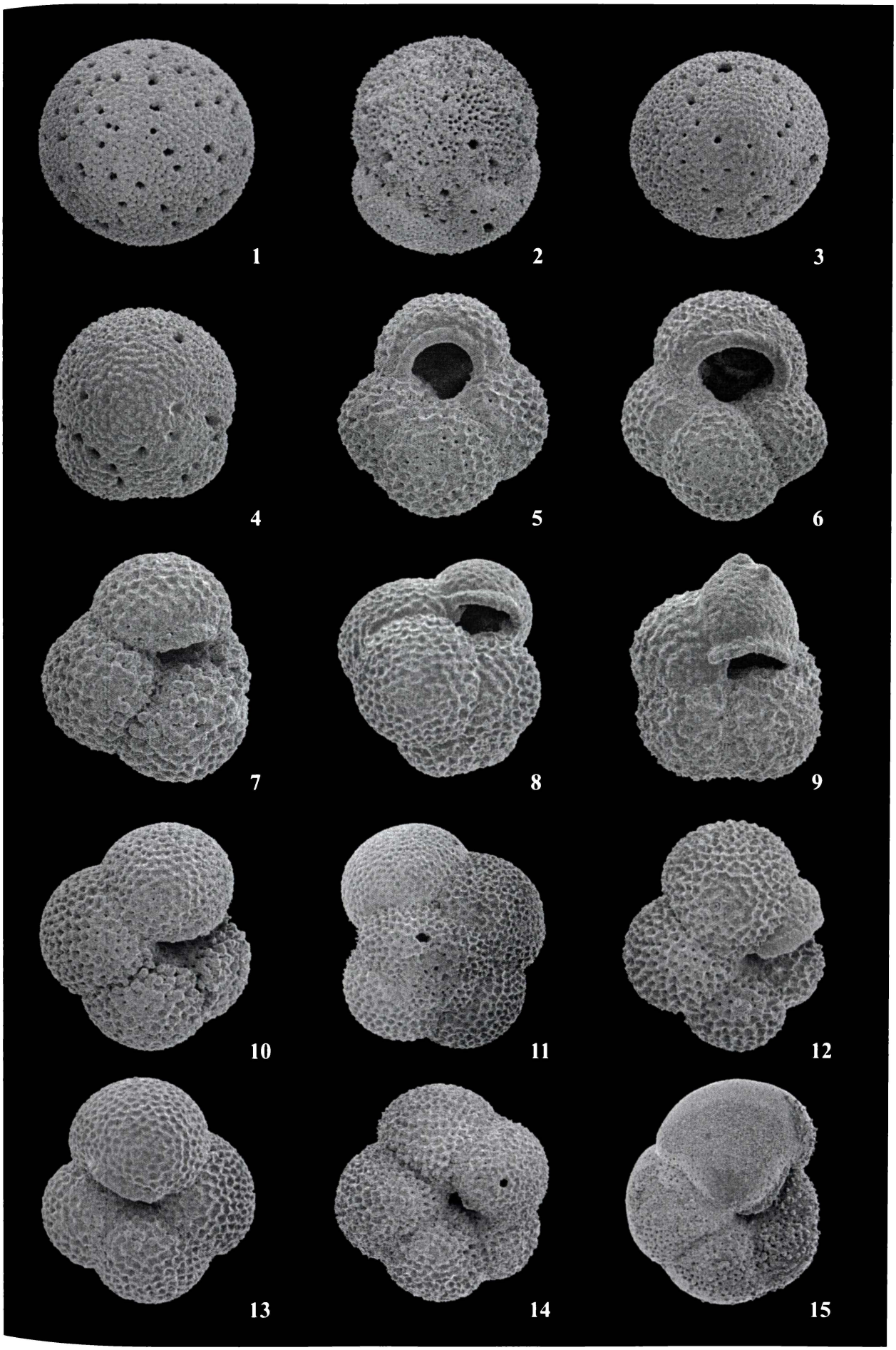


Plate 1.15

Upper Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593-21-3, 102-104 cm (191.52 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

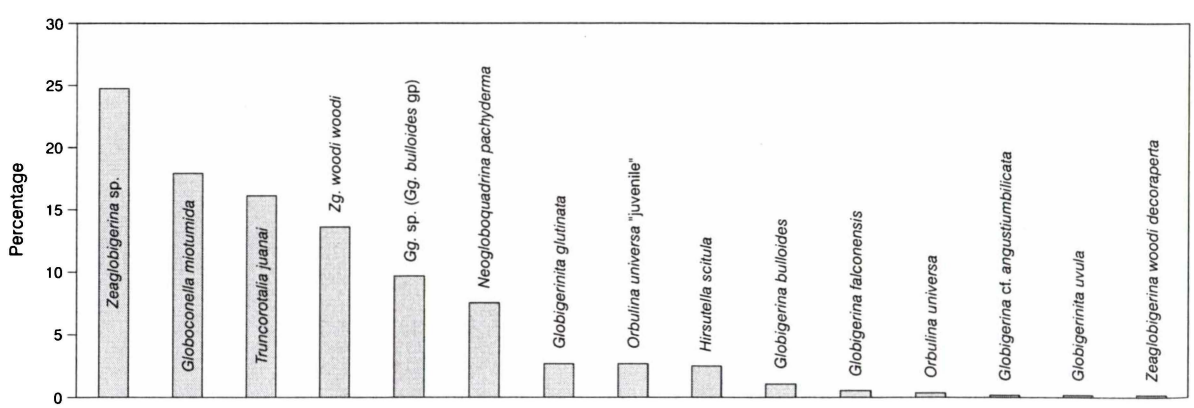
1) ***Hirsutella scitula* (Brady)**, 285 μm (Image 14862)
2) ***Hirsutella scitula* (Brady)**, 305 μm (Image 14863)
3) ***Hirsutella scitula* (Brady)**, 415 μm (Image 14861)

4) ***Truncorotalia juanai* (Bermudez and Bolli)**, spirally-domed, 355 μm (Image 14857)
5) ***Truncorotalia juanai* (Bermudez and Bolli)**, spirally-domed, 330 μm (Image 14859)
6) ***Truncorotalia juanai* (Bermudez and Bolli)**, spirally-domed, 325 μm (Image 14858)

7) ***Globoconella miotumida* (Jenkins)**, biconvex, 365 μm (Image 14845)
8) ***Globoconella miotumida* (Jenkins)**, biconvex, 345 μm (Image 14847)
9) ***Globoconella miotumida* (Jenkins)**, biconvex, 335 μm (Image 14846)

10) ***Globoconella miotumida* (Jenkins)**, ventroconical, 425 μm (Image 14854)
11) ***Globoconella miotumida* (Jenkins)**, ventroconical, 365 μm (Image 14848)
12) ***Globoconella miotumida* (Jenkins)**, ventroconical, 410 μm (Image 14851)

13) ***Globoconella miotumida* (Jenkins)**, compressed, 365 μm (Image 14850)
14) ***Globoconella miotumida* (Jenkins)**, compressed, 415 μm (Image 14852)
15) ***Globoconella miotumida* (Jenkins)**, compressed, 400 μm (Image 14855)



Faunal composition (191.52 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 558 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.15 – DSDP Site 593 (191.52 mbsf)

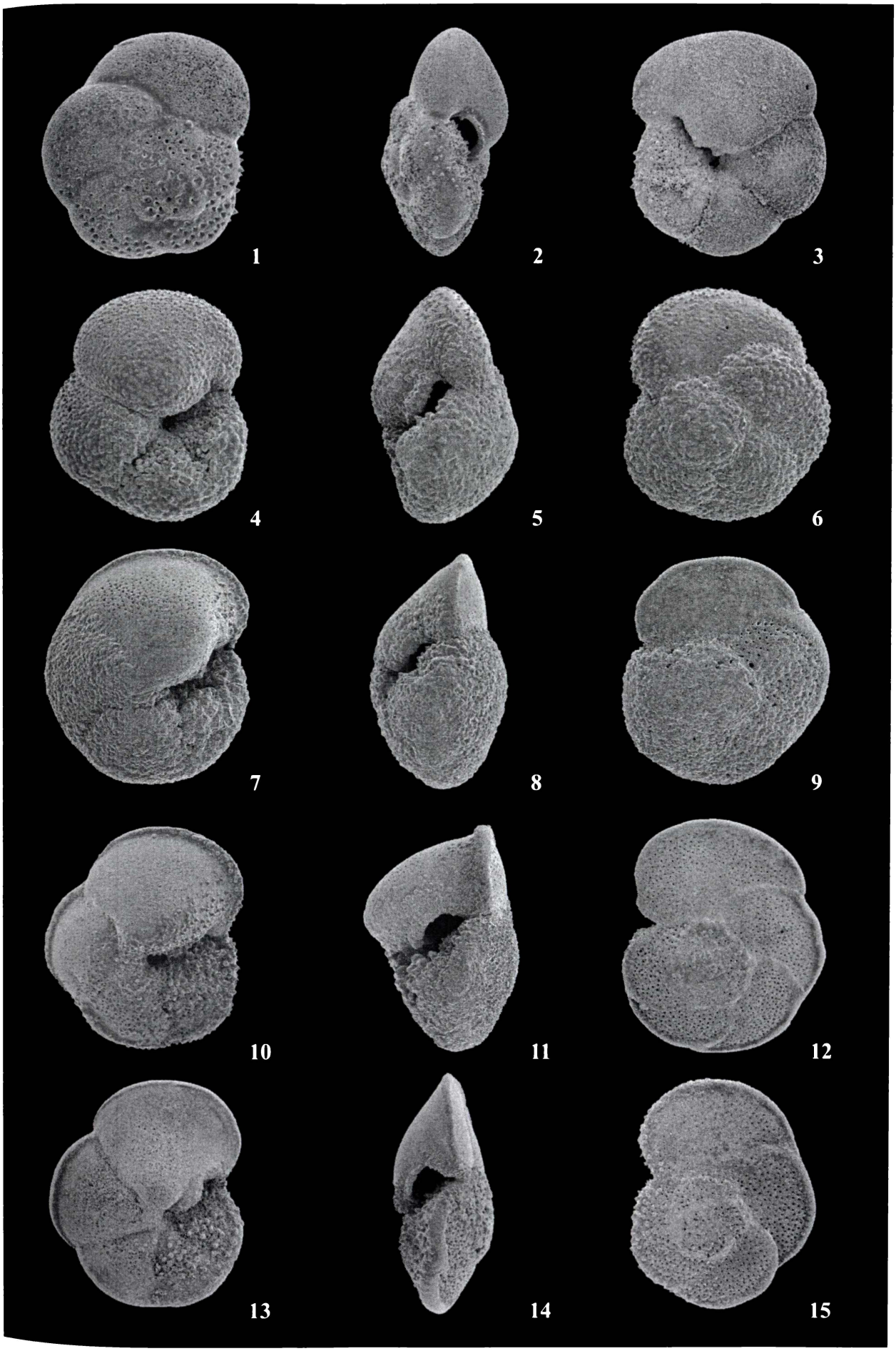


Plate 1.16

Upper Tongaporutuan (late Miocené) planktic foraminifers

DSDP Site 593-23X-2, 6-8 cm (208.26 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

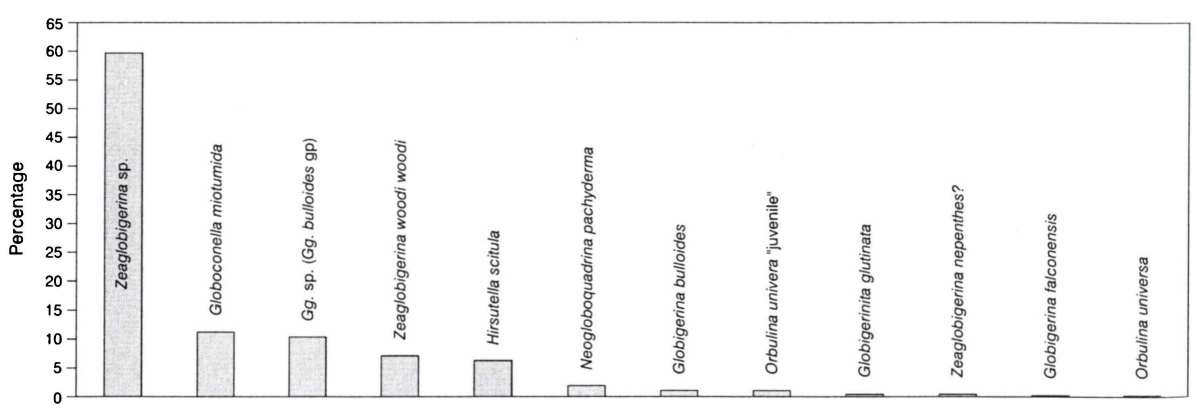
1) ***Globigerina bulloides*** **d'Orbigny**, 305 μm (Image 16878)
2) ***Globigerina bulloides*** **d'Orbigny**, 310 μm (Image 16879)
3) ***Globigerina falconensis*** **Blow**, 245 μm (Image 16880)

4) ***Globigerina*** **sp.**, 305 μm (Image 16881)
5) ***Globigerina*** **sp.**, 270 μm (Image 16883)
6) ***Globigerina*** **sp.**, 200 μm (Image 16886)

7) ***Globigerina quinqueloba*** **(Natland)**, 225 μm (Image 16888)
8) ***Globigerina quinqueloba*****? (Natland)**, 190 μm (Image 16889)
9) ***Globigerinita glutinata*** **(Egger)**, non-bullate, 165 μm (Image 16890)

10) ***Globigerinita glutinata*** **(Egger)**, 180 μm (Image 16891)
11) ***Globigerinita glutinata*** **(Egger)**, 160 μm (Image 16893)
12) ***Globigerinita uvula*** **(Ehrenberg)**, 160 μm (Image 16896)

13) ***Globigerinopsis obesa*** **(Bolli)**, 515 μm (Image 16897)
14) ***Globigerinopsis obesa*** **(Bolli)**, 435 μm (Image 16901)
15) ***Globigerinopsis obesa*** **(Bolli)**, 385 μm (Image 16900)



Faunal composition (208.26 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 464 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.16 – DSDP Site 593 (208.26 mbsf)

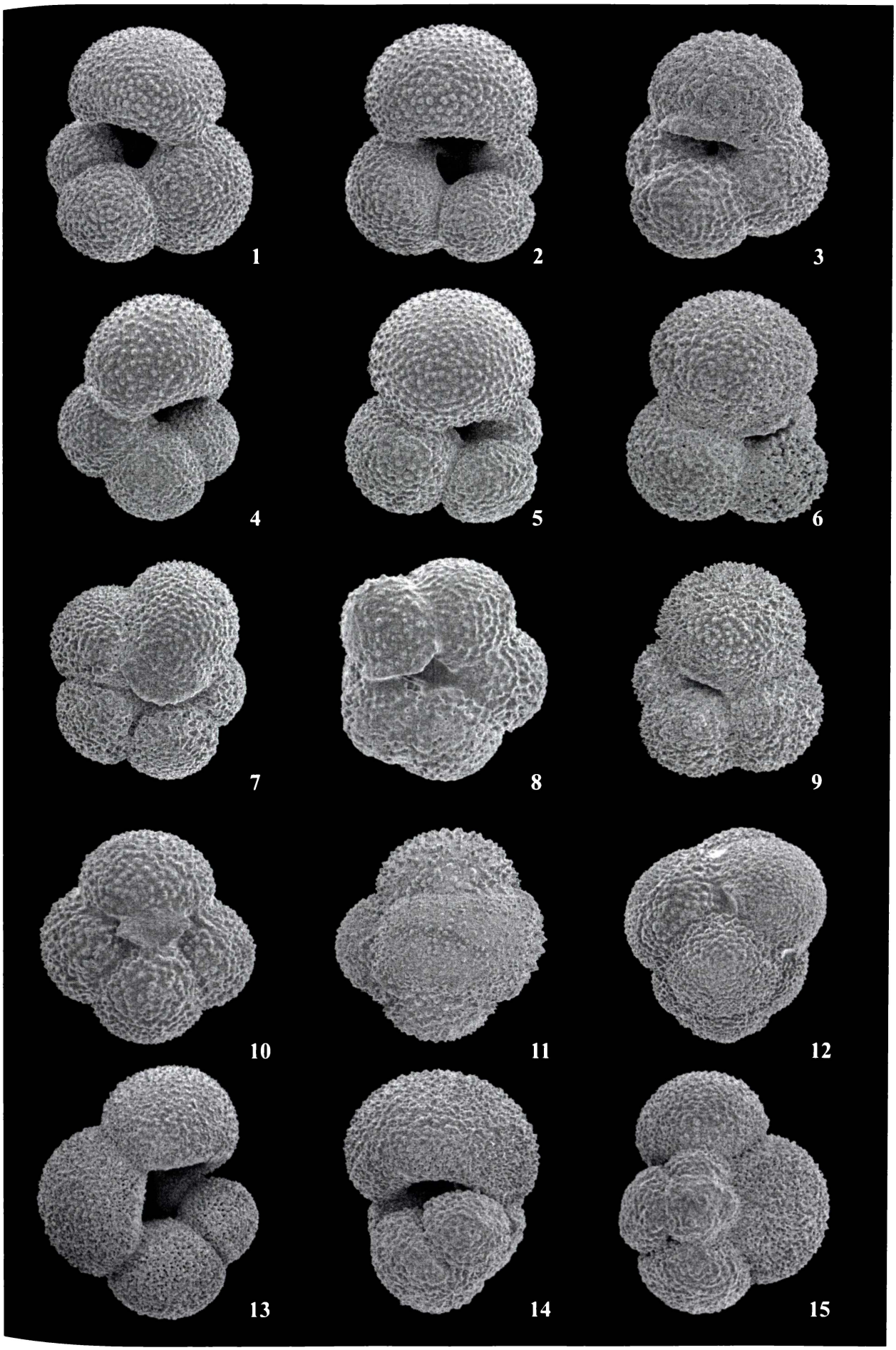


Plate 1.17

Upper Tongaporutuan (late Miocené) planktic foraminifers

DSDP Site 593-23X-2, 6-8 cm (208.26 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

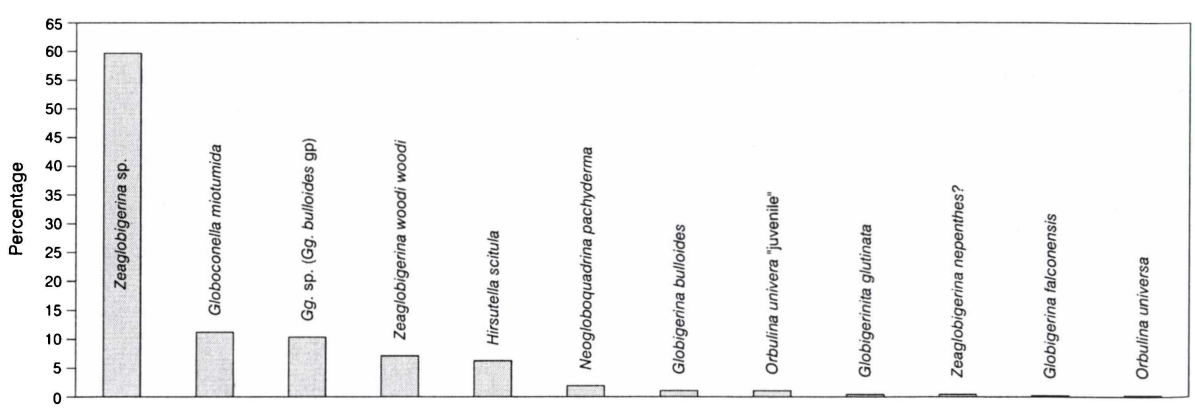
1) ***Orbulina universa* d'Orbigny**, 415 μm (Image 16902)
2) ***Orbulina bilobata* (d'Orbigny)**, 435 μm (Image 16904)
3) ***Orbulina universa* "juvenile"** 255 μm (Image 16908)

4) ***Orbulina universa* "juvenile"** 250 μm (Image 16906)
5) ***Zeaglobigerina woodi woodi* (Jenkins)**, 260 μm (Image 16911)
6) ***Zeaglobigerina woodi woodi* (Jenkins)**, 310 μm (Image 16912)

7) ***Zeaglobigerina* sp.**, 255 μm (Image 16916)
8) ***Zeaglobigerina* sp.**, 195 μm (Image 16918)
9) ***Zeaglobigerina* sp.**, 195 μm (Image 16919)

10) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 200 μm (Image 16922)
11) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 245 μm (Image 16925)
12) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 240 μm (Image 16924)

13) ***Hirsutella scitula* (Brady)**, 230 μm (Image 16928)
14) ***Hirsutella scitula* (Brady)**, 290 μm (Image 16931)
15) ***Hirsutella scitula* (Brady)**, 280 μm (Image 16930)



Faunal composition (208.26 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 464 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.17 – DSDP Site 593 (208.26 mbsf)

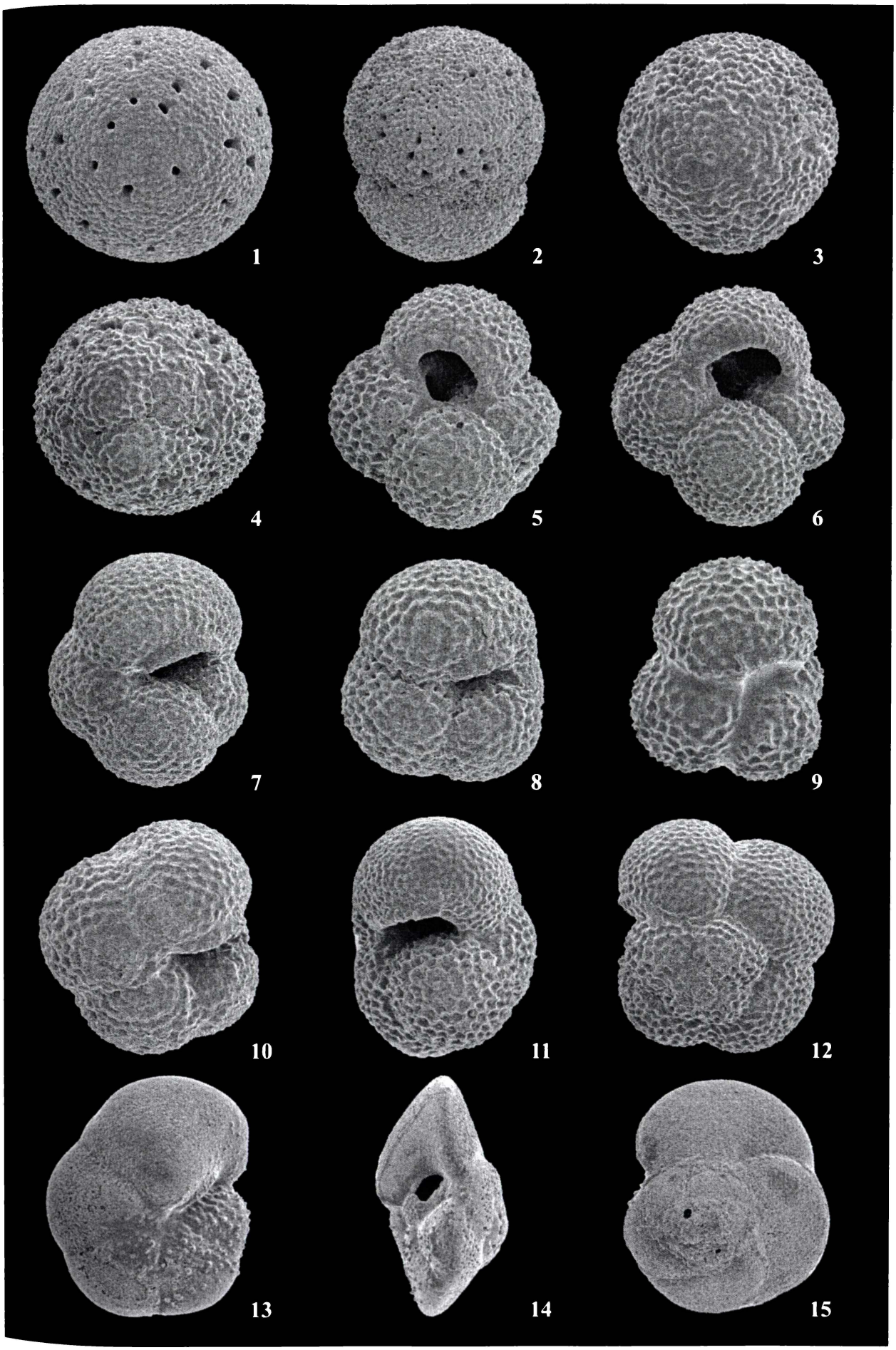


Plate 1.18

Upper Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593-23X-2, 6-8 cm (208.26 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

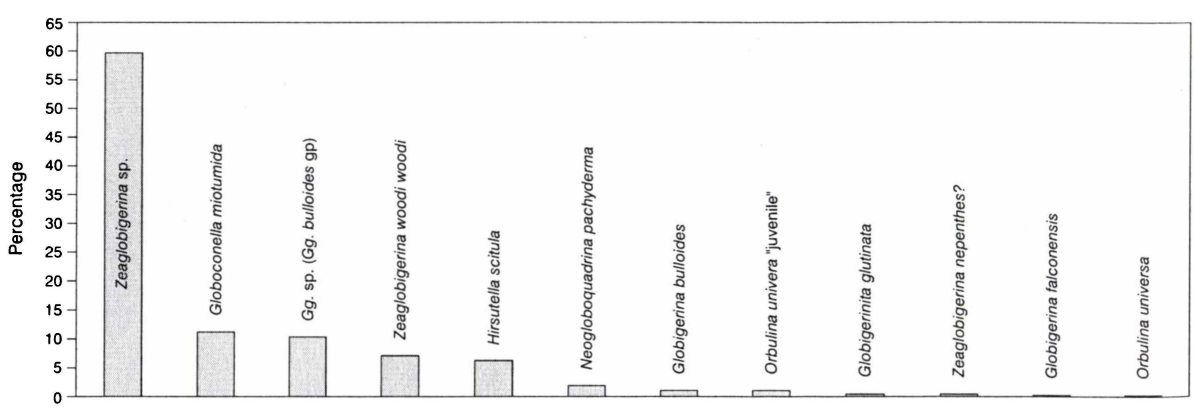
1) ***Hirsutella scitula* (Brady)**, 350 μm (Image 16935)
2) ***Hirsutella scitula* (Brady)**, 325 μm (Image 16938)
3) ***Hirsutella scitula* (Brady)**, 365 μm (Image 16934)

4) ***Hirsutella* cf. *scitula* (Brady)**, 375 μm (Image 16940)
5) ***Hirsutella* cf. *scitula* (Brady)**, 395 μm (Image 16941)
6) ***Hirsutella* cf. *scitula* (Brady)**, 390 μm (Image 16939)

7) ***Globoconella miotumida* (Jenkins)**, ventroconical, 580 μm (Image 16942)
8) ***Globoconella miotumida* (Jenkins)**, ventroconical, 395 μm (Image 16947)
9) ***Globoconella miotumida* (Jenkins)**, ventroconical, 435 μm (Image 16945)

10) ***Globoconella miotumida* (Jenkins)**, inflated ventroconical, 375 μm (Image 16952)
11) ***Globoconella miotumida* (Jenkins)**, inflated ventroconical, 370 μm (Image 16953)
12) ***Globoconella miotumida* (Jenkins)**, inflated ventroconical, 420 μm (Image 16955)

13) ***Globoconella miotumida* (Jenkins)**, biconvex, 440 μm (Image 16950)
14) ***Globoconella miotumida* (Jenkins)**, biconvex, 385 μm (Image 16951)
15) ***Globoconella miotumida* (Jenkins)**, biconvex, 480 μm (Image 16948)



Faunal composition (208.26 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 464 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.18 – DSDP Site 593 (208.26 mbsf)

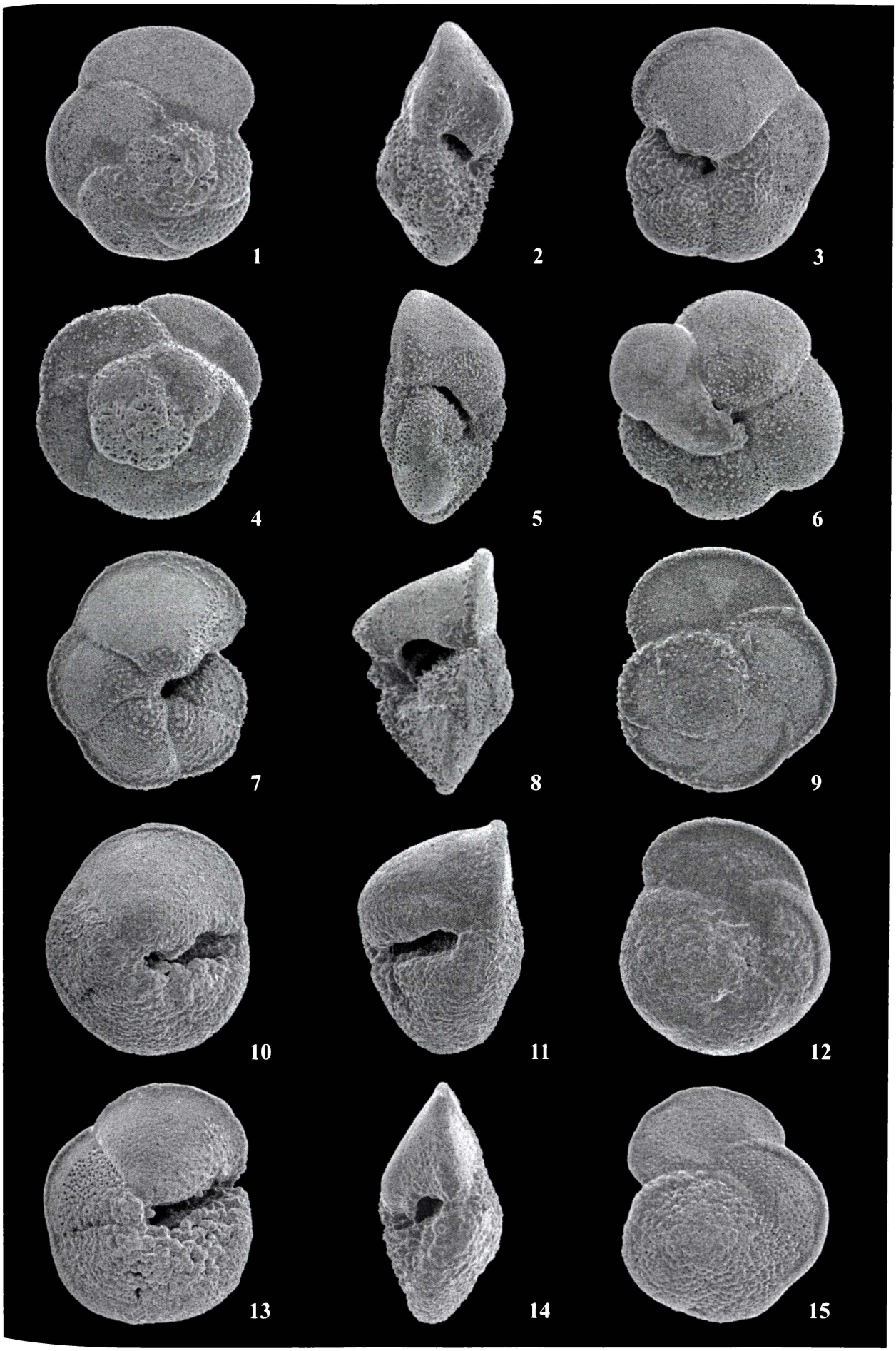


Plate 1.19

Upper Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593, core 24/4/86-88 (221.66 m)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

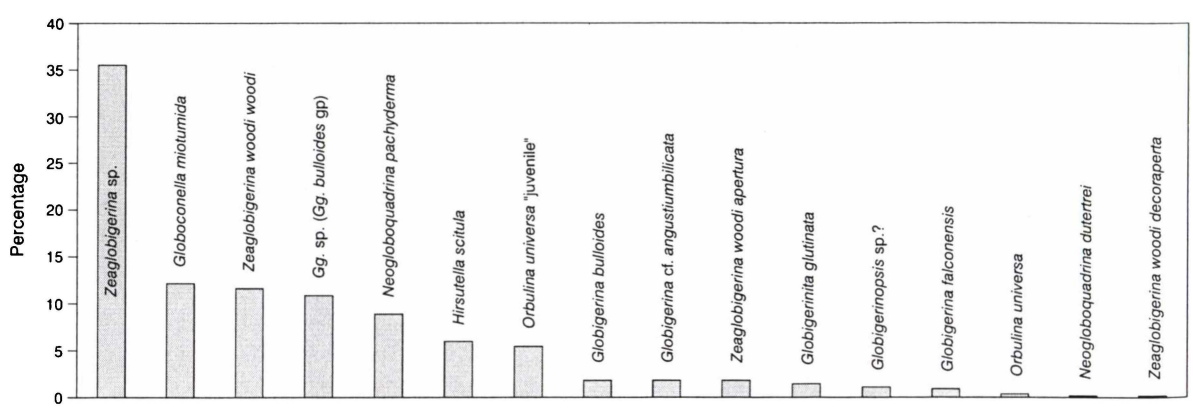
1) ***Globigerina bulloides*** **d'Orbigny**, 310 μm (Image 14917)
2) ***Globigerina bulloides*** **d'Orbigny**, 290 μm (Image 14916)
3) ***Globigerina falconensis*** **Blow**, 270 μm (Image 14918)

4) ***Globigerina falconensis*** **Blow**, 240 μm (Image 14919)
5) ***Globigerina*** **sp.**, *Gg.* cf. *foliata*, 235 μm (Image 14924)
6) ***Globigerina*** **sp.**, *Gg. bulloides*-like juvenile, 270 μm (Image 14920)

7) ***Globigerina quinqueloba*** **Natland**, 160 μm (Image 14925)
8) ***Globigerina quinqueloba*** **Natland**, 145 μm (Image 14926)
9) ***Globigerina quinqueloba*** **Natland**, 195 μm (Image 14929)

10) ***Globigerina*** **cf. *angustiumbilicata*** **(Bolli)**, 185 μm (Image 14927)
11) ***Globigerina*** **cf. *angustiumbilicata*** **(Bolli)**, 200 μm (Image 14928)
12) ***Globigerinita glutinata*** **(Egger)**, 185 μm (Image 14933)

13) ***Globigerinopsis obesa*** **(Bolli)**, 415 μm (Image 14937)
14) ***Globigerinopsis obesa*** **(Bolli)**, 415 μm (Image 14935)
15) ***Globigerinopsis obesa*** **(Bolli)**, 625 μm (Image 14936)



Faunal composition (221.66 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 552 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.19 – DSDP Site 593 (221.66 mbsf)

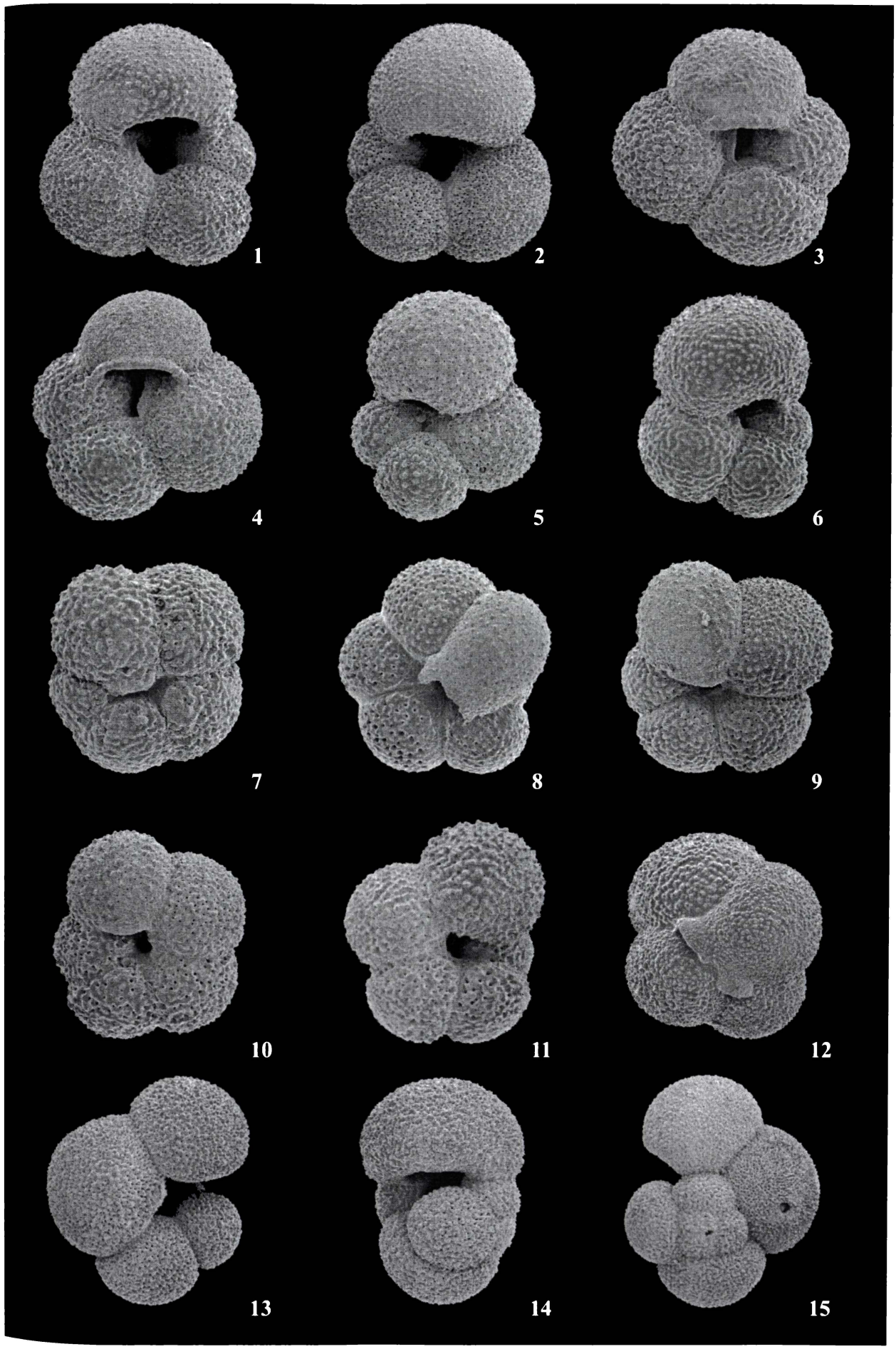


Plate 1.20

Upper Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593-24X-4, 86-88 cm (221.66 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

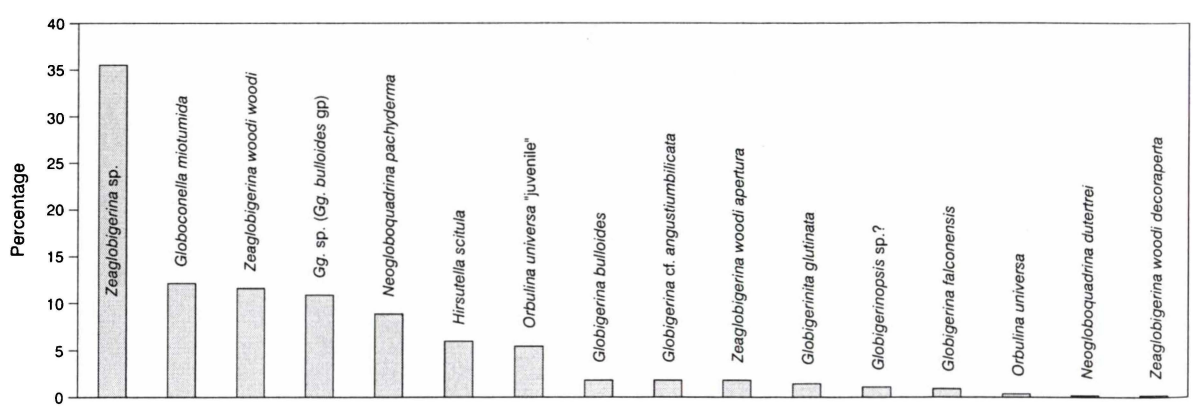
1) ***Orbulina universa* d'Orbigny**, 320 μm (Image 14960)
2) ***Orbulina universa* d'Orbigny**, 535 μm (Image 14959)
3) ***Orbulina bilobata* (d'Orbigny)**, 335 μm (Image 14961)

4) ***Orbulina universa* "juvenile"** 280 μm (Image 14963)
5) ***Orbulina universa* "juvenile"** 215 μm (Image 14964)
6) ***Orbulina universa* "juvenile"** 315 μm (Image 14962)

7) ***Zeaglobigerina woodi woodi* (Jenkins)**, 280 μm (Image 14970)
8) ***Zeaglobigerina woodi woodi* (Jenkins)**, 280 μm (Image 14971)
9) ***Zeaglobigerina* sp.**, 225 μm (Image 14969)

10) ***Zeaglobigerina woodi apertura* (Jenkins)**, 270 μm (Image 14974)
11) ***Zeaglobigerina woodi apertura* (Jenkins)**, 275 μm (Image 14973)
12) ***Zeaglobigerina nepenthes*? (Todd)**, compact, 225 μm (Image 14968)

13) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 240 μm (Image 14957)
14) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 200 μm (Image 14958)
15) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 250 μm (Image 14956)



Faunal composition (221.66 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 552 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.20 – DSDP Site 593 (221.66 mbsf)

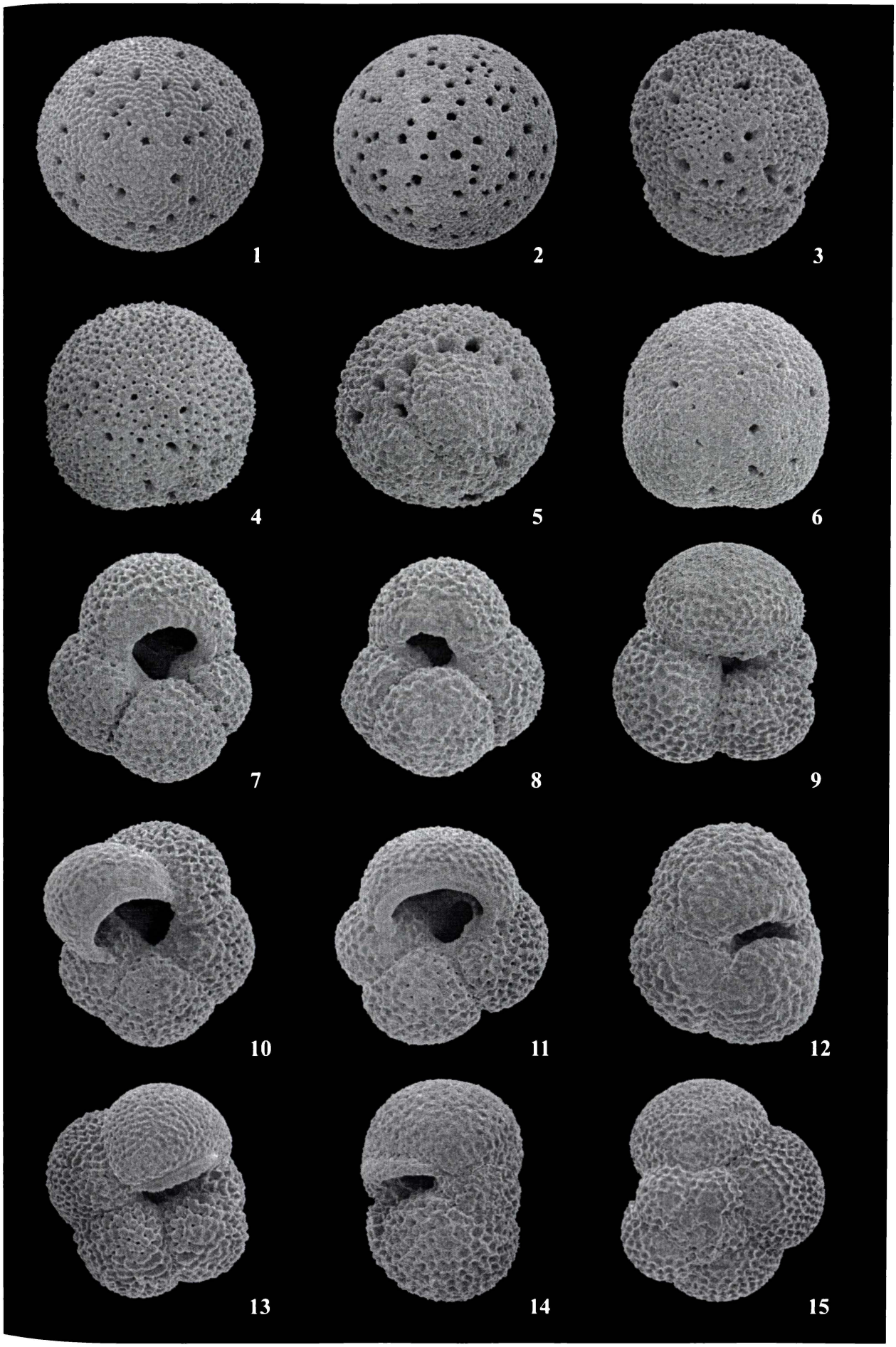


Plate 1.21

Upper Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593-24X-4, 86-88 cm (221.66 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

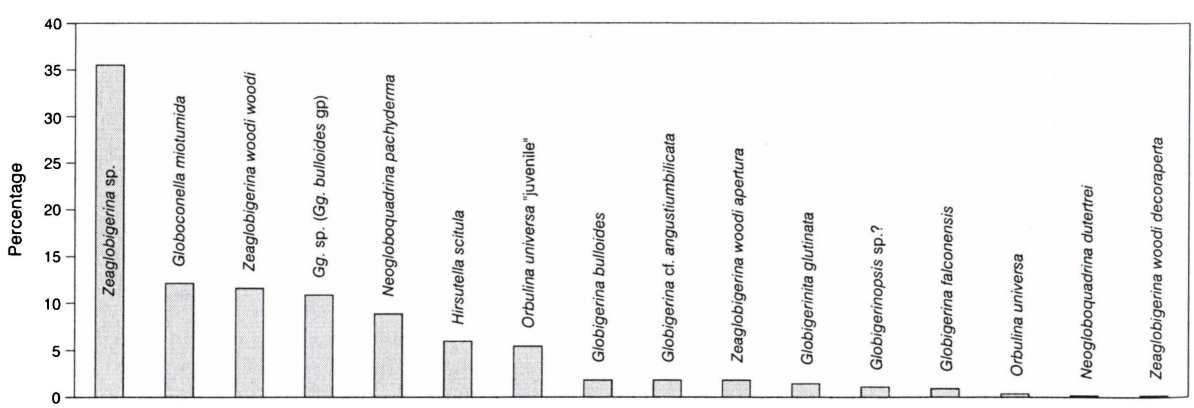
1) ***Hirsutella scitula* (Brady)**, 305 μm (Image 14953)
2) ***Hirsutella scitula* (Brady)**, 255 μm (Image 14954)
3) ***Hirsutella scitula* (Brady)** 320 μm (Image 14952)

4) ***Hirsutella scitula* (Brady)**, compressed, 300 μm (Image 14947)
5) ***Hirsutella scitula* (Brady)**, compressed, 365 μm (Image 14950)
6) ***Hirsutella scitula* (Brady)**, compressed, 335 μm (Image 14948)

7) ***Hirsutella scitula*? (Brady)**, inflated, 335 μm (Image 14951)
8) ***Globoconella explicationis* (Jenkins)**, 580 μm (Image 14946)
9) ***Globoconella miotumida* (Jenkins)**, biconvex, 455 μm (Image 14942)

10) ***Globoconella miotumida* (Jenkins)**, biconvex, 365 μm (Image 14938)
11) ***Globoconella miotumida* (Jenkins)**, biconvex, 400 μm (Image 14941)
12) ***Globoconella miotumida* (Jenkins)**, biconvex, 445 μm (Image 14940)

13) ***Globoconella miotumida* (Jenkins)**, ventroconical, 435 μm (Image 14943)
14) ***Globoconella miotumida* (Jenkins)**, ventroconical, 365 μm (Image 14945)
15) ***Globoconella miotumida* (Jenkins)**, ventroconical, 465 μm (Image 14944)



Faunal composition (221.66 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 552 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.21 – DSDP Site 593 (221.66 mbsf)

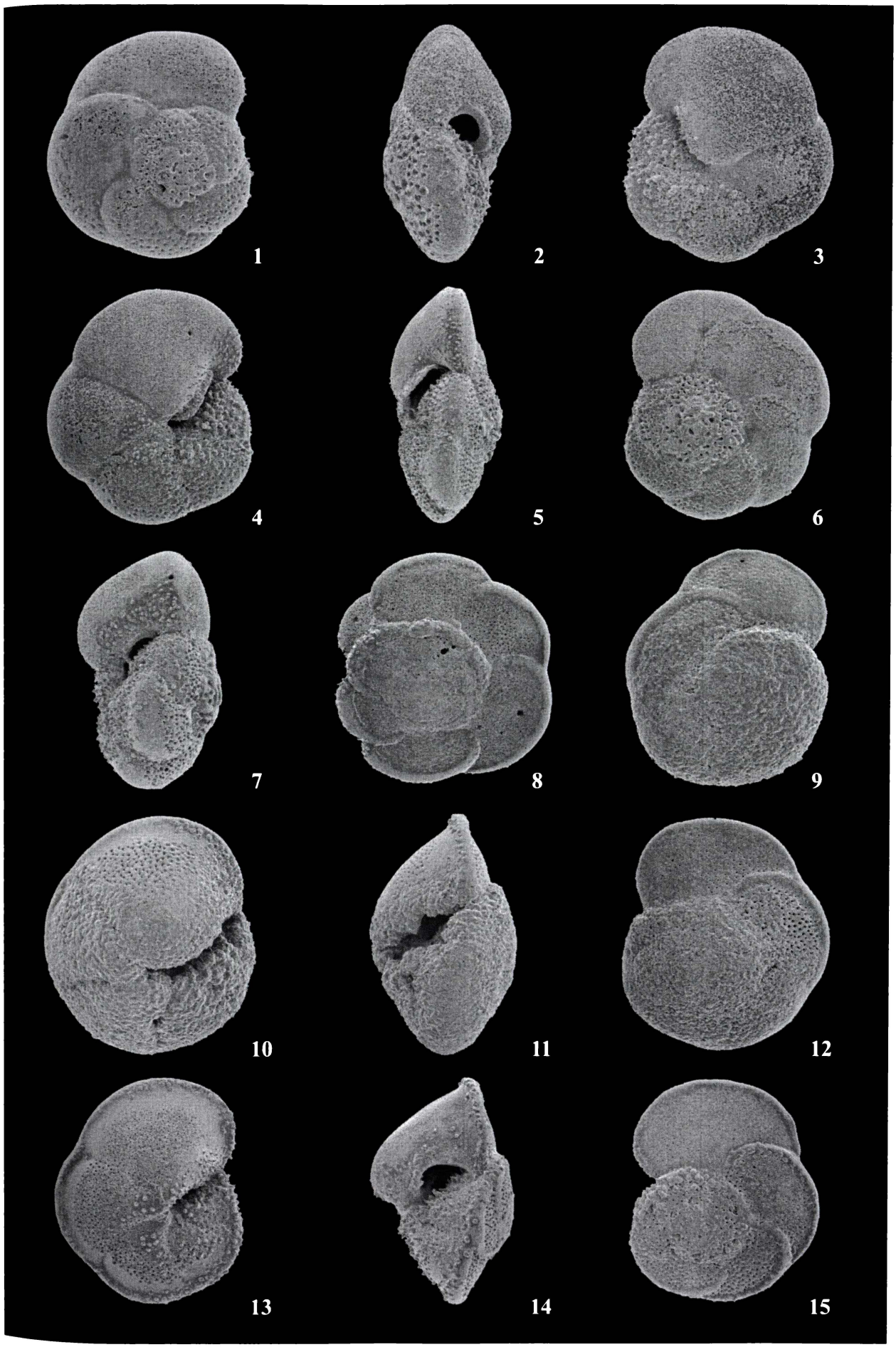


Plate 1.22

Upper Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593-27X-1, 142-144 cm (246.52 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

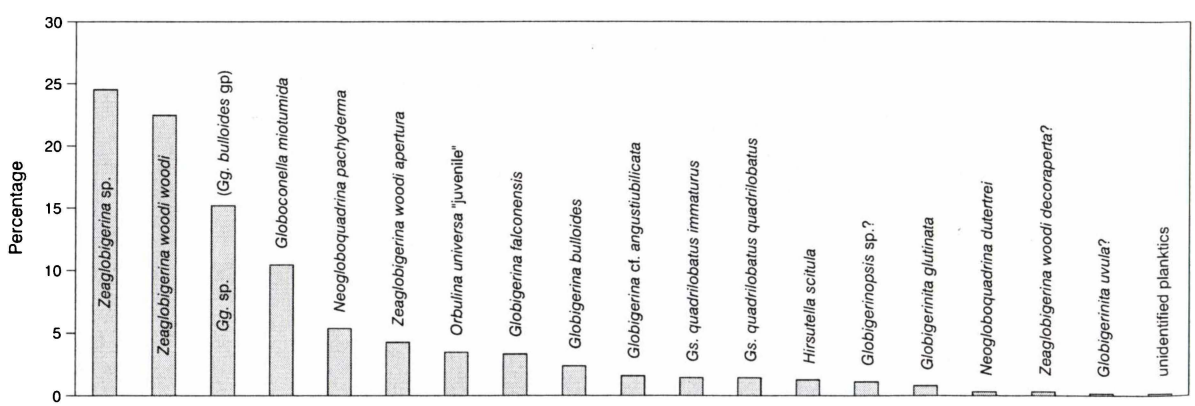
1) ***Globigerina bulloides*** **d'Orbigny**, 305 μm (Image 14991)
2) ***Globigerina falconensis*** **Blow**, 280 μm (Image 14994)
3) ***Globigerina*** **sp.**, *G. bulloides*-like juvenile, 300 μm (Image 14996)

4) ***Globigerina*** **sp.**, 265 μm (Image 14997)
5) ***Globigerina*** **cf. *angustiumbilicata* (Bolli)**, 180 μm (Image 15003)
6) ***Globigerina*** **cf. *angustiumbilicata* (Bolli)**, 190 μm (Image 15002)

7) ***Globigerina quinqueloba*? (Natland)**, 150 μm (Bermudez) - (Image 15001)
8) ***Globigerinita glutinata*** **(Egger)**, 170 μm (Image 15004)
9) ***Globigerinita glutinata*** **(Egger)**, non-bullate, 155 μm (Image 15005)

10) ***Globigerinopsis obesa*** **(Bolli)**, 360 μm (Image 15021)
11) ***Globigerinopsis obesa*** **(Bolli)**, 375 μm (Image 15024)
12) ***Globigerinopsis obesa*** **(Bolli)**, 415 μm (Image 15023)

13) ***Orbulina universa*** **d'Orbigny**, 435 μm (Image 15050)
14) ***Orbulina bilobata*** **(d'Orbigny)**, 335 μm (Image 15051)
15) ***Orbulina universa*** **"juvenile"** 245 μm (Image 15055)



Faunal composition (246.52 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 632 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.22 – DSDP Site 593 (246.52 mbsf)

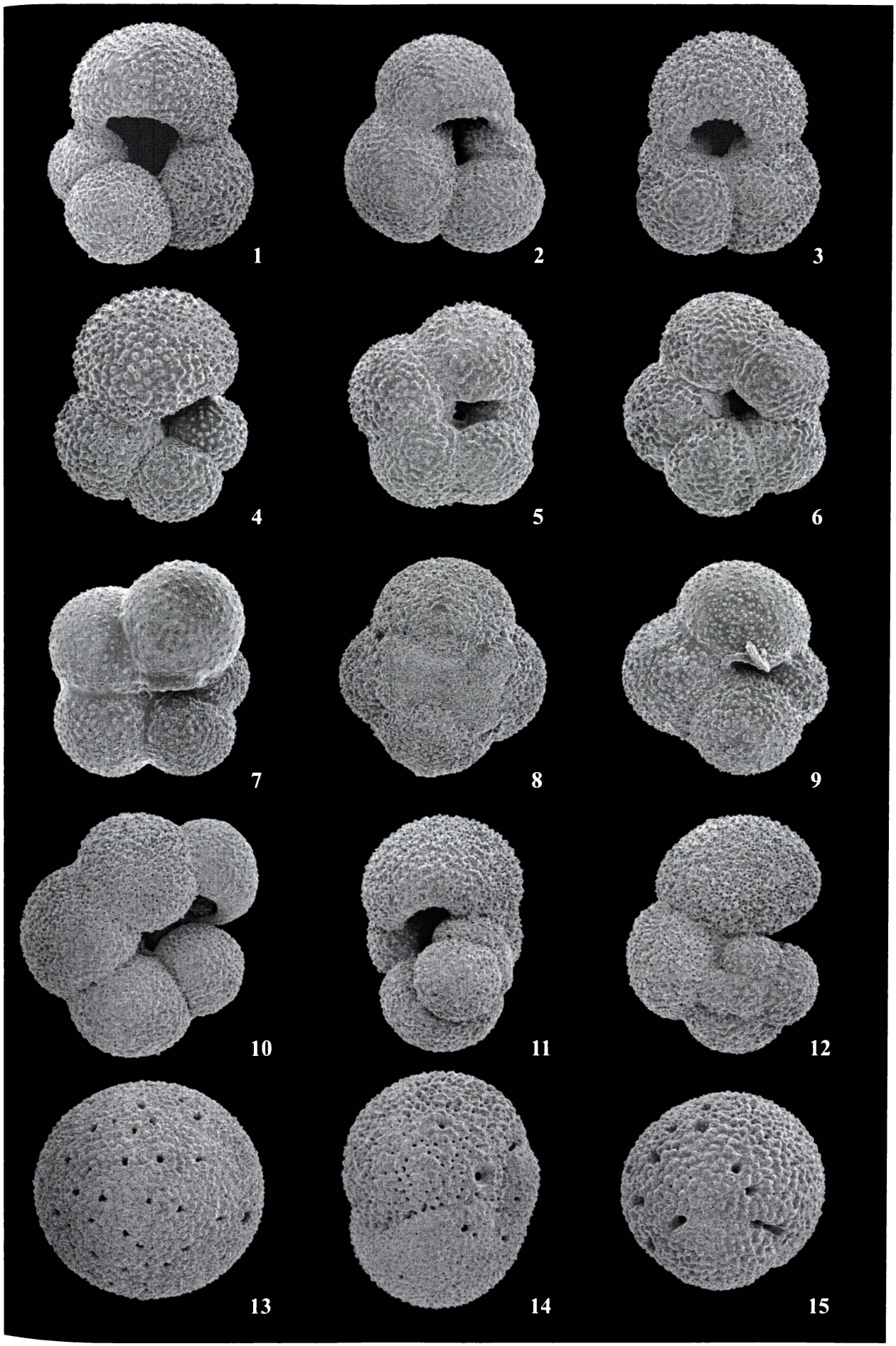


Plate 1.23

Upper Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593-27X-1, 142-144 cm (246.52 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

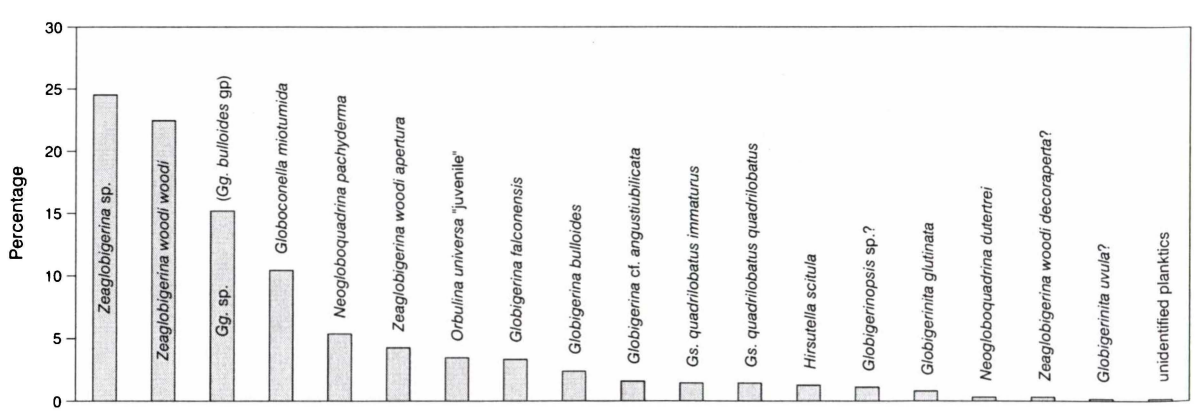
1) ***Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny)**, 370 μm (Image 15007)
2) ***Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny)**, 340 μm (Image 15009)
3) ***Globigerinoides quadrilobatus immaturus* Le Roy**, 325 μm (Image 15012)

4) ***Globigerinoides quadrilobatus immaturus* Le Roy**, 325 μm (Image 15013)
5) ***Globigerinoides quadrilobatus trilobus* (Reuss)**, 275 μm (Image 15016)
6) ***Globigerinoides quadrilobatus trilobus* (Reuss)**, 295 μm (Image 15018)

7) ***Zeaglobigerina woodi woodi* (Jenkins)**, 230 μm (Image 15058)
8) ***Zeaglobigerina woodi apertura* (Jenkins)**, 345 μm (Image 15060)
9) ***Zeaglobigerina nepenthes*? (Todd)**, 220 μm (Image 15061)

10) ***Zeaglobigerina nepenthes* (Todd)**, 185 μm (Image 15062)
11) ***Zeaglobigerina* sp.**, 180 μm (Image 15064)
12) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 190 μm (Image 15048)

13) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 210 μm (Image 15041)
14) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 190 μm (Image 15044)
15) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 180 μm (Image 15042)



Faunal composition (246.52 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 632 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.23 – DSDP Site 593 (246.52 mbsf)

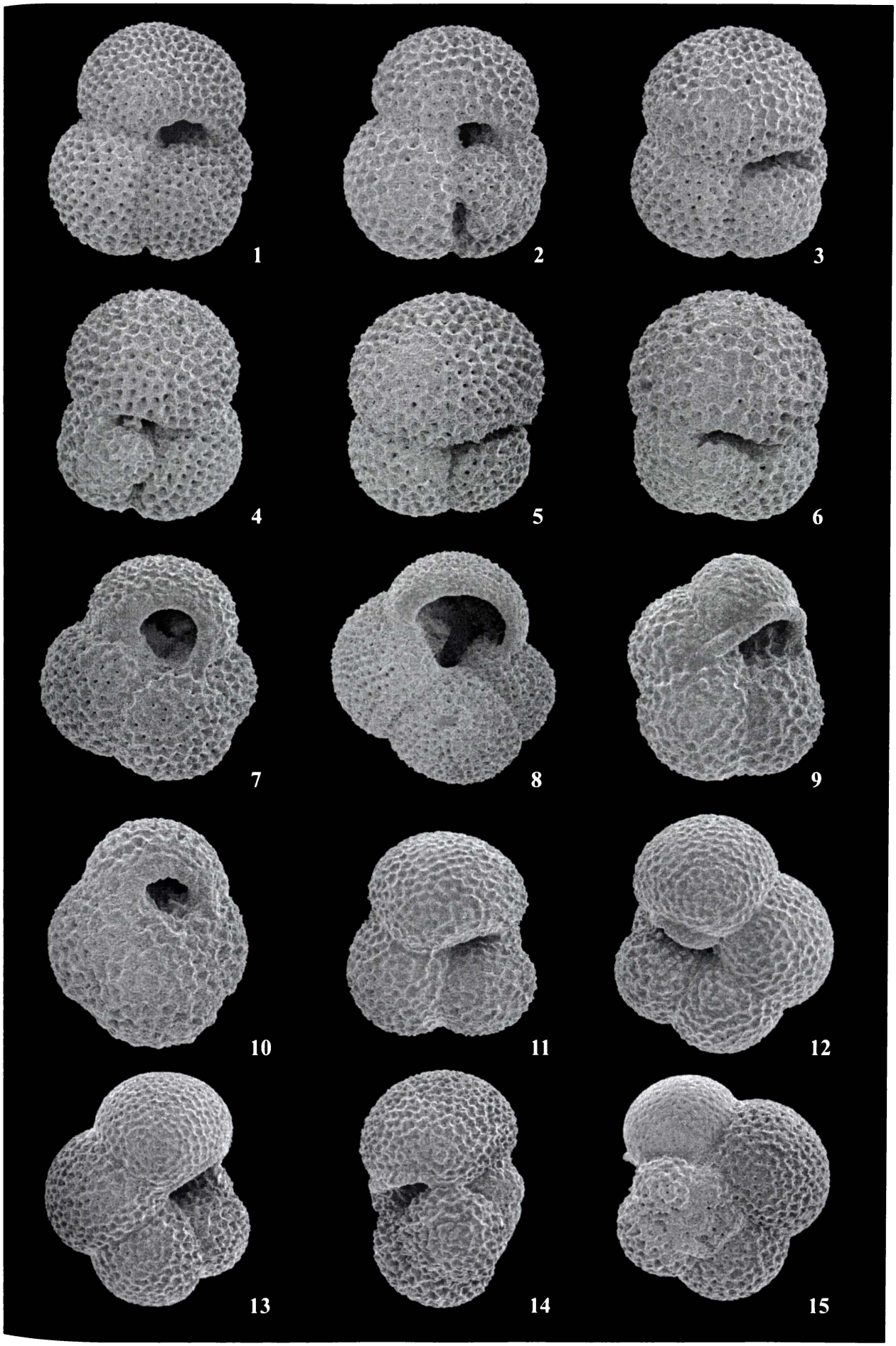


Plate 1.24

Upper Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593-27X-1, 142-144 cm (246.52 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

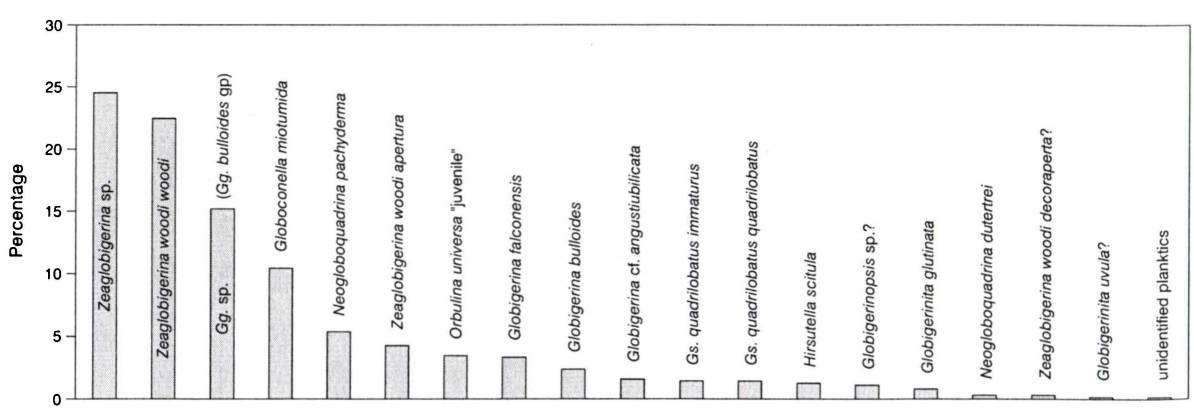
1) ***Neogloboquadrina dutertrei*? (d'Orbigny)**, 210 μm (Image 15046)
2) ***Neogloboquadrina dutertrei* (d'Orbigny)**, 185 μm (Image 15049)
3) ***Hirsutella scitula* (Brady)**, 345 μm (Image 15034)

4) ***Hirsutella scitula* (Brady)**, 345 μm (Image 15035)
5) ***Hirsutella scitula* (Brady)**, 350 μm (Image 15036)
6) ***Hirsutella scitula* (Brady)**, 170 μm (Image 15039)

7) ***Hirsutella scitula* (Brady)**, 180 μm (Image 15038)
8) ***Globoconella miotumida* (Jenkins)**, 375 μm (Image 15028)
9) ***Globoconella miotumida* (Jenkins)**, 300 μm (Image 15033)

10) ***Globoconella miotumida* (Jenkins)**, biconvex, 570 μm (Image 15025)
11) ***Globoconella miotumida* (Jenkins)**, biconvex, 415 μm (Image 15027)
12) ***Globoconella miotumida* (Jenkins)**, biconvex, 540 μm (Image 15026)

13) ***Globoconella miotumida* (Jenkins)**, ventroconical, 505 μm (Image 15029)
14) ***Globoconella miotumida* (Jenkins)**, ventroconical, 475 μm (Image 15032)
15) ***Globoconella miotumida* (Jenkins)**, ventroconical, 495 μm (Image 15030)



Faunal composition (246.52 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 632 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.24 – DSDP Site 593 (246.52 mbsf)

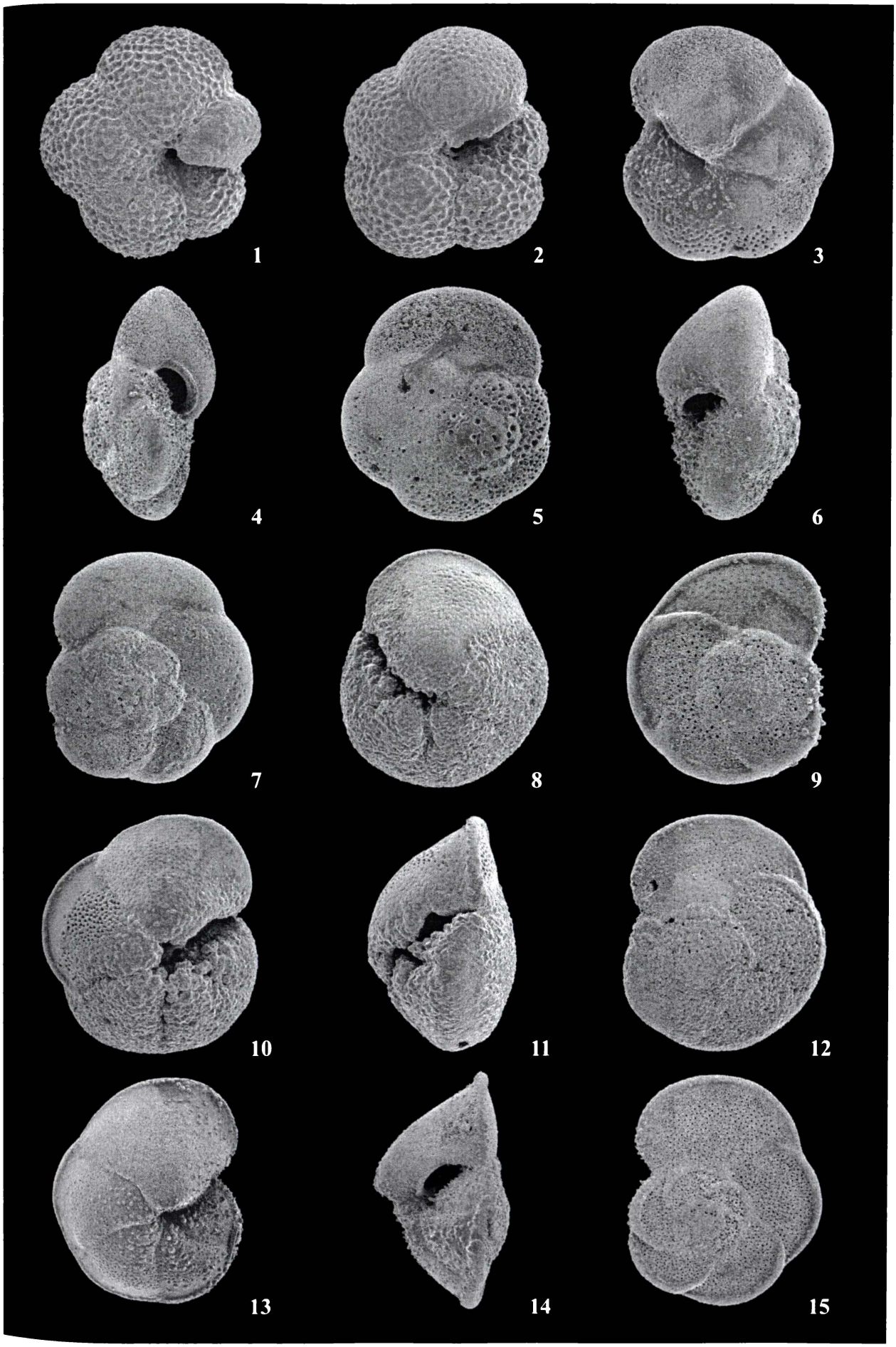


Plate 1.25

Lower Tongaporutuan (late Miocené) planktic foraminifers

DSDP Site 593-29X-5, 1-3 (270.31 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

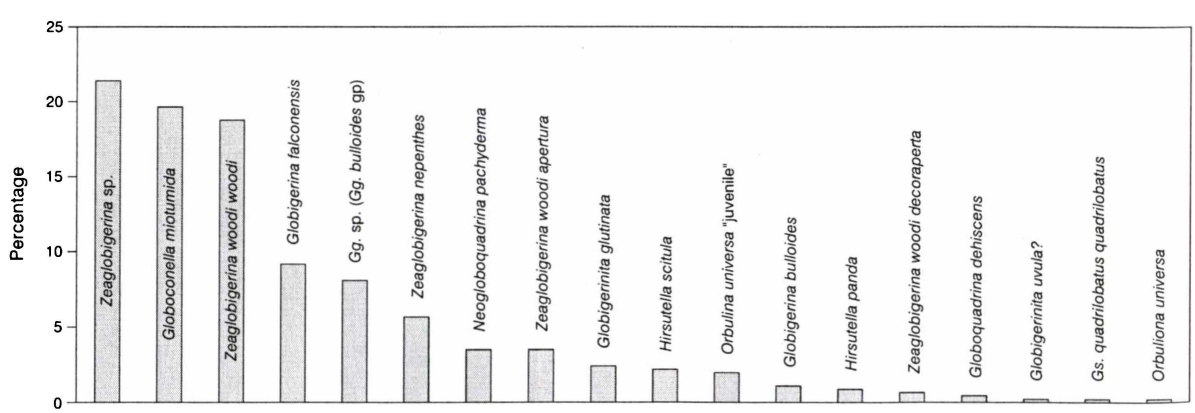
1) ***Globigerina bulloides*** **d'Orbigny,** 285 μm (Image 15090)
2) ***Globigerina falconensis*** **Blow,** 280 μm (Image 15092)
3) ***Globigerina*** **sp.**, 220 μm (Image 15098)

4) ***Globigerina*** **cf.** ***angustiumbilicata*** **(Bolli)**, 150 μm (Image 15099)
5) ***Globigerina*** **cf.** ***angustiumbilicata?*** **(Bolli)**, 160 μm (Image 15104)
6) ***Globigerinita glutinata*** **(Egger)**, 190 μm (Image 15105)

7) ***Globigerinopsis obesa*** **(Bolli)**, 445 μm (Image 15115)
8) ***Globigerinopsis obesa*** **(Bolli)**, 450 μm (Image 15112)
9) ***Globigerinopsis obesa*** **(Bolli)**, 585 μm (Image 15113)

10) ***Globigerinopsis obesa*** **(Bolli)**, juvenile, 255 μm (Image 15116)
11) ***Orbulina universa*** **d'Orbigny**, 325 μm (Image 15154)
12) ***Orbulina universa*** **"juvenile"** 240 μm (Image 16156)

13) ***Orbulina bilobata*** **(d'Orbigny)**, 280 μm (Image 15155)
14) ***Globigerinoides quadrilobatus quadrilobatus*** **(d'Orbigny)**, 250 μm (Image 15108)
15) ***Globigerinoides quadrilobatus quadrilobatus*** **(d'Orbigny)**, 275 μm (Image 15109)



Faunal composition (270.31 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 458 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.25 – DSDP Site 593 (270.31 mbsf)

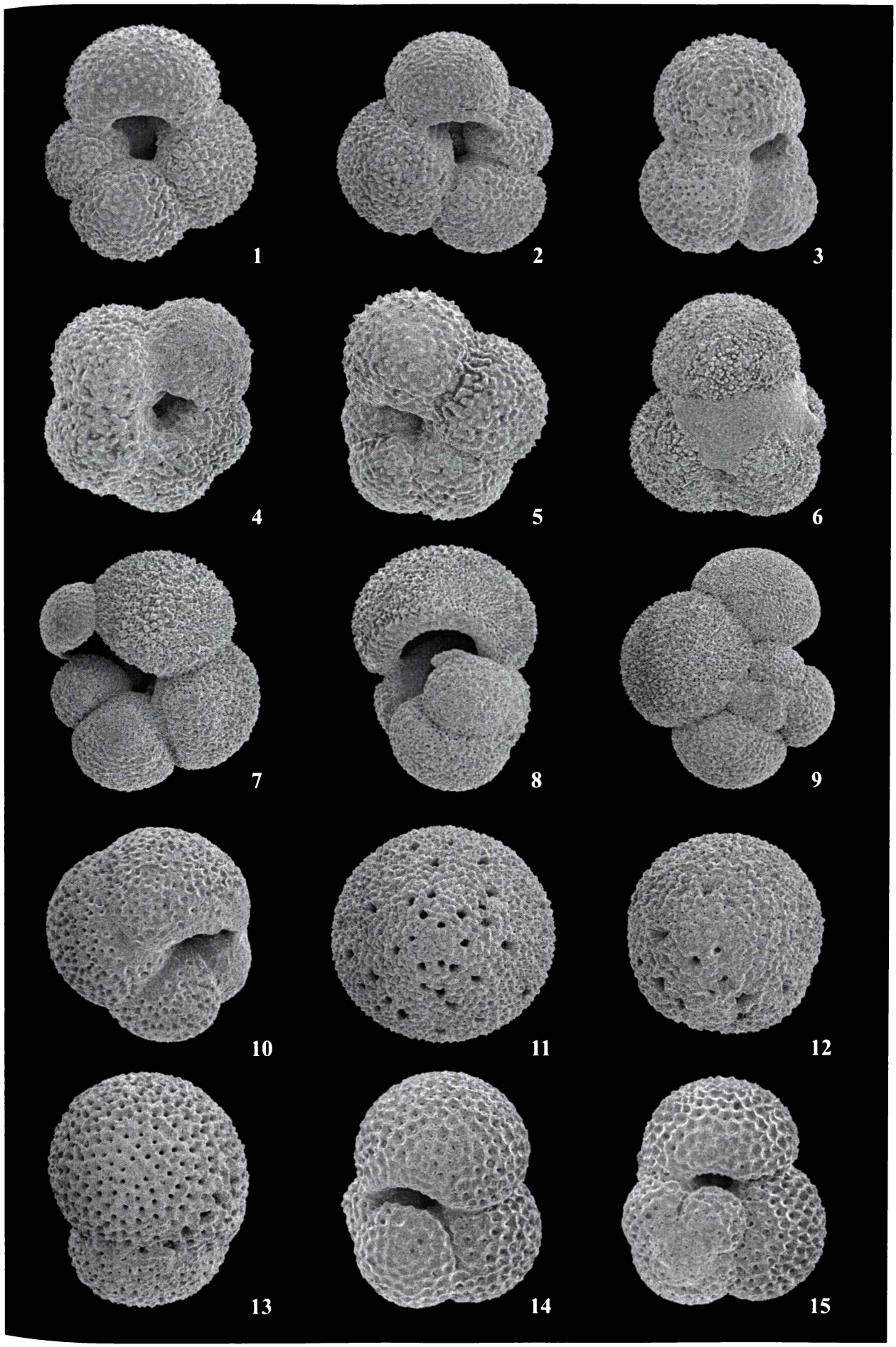


Plate 1.26

Lower Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593-29X-5, 1-3 (270.31 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

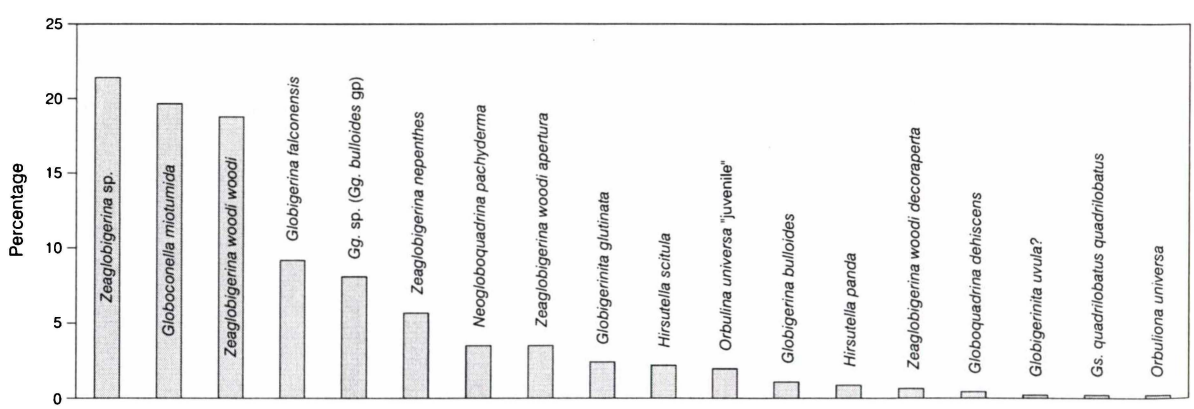
1) ***Globigerinoides quadrilobatus trilobus* (Reuss)**, 265 μm (Image 15111)
2) ***Globigerinoides quadrilobatus trilobus* (Reuss)**, 295 μm (Image 15110)
3) ***Zeaglobigerina woodi decoraperta* (Takayanagi and Saito)**, 200 μm (Image 15167)

4) ***Zeaglobigerina woodi woodi* (Jenkins)**, 275 μm (Image 15160)
5) ***Zeaglobigerina woodi apertura* (Jenkins)**, 305 μm (Image 15158)
6) ***Zeaglobigerina nepenthes*? (Todd)**, compact, 215 μm (Image 15164)

7) ***Zeaglobigerina nepenthes* (Todd)**, 300 μm (Image 15163)
8) ***Globoquadrina dehiscens* (Chapman, Parr and Collins)**, 485 μm (Image 15135)
9) ***Globoquadrina dehiscens* (Chapman, Parr and Collins)**, 335 μm (Image 15137)

10) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 235 μm (Image 15152)
11) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 235 μm (Image 15150)
12) ***Hirsutella scitula* (Brady)**, spirconical, 230 μm (Image 15147)

13) ***Hirsutella* cf. *scitula* (Brady)**, 195 μm (Image 15144)
14) ***Hirsutella* cf. *scitula* (Brady)**, 195 μm (Image 15146)
15) ***Hirsutella* cf. *scitula* (Brady)**, 185 μm (Image 14145)



Faunal composition (270.31 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 458 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.26 – DSDP Site 593 (270.31 mbsf)

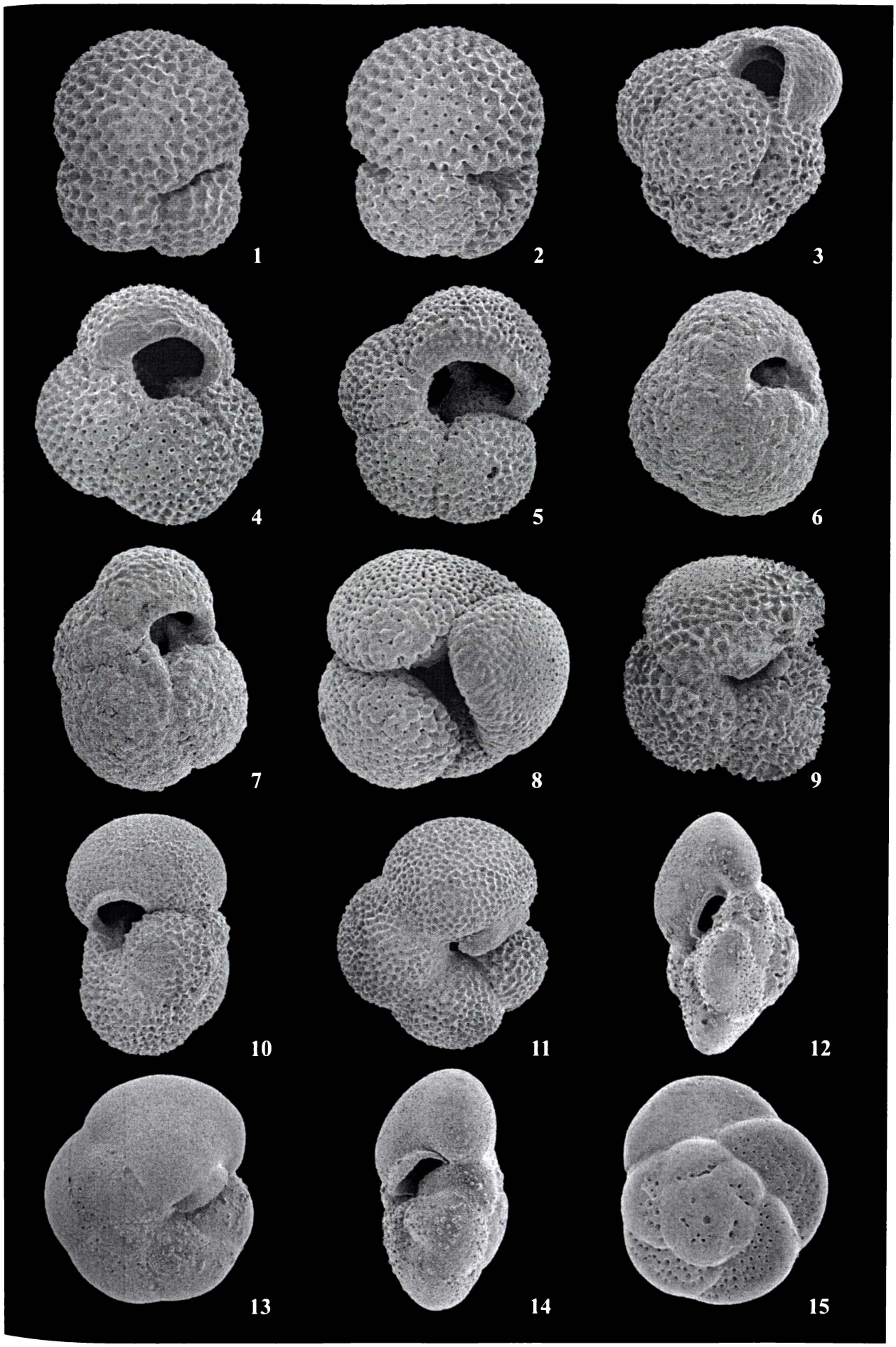


Plate 1.27

Lower Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593-29X-5, 1-3 (270.31 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

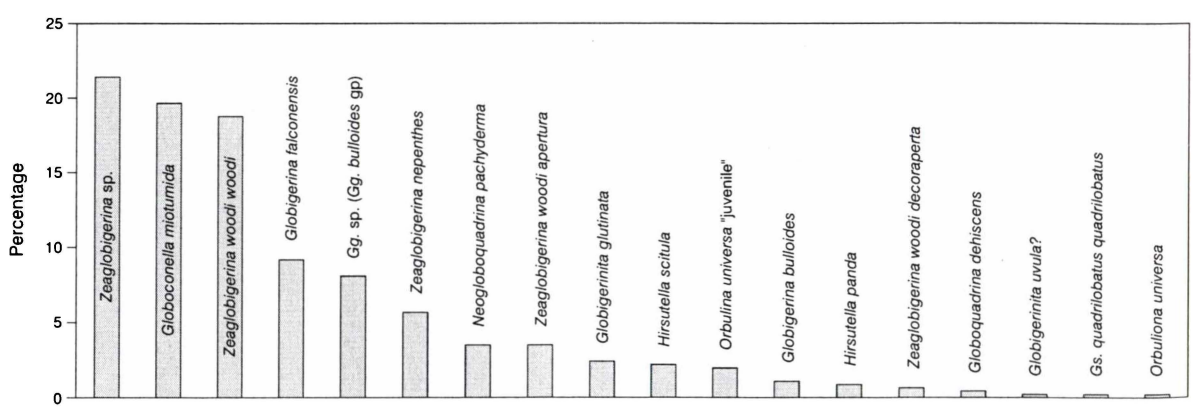
1) ***Hirsutella scitula* (Brady)**, 230 μm (Image 15141)
2) ***Hirsutella scitula* (Brady)**, 230 μm (Image 15142)
3) ***Hirsutella scitula* (Brady)**, 285 μm (Image 15140)

4) ***Hirsutella scitula* (Brady)**, spiroconical, 320 μm (Image 15143)
5) ***Globoconella miotumida* (Jenkins)**, inflated ventroconical, 470 μm (Image 15121)
6) ***Globoconella miotumida* (Jenkins)**, biconvex, 390 μm (Image 15122)

7) ***Globoconella miotumida* (Jenkins)**, inflated biconvex, 515 μm (Image 15124)
8) ***Globoconella miotumida* (Jenkins)**, inflated biconvex, 400 μm (Image 15125)
9) ***Globoconella miotumida* (Jenkins)**, inflated biconvex, 560 μm (Image 15123)

10) ***Globoconella miotumida* (Jenkins)**, ventroconical, 405 μm (Image 15131)
11) ***Globoconella miotumida* (Jenkins)**, four-chambered, ventroconical, 415 μm (Image 15133)
12) ***Globoconella miotumida* (Jenkins)**, ventroconical, 570 μm (Image 15132)

13) ***Globoconella miotumida* (Jenkins)**, 485 μm (Image 15128)
14) ***Globoconella miotumida* (Jenkins)**, ventroconical, 480 μm (Image 15126)
15) ***Globoconella miotumida* (Jenkins)**, four-chambered, ventroconical, 465 μm (Image 15129)



Faunal composition (270.31 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 458 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.27 – DSDP Site 593 (270.31 mbsf)

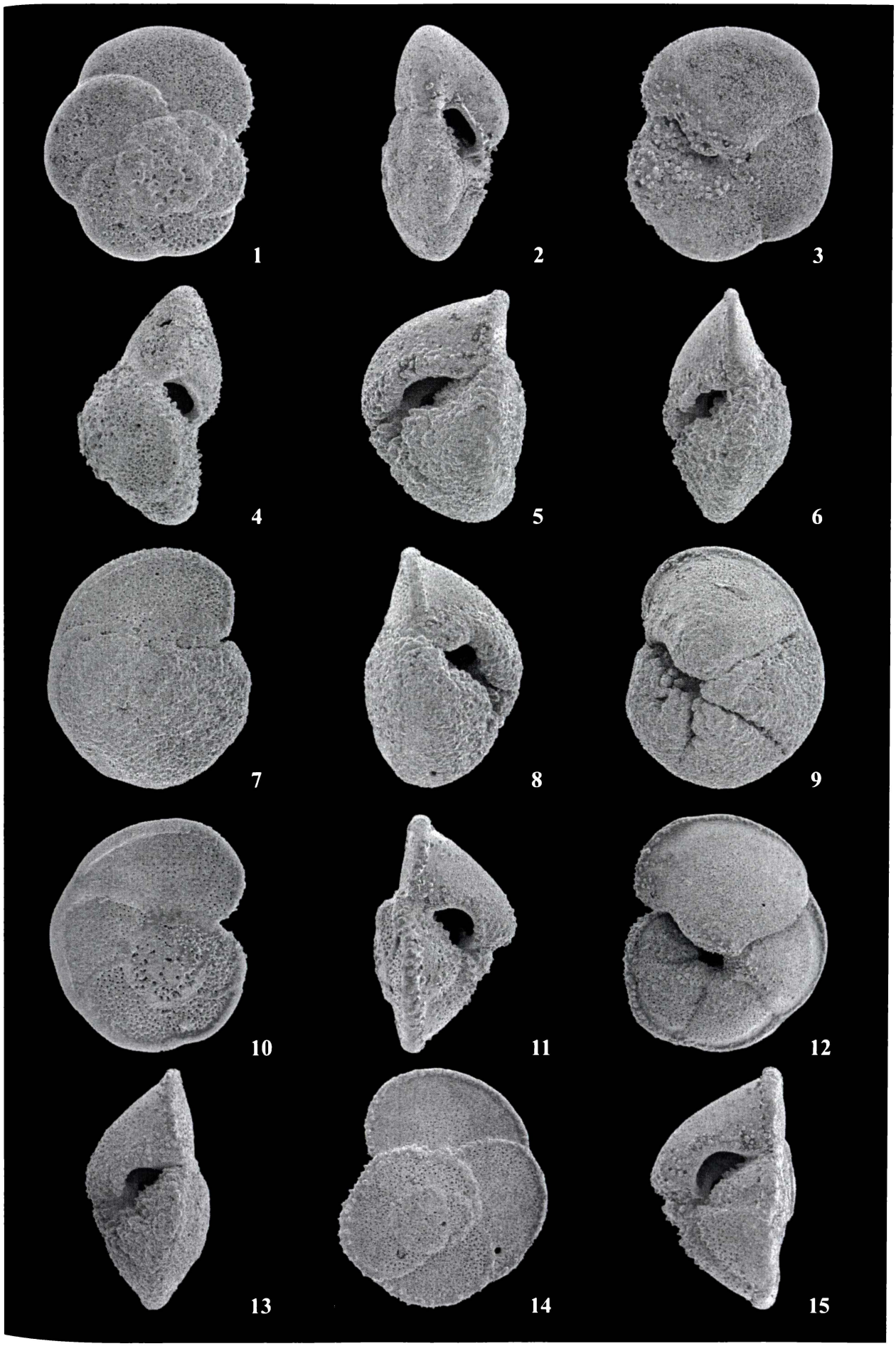


Plate 1.28

Lower Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593-31X-5, 62-64 cm (290.12 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

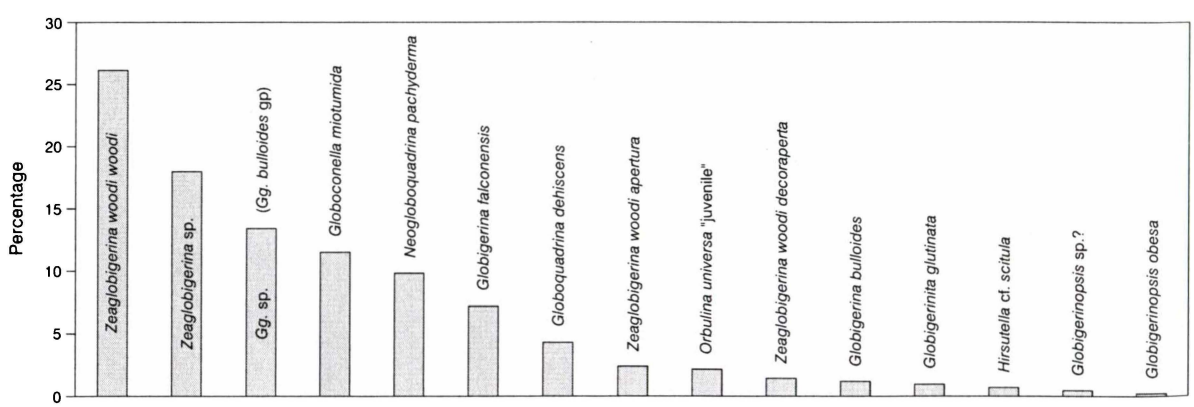
1) ***Globigerina bulloides* d'Orbigny,** 305 μm (Image 15177)
2) ***Globigerina falconensis* Blow**, 300 μm (Image 15178)
3) ***Globigerina eamesi* Blow**, 250 μm (Image 15181)

4) ***Globigerina* sp.**, *Gg. bulloides*-like juvenile, 255 μm (Image 15182)
5) ***Globigerina* sp.**, 220 μm (Image 15183)
6) ***Globigerina* sp.**, 255 μm (Image 15184)

7) ***Globigerina* cf. *angustiumbilicata* (Bolli),** 140 μm (Image 15185)
8) ***Globigerina* cf. *angustiumbilicata* (Bolli),** 175 μm (Image 15187)
9) ***Globigerina* cf. *angustiumbilicata* (Bolli),** 145 μm (Image 15188)

10) ***Globigerinita glutinata* (Egger)**, 170 μm (Image 15190)
11) ***Globigerinita glutinata* (Egger)**, 185 μm (Image 15191)
12) ***Globigerinita uvula* (Ehrenberg)**, 135 μm (Image 15193)

13) ***Globigerinopsis obesa* (Bolli)**, 435 μm (Image 15201)
14) ***Globigerinopsis obesa* (Bolli)**, 375 μm (Image 15202)
15) ***Globigerinopsis obesa* (Bolli)**, 430 μm (Image 15200)



Faunal composition (290.12 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 417 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.28 – DSDP Site 593 (290.12 mbsf)

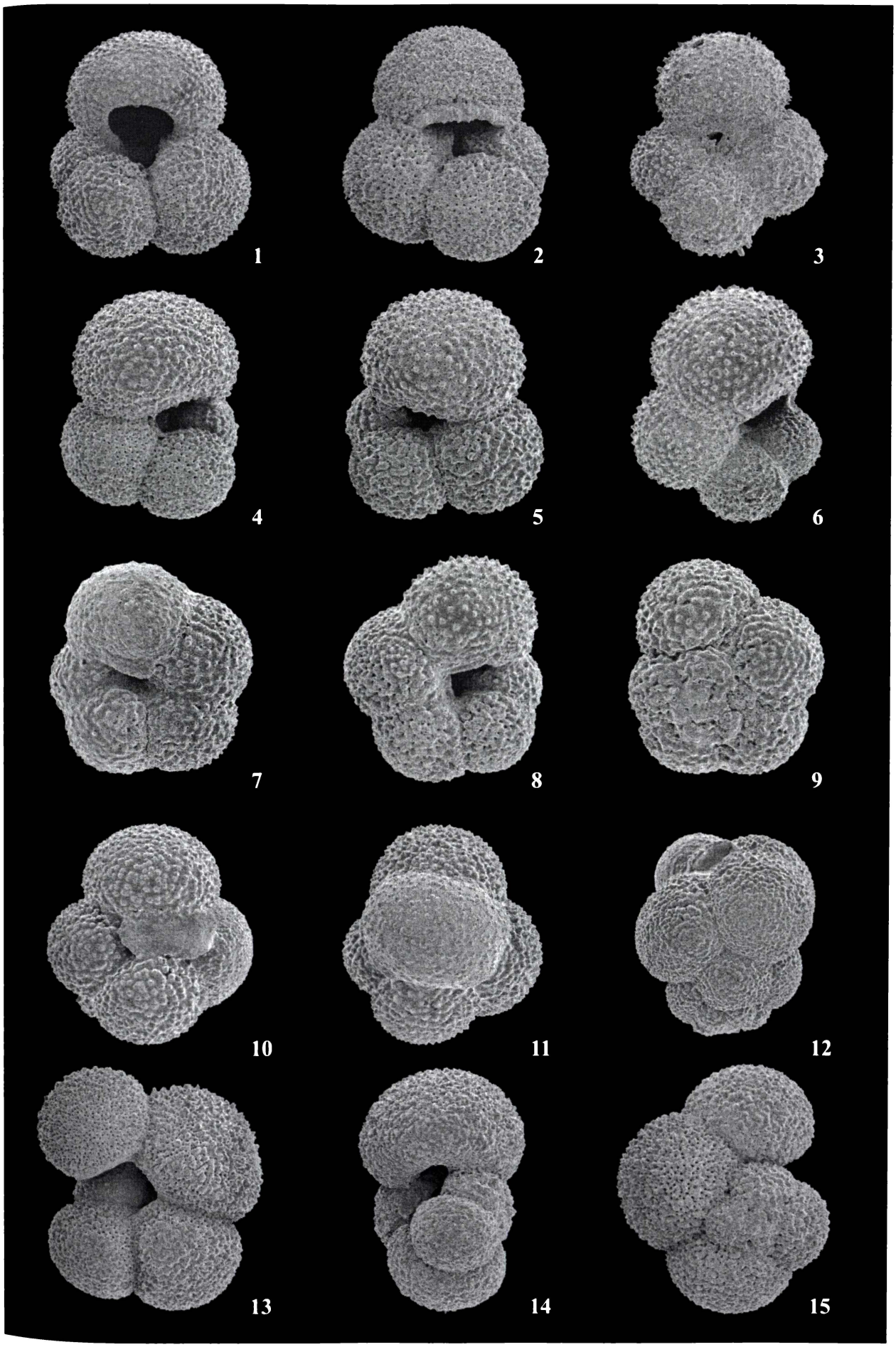


Plate 1.29

Lower Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593-31X-5, 62-64 cm (290.12 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

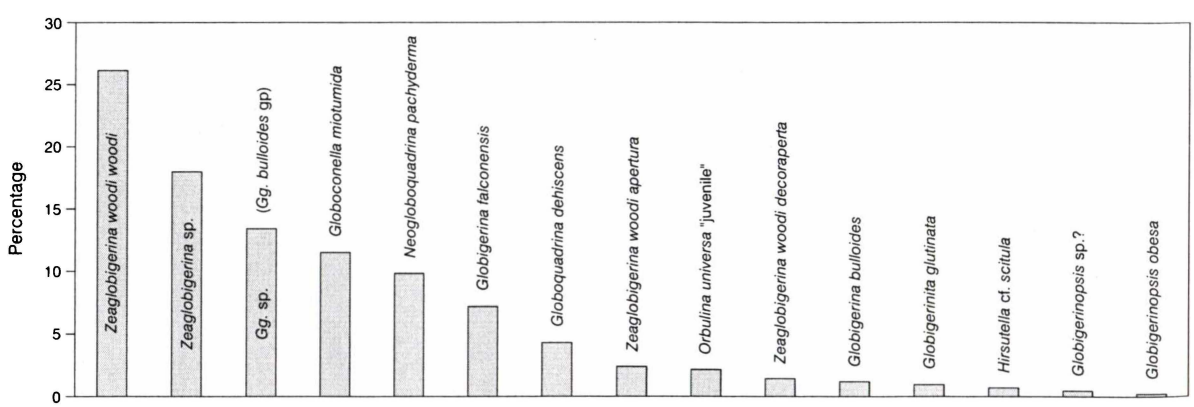
1) ***Globigerinopsis obesa*? (Bolli)**, 275 μm (Image 15199)
2) ***Orbulina universa* "juvenile"** 510 μm (Image 15227)
3) ***Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny)**, 280 μm (Image 15198)

4) ***Globigerinoides quadrilobatus immaturus* Le Roy**, 260 μm (Image 15196)
5) ***Zeaglobigerina woodi woodi* (Jenkins)**, 285 μm (Image 15236)
6) ***Zeaglobigerina woodi apertura* (Jenkins)**, 300 μm (Image 15240)

7) ***Zeaglobigerina woodi decoraperta* (Takayanagi and Saito)**, 180 μm (Image 15230)
8) ***Zeaglobigerina* sp.**, 230 μm (Image 15233)
9) ***Zeaglobigerina nepenthes* (Todd)**, 255 μm (Image 15232)

10) ***Zeaglobigerina nepenthes*? (Todd)**, compact, 210 μm (Image 15231)
11) ***Globoquadrina dehiscens* (Chapman, Parr and Collins)**, 435 μm (Image 15215)
12) ***Globoquadrina dehiscens* (Chapman, Parr and Collins)**, 405 μm (Image 15216)

13) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 250 μm (Image 15220)
14) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 210 μm (Image 15221)
15) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 215 μm (Image 14222)



Faunal composition (290.12 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 417 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.29 – DSDP Site 593 (290.12 mbsf)

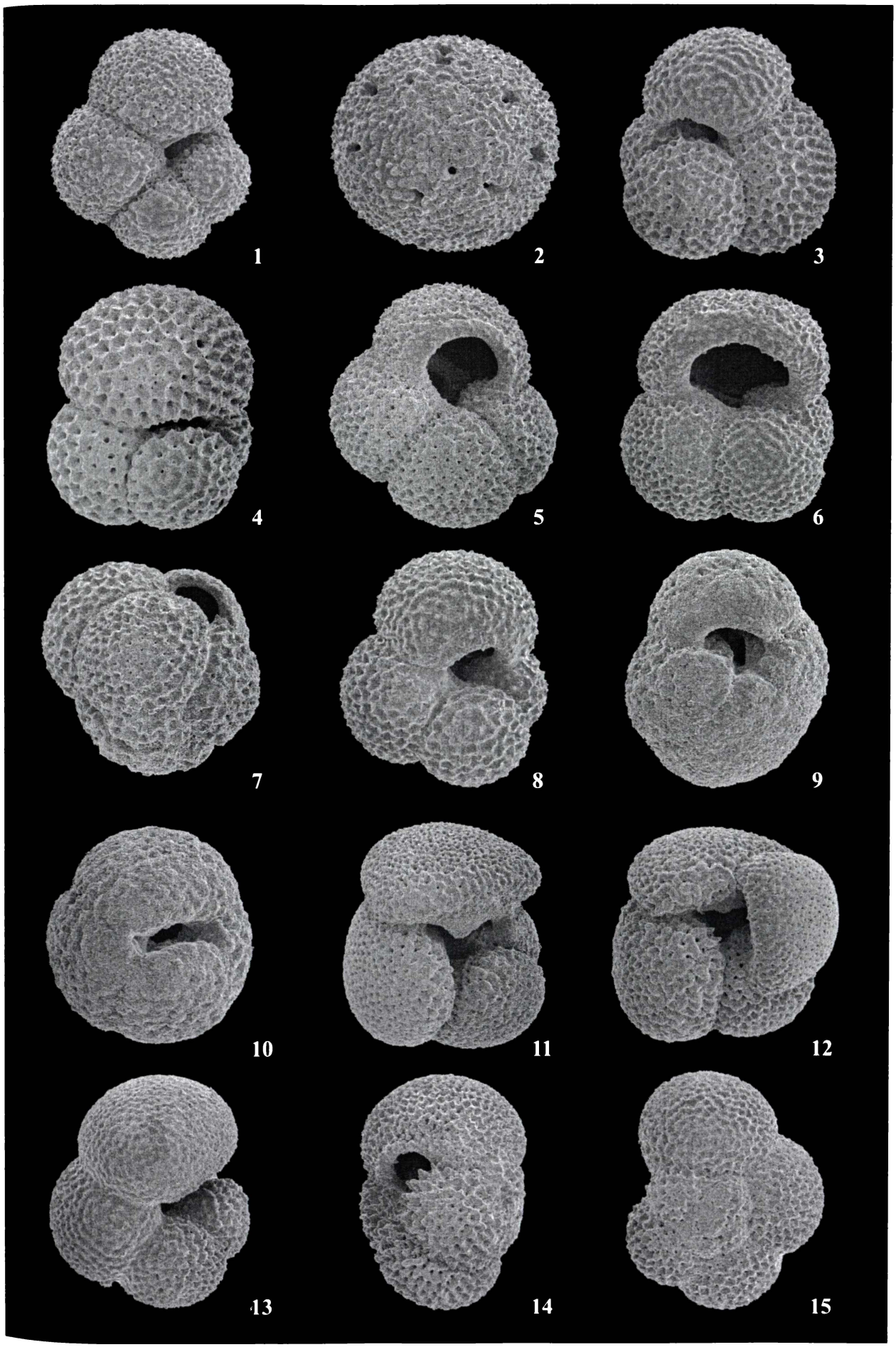


Plate 1.30

Lower Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593-31X-5, 62-64 cm (290.12 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

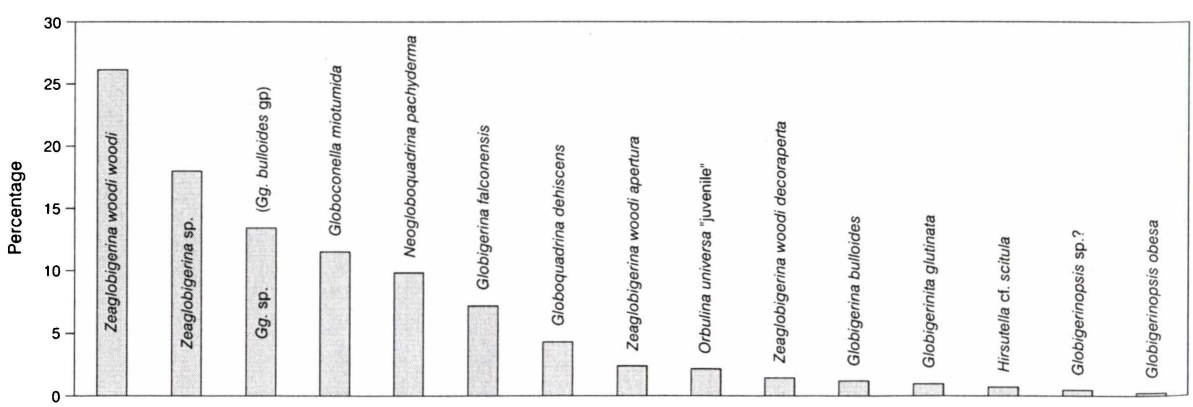
1) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 195 μm (Image 15225)
2) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 195 μm (Image 16829)
3) ***Neogloboquadrina pachyderma* (Ehrenberg)**, 225 μm (Image 15223)

4) ***Hirsutella scitula* (Brady)**, 310 μm (Image 15217)
5) ***Hirsutella scitula* (Brady)**, 255 μm (Image 15219)
6) ***Hirsutella scitula* (Brady)**, 260 μm (Image 15218)

7) ***Globoconella miotumida* (Jenkins)**, compressed, 510 μm (Image 15203)
8) ***Globoconella miotumida* (Jenkins)**, compressed, 530 μm (Image 15205)
9) ***Globoconella miotumida* (Jenkins)**, compressed, 485 μm (Image 15204)

10) ***Globoconella miotumida* (Jenkins)**, ventroconical, 340 μm (Image 15206)
11) ***Globoconella miotumida* (Jenkins)**, ventroconical, 305 μm (Image 15208)
12) ***Globoconella miotumida* (Jenkins)**, ventroconical, 460 μm (Image 15207)

13) ***Globoconella explicationis* (Jenkins)**, four-chambered, 445 μm (Image 15211)
14) ***Globoconella explicationis* (Jenkins)**, 745 μm (Image 15213)
15) ***Globoconella explicationis* (Jenkins)**, 680 μm (Image 15210)



Faunal composition (290.12 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 417 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.30 – DSDP Site 593 (290.12 mbsf)

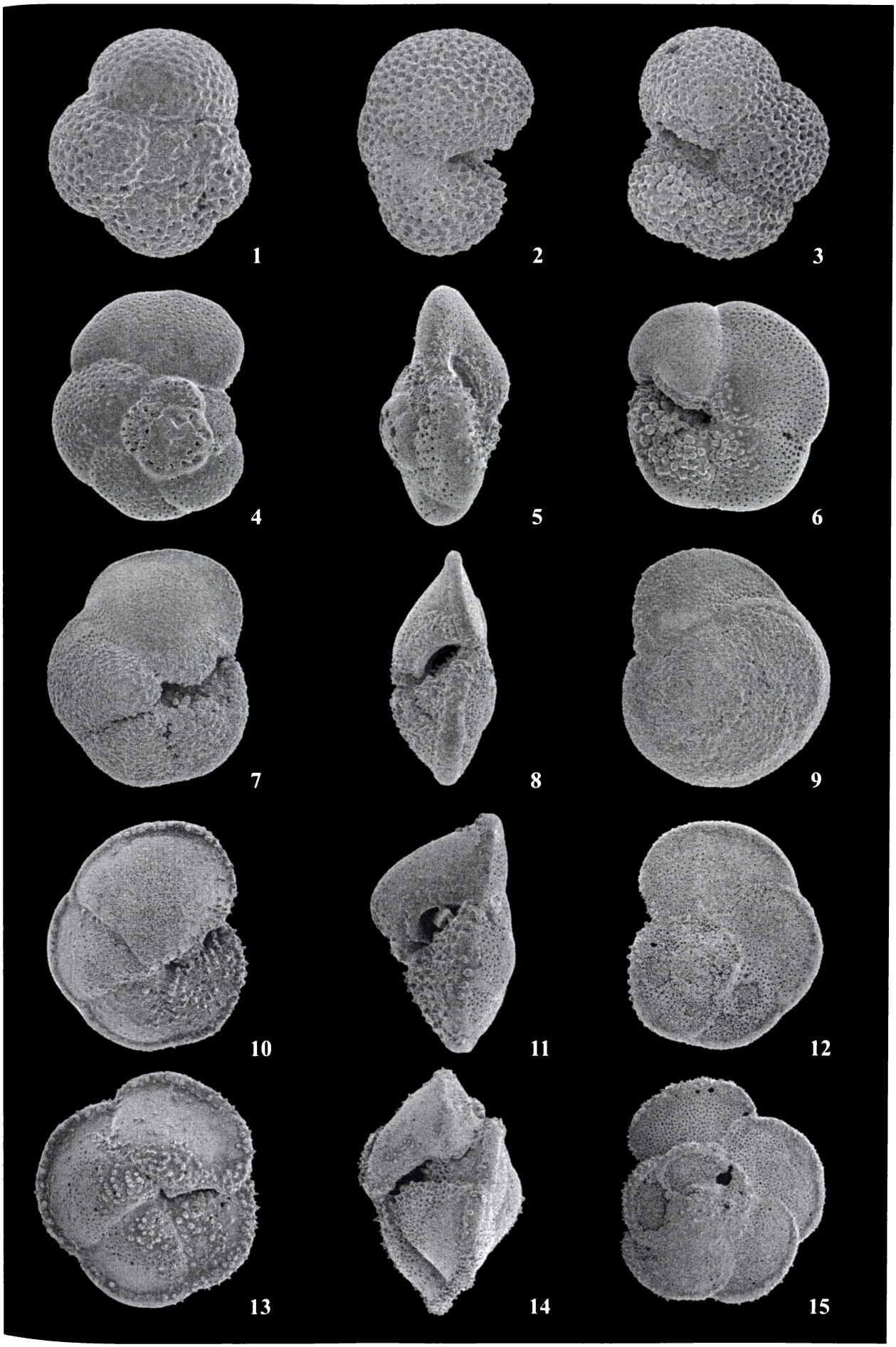


Plate 1.31

Lower Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593-34X-2, 133-135 cm (315.13 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

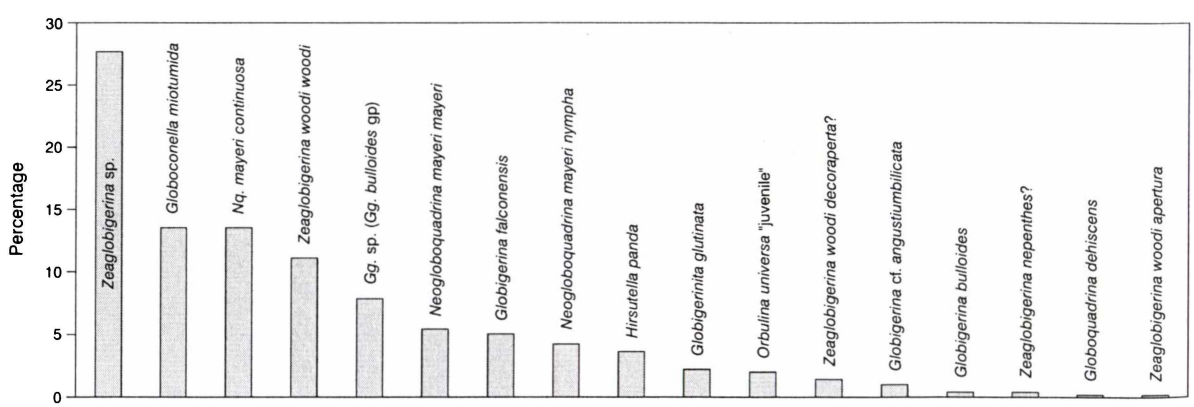
1) ***Globigerina bulloides*** **d'Orbigny,** 275 μm (Image 15242)
2) ***Globigerina falconensis*** **Blow,** 245 μm (Image 15244)
3) ***Globigerina*** **sp.**, 210 μm (Image 15246)

4) ***Globigerina*** **sp.**, 275 μm (Image 15245)
5) ***Globigerina*** **cf.** ***angustiumbilicata*** **(Bolli),** 185 μm (Image 15249)
6) ***Globigerina*** **cf.** ***angustiumbilicata*** **(Bolli),** 195 μm (Image 15248)

7) ***Globigerinita glutinata*** **(Egger)**, 190 μm (Image 15254)
8) ***Globigerinita glutinata*** **(Egger)**, 145 μm (Image 15255)
9) ***Globigerinita uvula*** **(Ehrenberg)**, 155 μm (Image 15257)

10) ***Globigerinopsis obesa*** **(Bolli)**, 450 μm (Image 15260)
11) ***Globigerinopsis obesa*** **(Bolli)**, juvenile, 185 μm (Image 15258)
12) ***Orbulina bilobata*** **(d'Orbigny),** 240 μm (Image 15300)

13) ***Orbulina universa*** **"juvenile"** 435 μm (Image 15299)
14) ***Orbulina universa*** **"juvenile"** 265 μm (Image 15301)
15) ***Orbulina universa*** **"juvenile"** 215 μm (Image 15302)



Faunal composition (315.13 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 495 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.31 – DSDP Site 593 (315.13 mbsf)

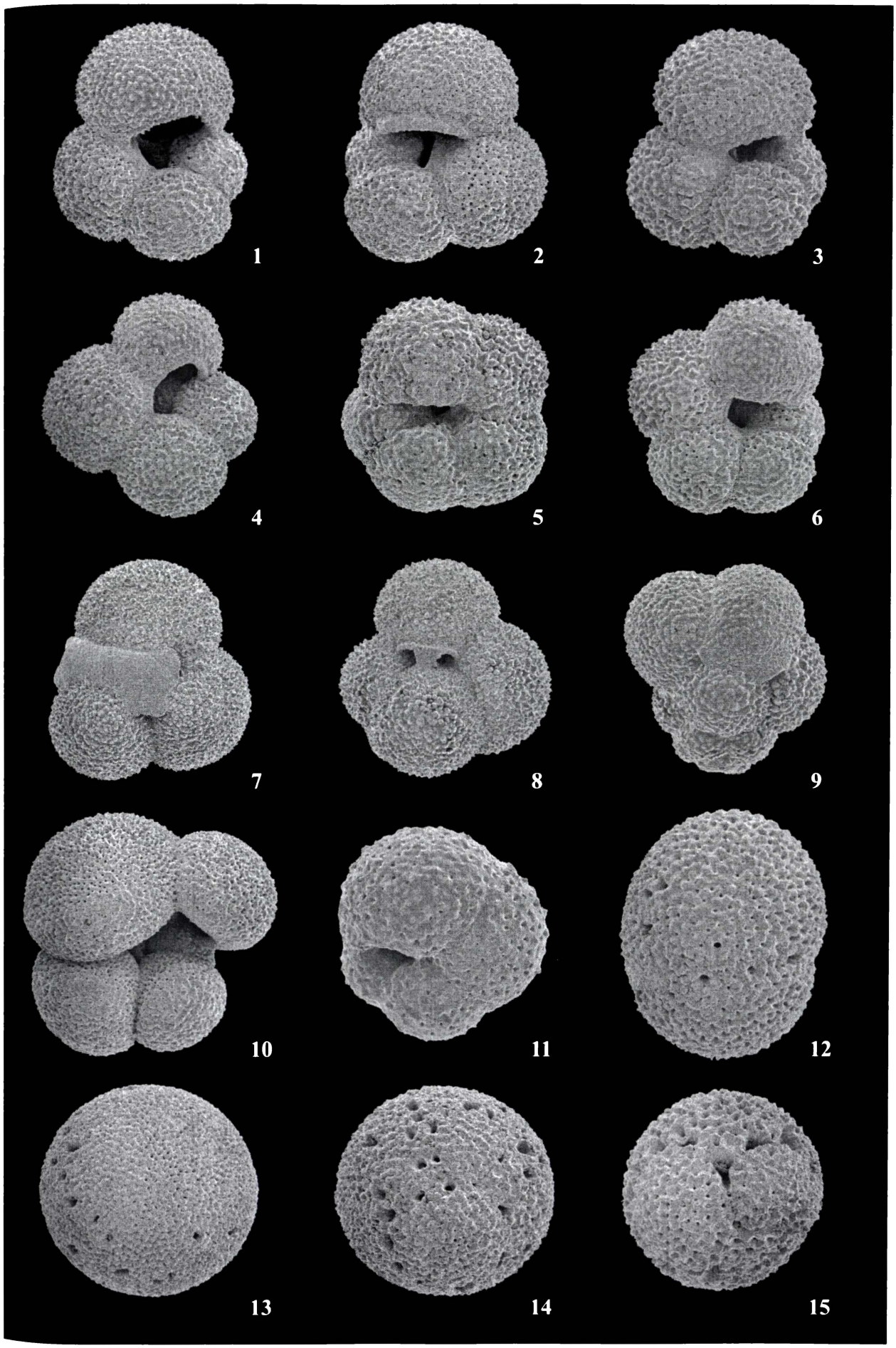


Plate 1.32

Lower Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593-34X-2, 133-135 cm (315.13 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

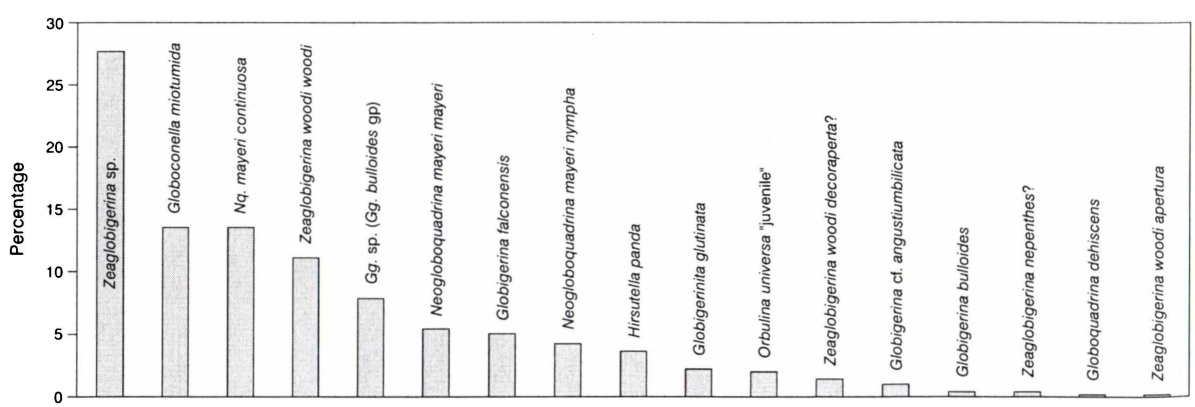
1) ***Zeaglobigerina woodi woodi*** **(Jenkins)**, 260 μm (Image 15303)
2) ***Zeaglobigerina woodi apertura*** **(Jenkins)**, 300 μm (Image 15305)
3) ***Zeaglobigerina woodi decoraperta*** **(Takayanagi and Saito)**, 295 μm (Image 15312)

4) ***Zeaglobigerina nepenthes*** **(Todd)**, 200 μm (Image 15310)
5) ***Zeaglobigerina nepenthes?*** **(Todd)**, compact, 200 μm (Image 15308)
6) ***Zeaglobigerina*** **sp.**, 235 μm (Image 15307)

7) ***Globoquadrina dehiscens*** **(Chapman, Parr and Collins)**, 425 μm (Image 15298)
8) ***Globoquadrina dehiscens*** **(Chapman, Parr and Collins)**, 290 μm (Image 15295)
9) ***Neogloboquadrina mayeri mayeri*** **(Cushman)**, 215 μm (Image 15296)

10) ***Neogloboquadrina mayeri mayeri*** **(Cushman)**, 220 μm (Image 15289)
11) ***Neogloboquadrina mayeri mayeri*** **(Cushman)**, 225 μm (Image 15292)
12) ***Neogloboquadrina mayeri mayeri*** **(Cushman)**, 195 μm (Image 15290)

13) ***Neogloboquadrina mayeri nympha*** **(Jenkins)**, 195 μm (Image 15284)
14) ***Neogloboquadrina mayeri nympha*** **(Jenkins)**, 205 μm (Image 15286)
15) ***Neogloboquadrina mayeri nympha*** **(Jenkins)**, 180 μm (Image 15285)



Faunal composition (315.13 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 495 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.32 – DSDP Site 593 (315.13 mbsf)

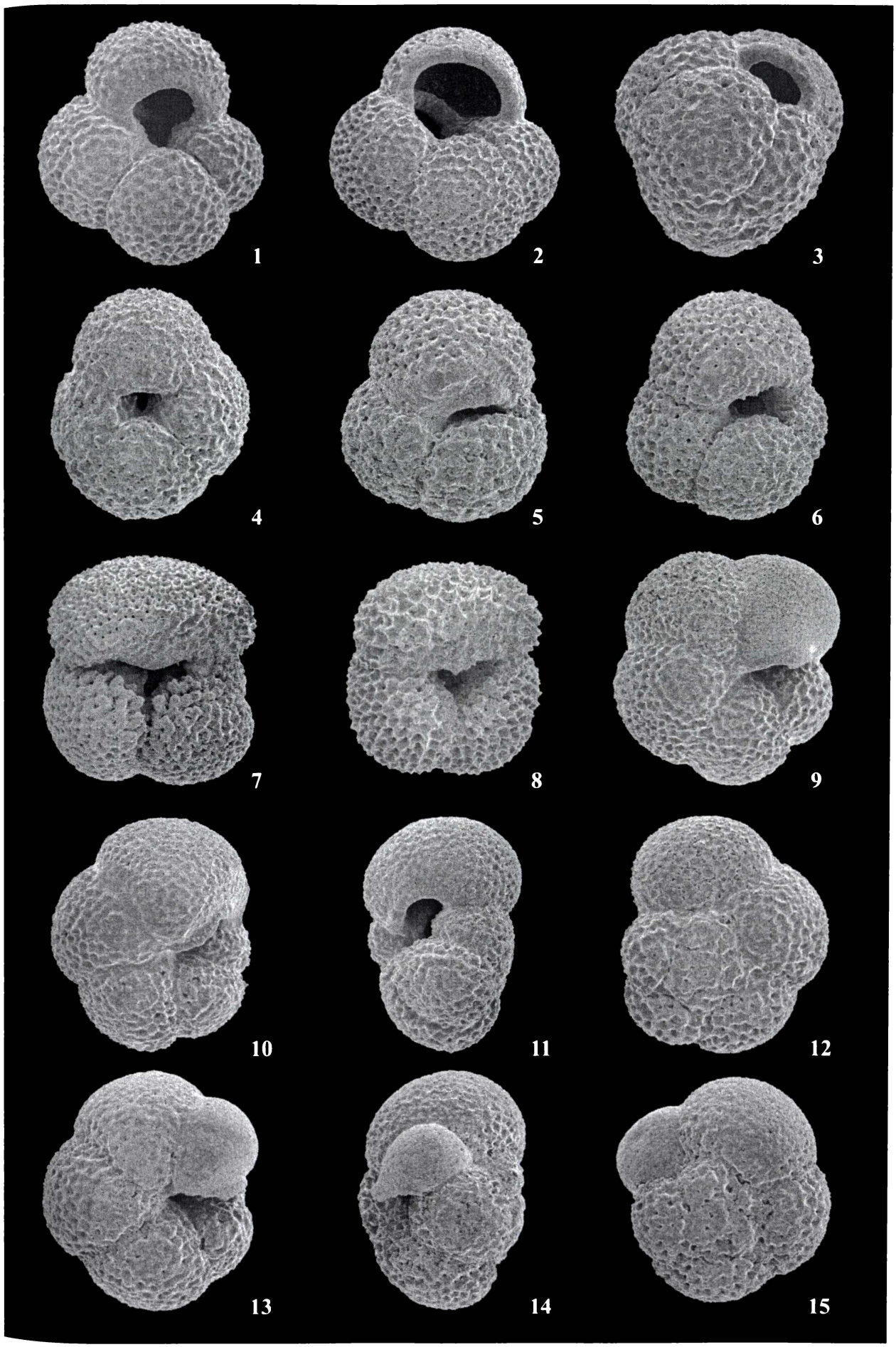


Plate 1.33

Lower Tongaporutuan (late Miocene) planktic foraminifers

DSDP Site 593-34X-2, 133-135 cm (315.13 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

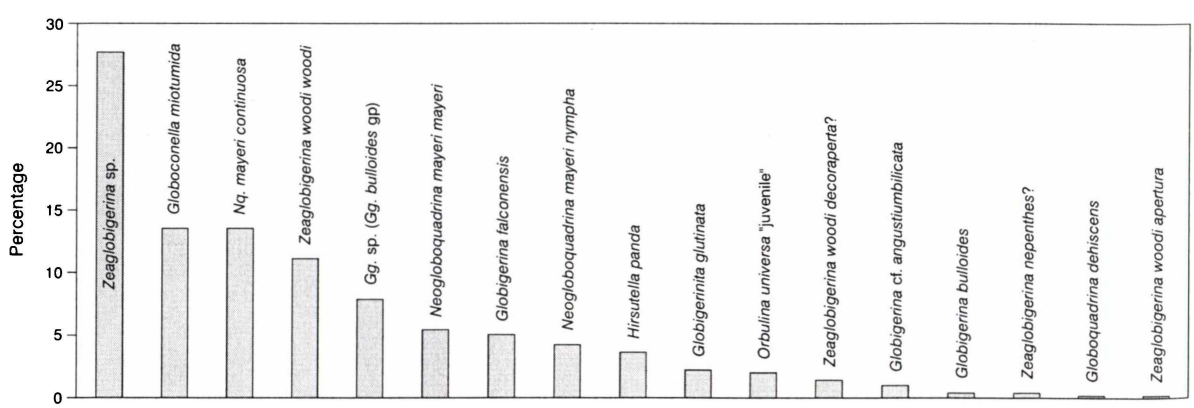
1) ***Neogloboquadrina mayeri continuosa*** **(Blow)**, 225 μm (Image 15276)
2) ***Neogloboquadrina mayeri continuosa*** **(Blow)**, 215 μm (Image 15279)
3) ***Neogloboquadrina mayeri continuosa*** **(Blow)**, 210 μm (Image 15278)

4) ***Neogloboquadrina mayeri continuosa?*** **(Blow)**, cf. *Nq. falconarae,* 185 μm (Image 17038)
5) ***Neogloboquadrina mayeri continuosa?*** **(Blow)**, cf. *Nq. falconarae* 185 μm (Image 17042)
6) ***Neogloboquadrina mayeri mayeri*** **(Cushman)**, 230 μm (Image 15287)

7) ***Hirsutella panda*** **(Jenkins)**, 375 μm (Image 15268)
8) ***Hirsutella panda*** **(Jenkins)**, 415 μm (Image 15269)
9) ***Hirsutella panda*** **(Jenkins)**, 480 μm (Image 15267)

10) ***Globoconella miotumida*** **(Jenkins)**, biconvex, 465 μm (Image 15261)
11) ***Globoconella miotumida*** **(Jenkins)**, biconvex, 430 μm (Image 15263)
12) ***Globoconella miotumida*** **(Jenkins)**, biconvex, 410 μm (Image 15262)

13) ***Globoconella miotumida*** **(Jenkins)**, four-chambered, 355 μm (Image 15264)
14) ***Globoconella miotumida*** **(Jenkins)**, four-chambered, 360 μm (Image 15266)
15) ***Globoconella miotumida*** **(Jenkins)**, four-chambered, 360 μm (Image 15265)



Faunal composition (315.13 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 495 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.33 – DSDP Site 593 (315.13 mbsf)

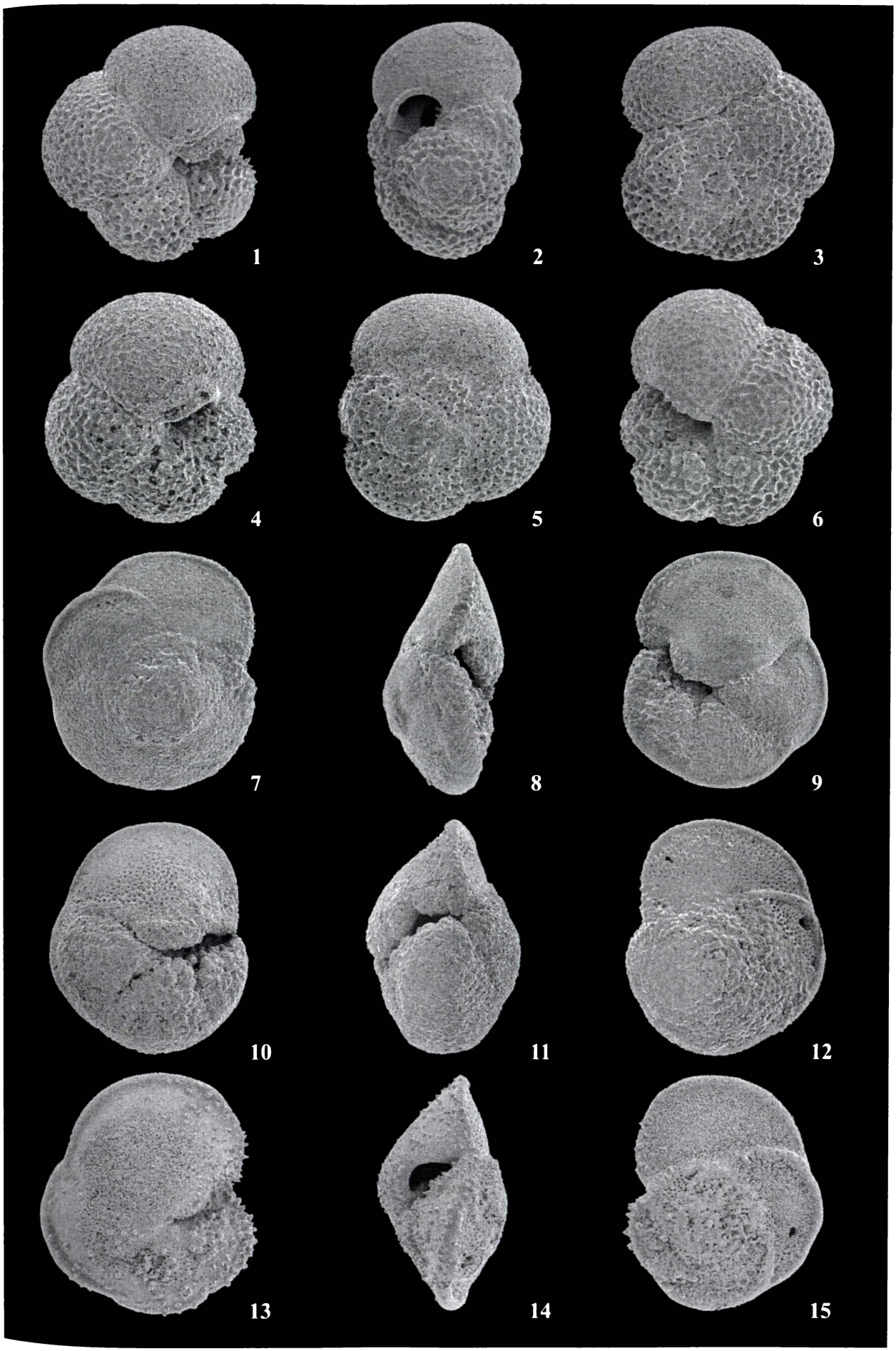


Plate 1.34

Upper Waiauan (middle Miocene) planktic foraminifers

DSDP Site 593-36X-1, 148-150 cm (332.98 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

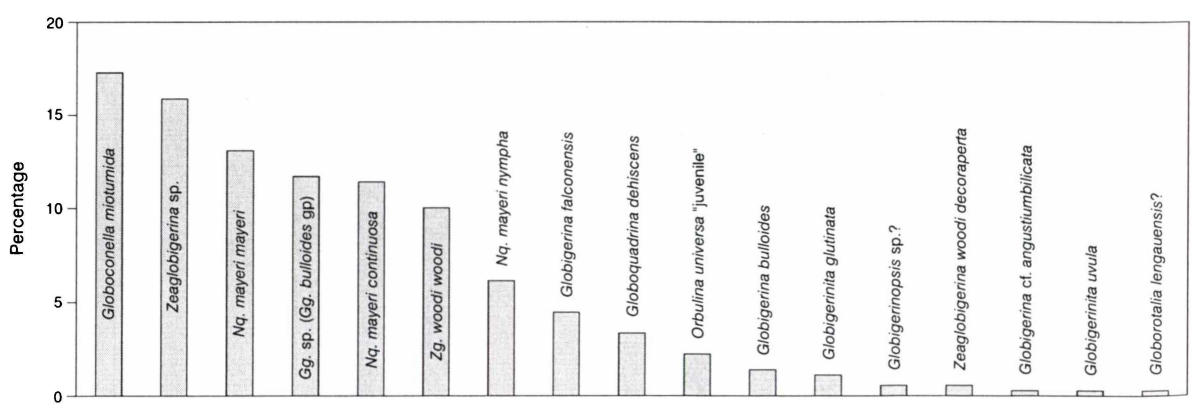
1) ***Globigerina bulloides*** **d'Orbigny,** 290 μm (Image 15319)
2) ***Globigerina bulloides*** **d'Orbigny**, 305 μm (Image 15320)
3) ***Globigerina falconensis*** **Blow**, 260 μm (Image 15322)

4) ***Globigerina*** **sp.**, 265 μm (Image 15323)
5) ***Globigerina*** **cf.** ***angustiumbilicata*** **(Bolli)**, 165 μm (Image 15326)
6) ***Globigerina*** **cf.** ***angustiumbilicata*** **(Bolli)**, 150 μm (Image 15330)

7) ***Globigerina*** **cf.** ***angustiumbilicata*** **(Bolli)**, 195 μm (Image 15327)
8) ***Globigerinita glutinata*** **(Egger)**, 170 μm (Image 15332)
9) ***Globigerinita uvula*** **(Ehrenberg)**, 175 μm (Image 15334)

10) ***Orbulina universa*** **d'Orbigny,** 340 μm (Image 15370)
11) ***Orbulina bilobata*** **(d'Orbigny)**, 265 μm (Image 15371)
12) ***Orbulina universa*** **"juvenile"** 195 μm (Image 15374)

13) ***Orbulina universa*** **"juvenile"** 245 μm (Image 15372)
14) ***Zeaglobigerina woodi woodi*** **(Jenkins)**, 265 μm (Image 15375)
15) ***Zeaglobigerina nepenthes?*** **(Todd)**, compact, 255 μm (Image 15378)



Faunal composition (332.98 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 359 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.34 – DSDP Site 593 (332.98 mbsf)

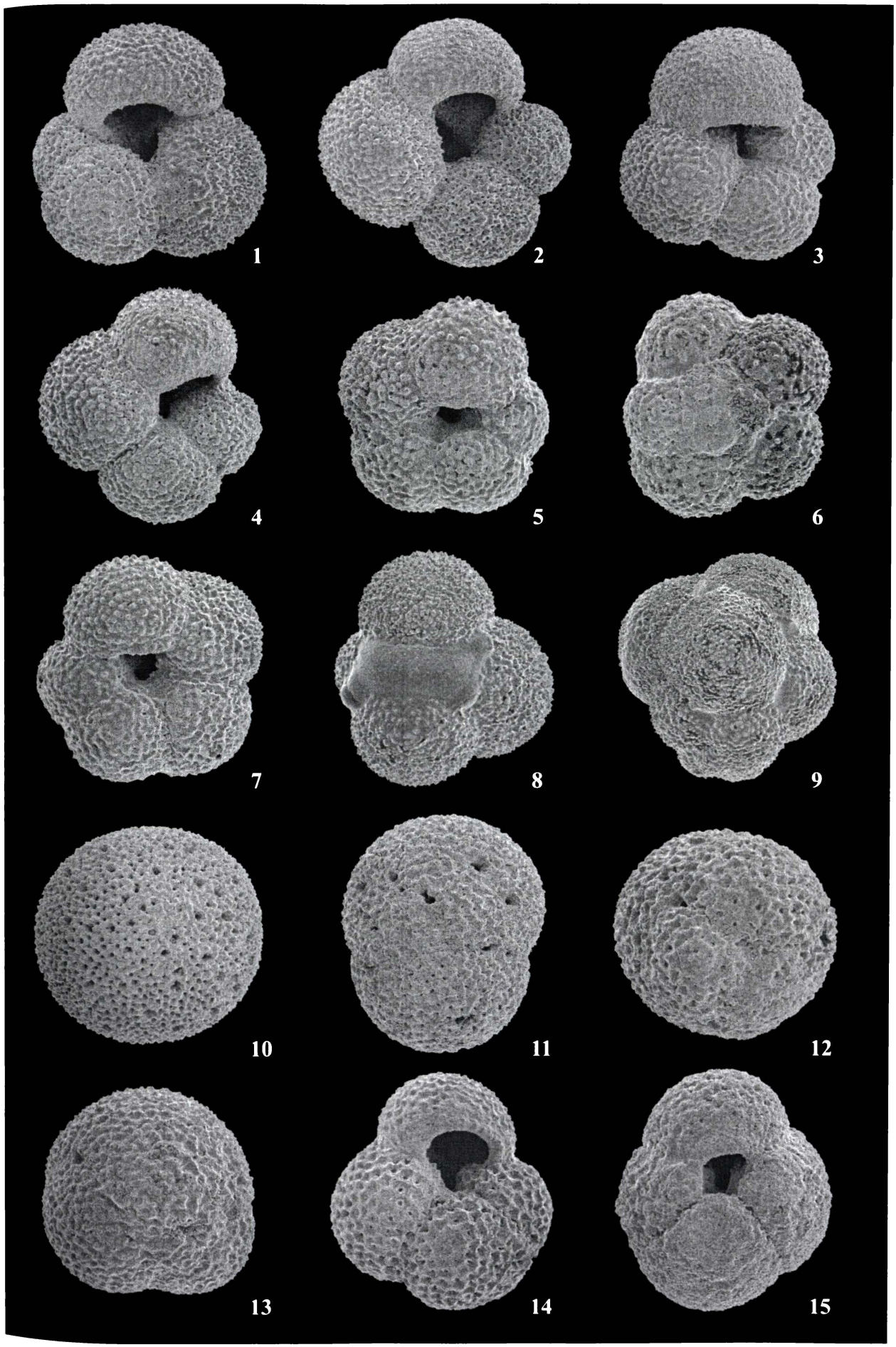


Plate 1.35

Upper Waiauan (middle Miocene) planktic foraminifers

DSDP Site 593-36X-1, 148-150 cm (332.98 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

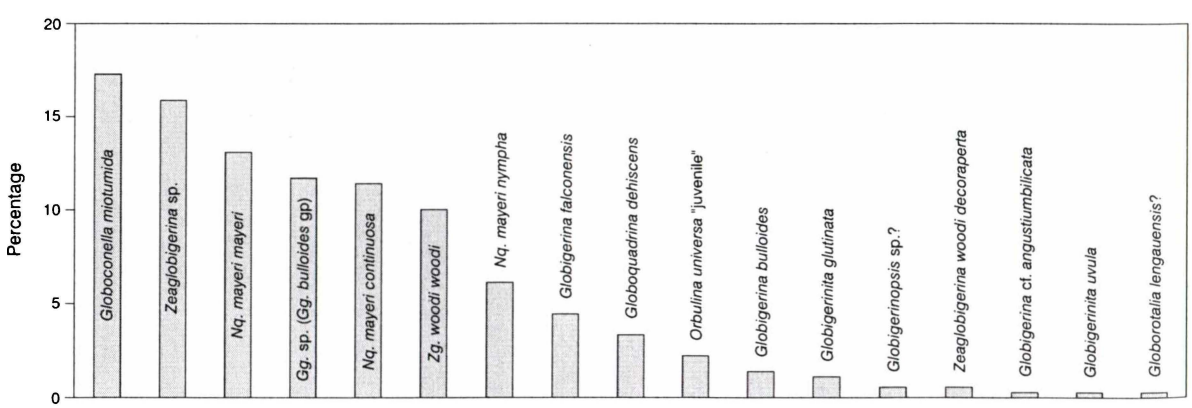
1) ***Globoquadrina dehiscens*** **(Chapman, Parr and Collins)**, 465 μm (Image 15349)
2) ***Globoquadrina dehiscens*** **(Chapman, Parr and Collins)**, 320 μm (Image 15351)
3) ***Globoquadrina dehiscens*** **(Chapman, Parr and Collins)**, 240 μm (Image 15352)

4) ***Neogloboquadrina mayeri continuosa?*** **(Blow)**, cf. *Nq. falconarae,* 200 μm (Image 15358)
5) ***Neogloboquadrina mayeri continuosa*** **(Blow)**, 205 μm (Image 15359)
6) ***Neogloboquadrina mayeri continuosa*** **(Blow)**, 220 μm (Image 15360)

7) ***Neogloboquadrina mayeri continuosa*** **(Blow)**, 190 μm (Image 15362)
8) ***Neogloboquadrina mayeri continuosa*** **(Blow)**, 220 μm (Image 15365)
9) ***Neogloboquadrina mayeri continuosa*** **(Blow)**, 195 μm (Image 15363)

10) ***Neogloboquadrina mayeri mayeri?*** **(Cushman)**, 215 μm (Image 15364)
11) ***Neogloboquadrina mayeri mayeri?*** **(Cushman)**, 210 μm (Image 15356)
12) ***Neogloboquadrina mayeri mayeri*** **(Cushman)**, 210 μm (Image 15369)

13) ***Neogloboquadrina mayeri mayeri*** **(Cushman)**, 235 μm (Image 15366)
14) ***Neogloboquadrina mayeri mayeri*** **(Cushman)**, 235 μm (Image 15368)
15) ***Neogloboquadrina mayeri mayeri*** **(Cushman)**, 220 μm (Image 15367)



Faunal composition (332.98 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 359 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.35 – DSDP Site 593 (332.98 mbsf)

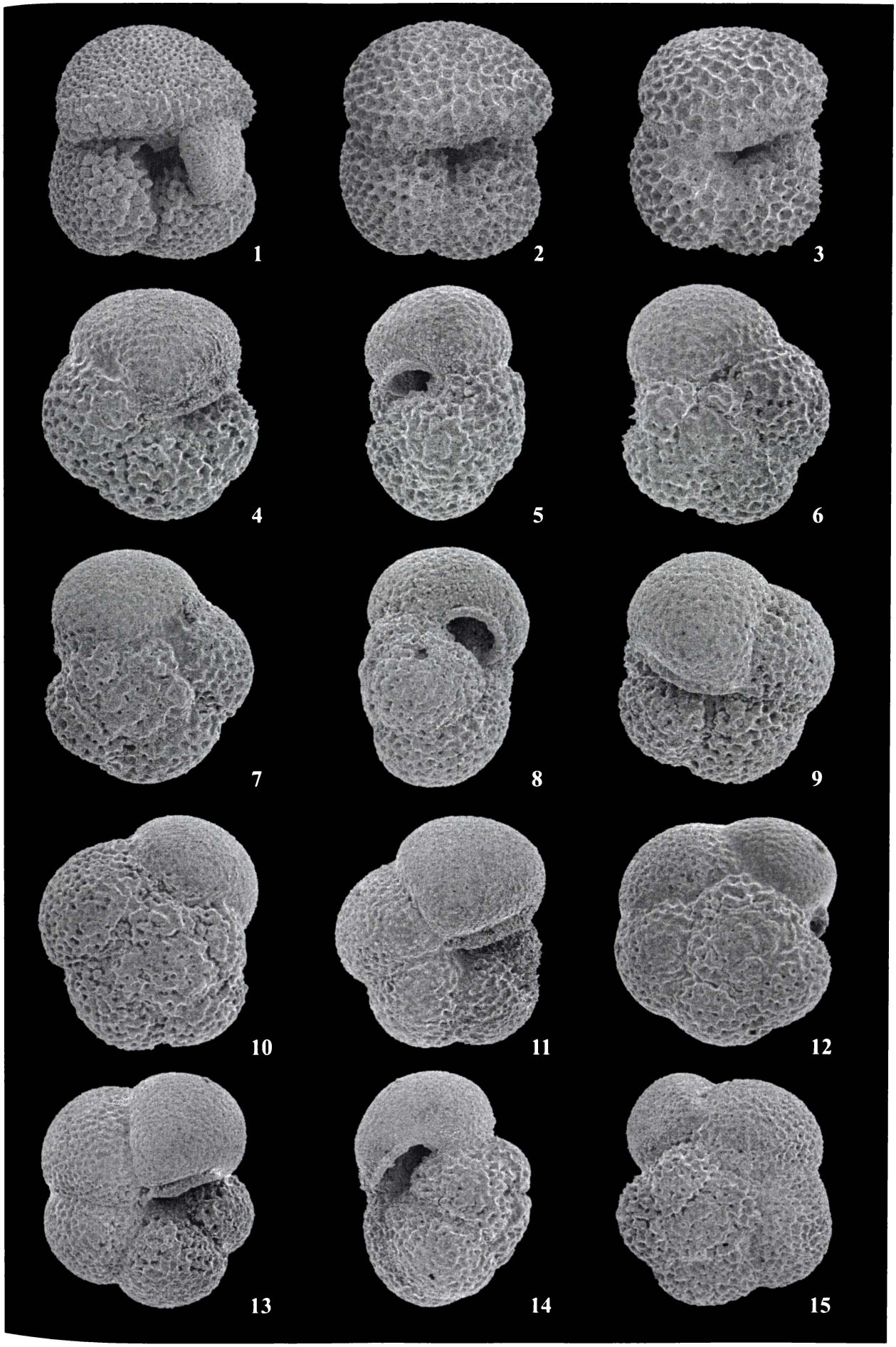


Plate 1.36

Upper Waiauan (middle Miocene) plánktic foraminifers

DSDP Site 593-36X-1, 148-150 cm (332.98 mbsf)

NB. The maximum dimension is given for each illustrated specimen, followed by its image file number. Specimens are not shown to the same scale.

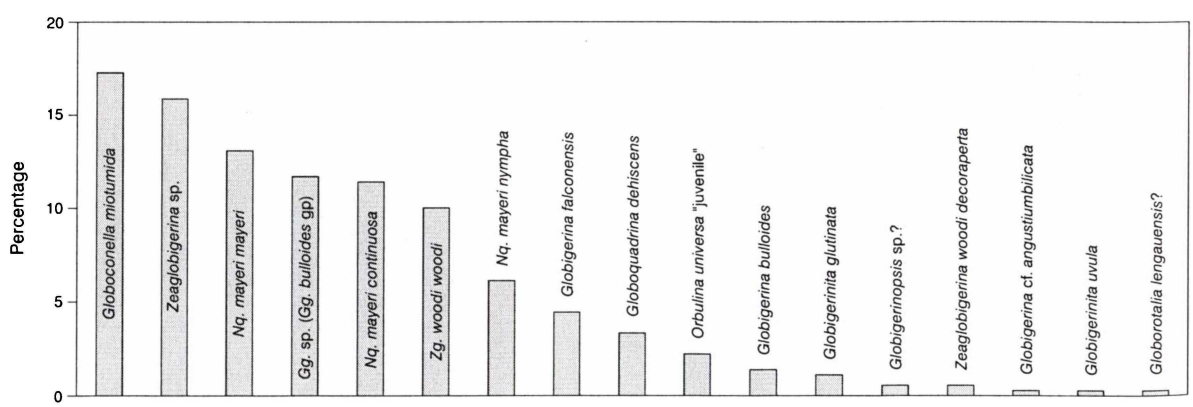
1) ***Hirsutella* cf. *scitula* (Brady)**, 240 μm (Image 15354)
2) ***Hirsutella* cf. *scitula* (Brady)**, 225 μm (Image 15355)
3) ***Hirsutella* cf. *scitula* (Brady)**, 215 μm (Image 15353)

4) ***Globoconella miotumida* (Jenkins)**, biconvex, 545 μm (Image 15336)
5) ***Globoconella miotumida* (Jenkins)**, biconvex, 530 μm (Image 15338)
6) ***Globoconella miotumida* (Jenkins)**, biconvex, 465 μm (Image 15337)

7) ***Globoconella miotumida* (Jenkins)**, 405 μm (Image 15340)
8) ***Globoconella miotumida* (Jenkins)**, 405 μm (Image 15342)
9) ***Globoconella miotumida* (Jenkins)**, 365 μm (Image 15341)

10) ***Globoconella miotumida* (Jenkins)**, biconvex, 420 μm (Image 15343)
11) ***Globoconella miotumida* (Jenkins)**, biconvex, 430 μm (Image 15345)
12) ***Globoconella miotumida* (Jenkins)**, 435 μm (Image 15344)

13) ***Globoconella explicationis* (Jenkins)**, 570 μm (Image 15346)
14) ***Globoconella explicationis* (Jenkins)**, 4-chambered, 410 μm (Image 15348)
15) ***Globoconella explicationis* (Jenkins)**, 625 μm (Image 15347)



Faunal composition (332.98 mbsf): Taxa ordered according to abundance. Percentage data, based on a pick of 359 whole or nearly whole specimens in an unbiased aliquot (>150 μm size fraction).

Plate 1.36 – DSDP Site 593 (332.98 mbsf)

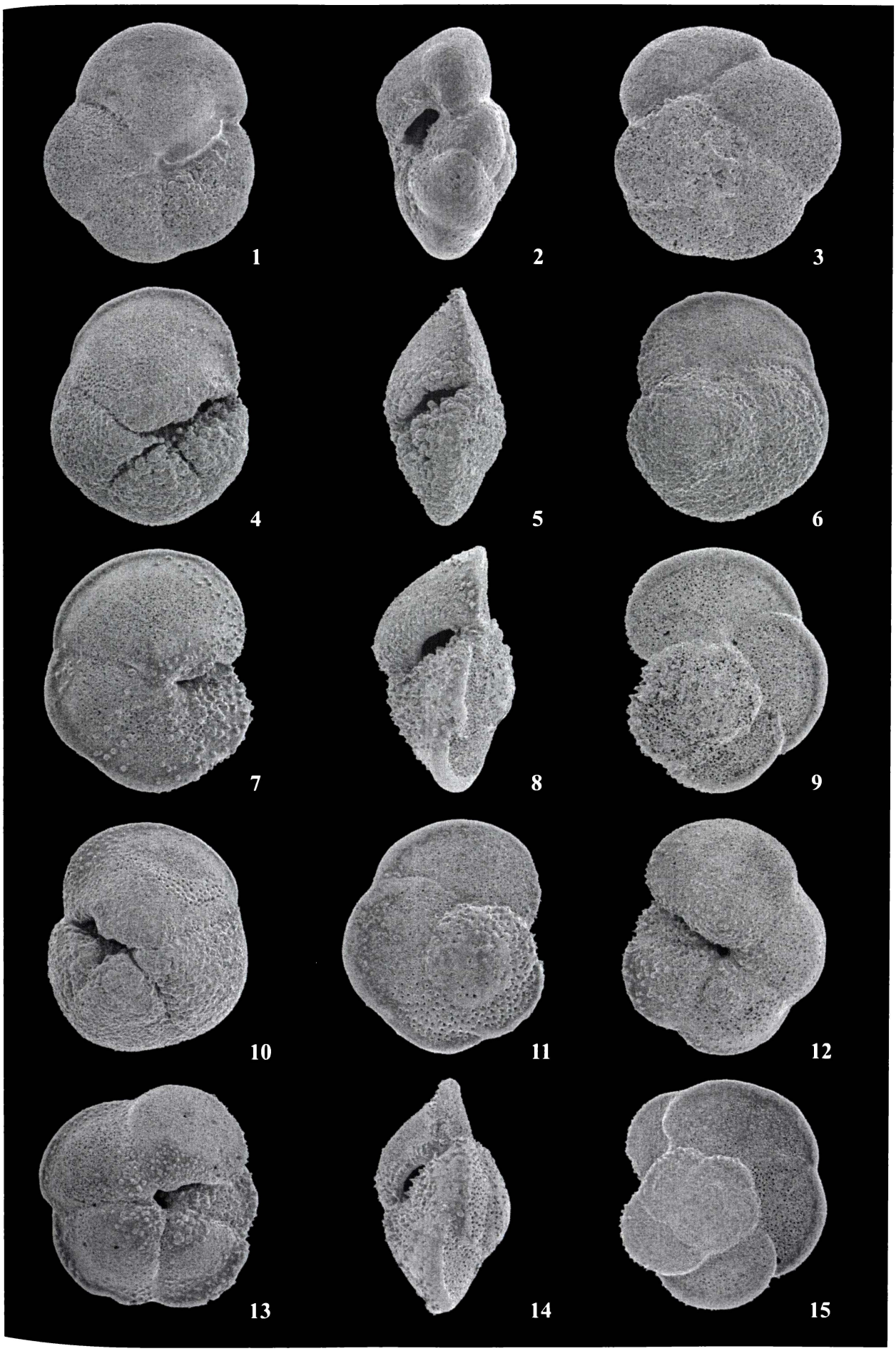


Plate 1.37

Miscellaneous Late Miocene planktic foraminifers

DSDP Site 593, various horizons

NB. The maximum dimension is given for each illustrated specimen, based on the orientation shown. This is followed by its age, stratigraphic horizon, and image file number. Specimens are not shown to the same scale.

1) ***Globigerinella aequilateralis* (Brady)**, 250 μm, (lWo) 123.10 mbsf, (Image 16257)
2) ***Globigerinoides obliquus* Bolli**, 255 μm, (lWo) 121.49 mbsf, (Image 16240)
3) ***Globigerinoides obliquus* Bolli**, 275 μm, (lWo) 121.49 mbsf, (Image 16238)

4) ***Zeaglobigerina* sp.**, 275 μm, (uTt) 226.53 mbsf, (Image 16378)
5) ***Sphaeroidinellopsis paenedehiscens* Blow**, 270 μm, (uTt) 258.54 mbsf, (Image 16380)
6) ***Sphaeroidinellopsis seminulina* (Schwager)**, 290 μm, (lTk) 155.10 mbsf, (Image 16207)

7) ***Globorotaloides hexagonus* (Natland)**, 230 μm, (lTt) 306.86 mbsf, (Image 15386)
8) ***Globorotaloides hexagonus* (Natland)**, 250 μm, (lTt) 306.86 mbsf, (Image 15387)
9) ***Globorotaloides hexagonus* (Natland)**, 310 μm, (lTt) 306.86 mbsf, (Image 15383)

10) ***Globorotaloides hexagonus* (Natland)**, 310 μm, (lTt) 306.86 mbsf, (Image 15385)
11) ***Zeaglobigerina woodi woodi* (Jenkins)**, cf. *Gs. bollii*, 280 μm, (lTt) 290.12 mbsf, (Image 16825)
12) ***Zeaglobigerina woodi woodi* (Jenkins)**, cf. *Gs. bollii*, 255 μm, (lTt) 290.12 mbsf, (Image 15238)

13) ***Globorotalia lenguaensis* Bolli**, 200 μm, (lTk) 157.12 mbsf (Image 16397)
14) ***Globorotalia lenguaensis* Bolli**, 220 μm, (lTt) 271.15 mbsf, (Image 16276)
15) ***Globorotalia lenguaensis* Bolli**, 215 μm, (lTt) 284.55 mbsf, (Image 16275)

Plate 1.37 – DSDP Site 593 (miscellaneous planktics)

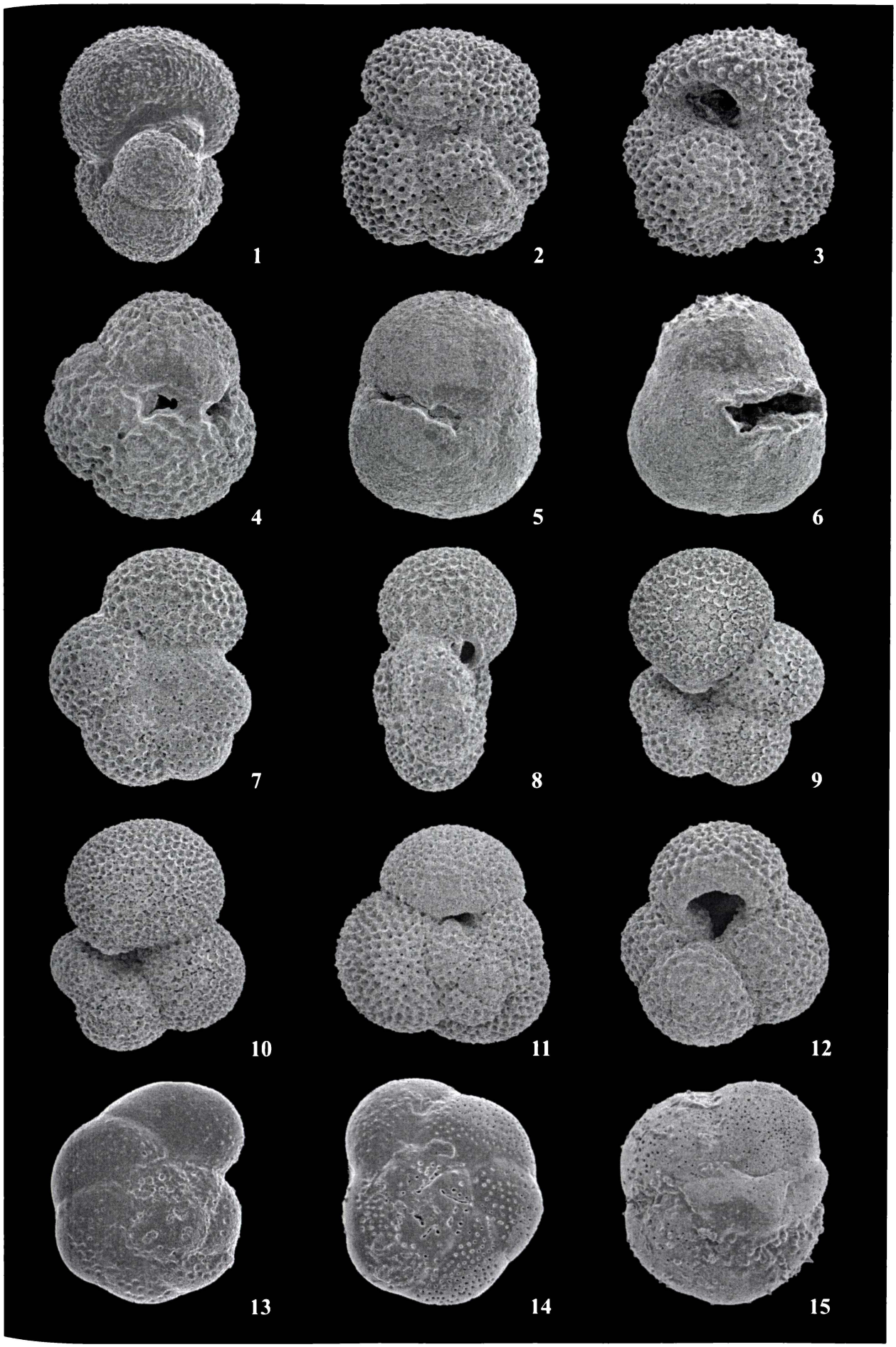


Plate 1.38

Miscellaneous Late Miocene planktic foraminifers

DSDP Site 593, various horizons

NB. The maximum dimension is given for each illustrated specimen, based on the orientation shown. This is followed by its age, stratigraphic horizon, and image file number. Specimens are not shown to the same scale.

1) ***Hirsutella* cf. *scitula* (Brady)**, 195 μm, (lTt) 260.54 mbsf, (Image 16151)
2) ***Hirsutella* sp.**, 200 μm, (uTt) 233.67 mbsf, (Image 16226)
3) ***Hirsutella* sp.**, 210 μm, (uTt) 233.67 mbsf, (Image 16224)

4) ***Hirsutella scitula* (Brady)**, spiroconical, 300 μm, (lTt) 270.72 mbsf, (Image 16176)
5) ***Hirsutella scitula* (Brady)**, spiroconical, 335 μm, (lTt) 270.72 mbsf, (Image 16178)
6) ***Hirsutella scitula* (Brady)**, spiroconical, 315 μm, (lTt) 270.72 mbsf, (Image 16175)

7) ***Hirsutella* cf. *ichinosekiensis* (Takayanagi and Oda)**, 345 μm, (lTt) 270.72 mbsf (Image 16179)
8) ***Hirsutella scitula* (Brady)**, spiroconical, 320 μm, (lTt) 270.72 mbsf, (Image 16180)
9) ***Hirsutella scitula* (Brady)**, spiroconical, 325 μm, (lTt) 270.72 mbsf, (Image 16182)

10) ***Hirsutella margaritae* (Bolli and Bermudez)**, 300 μm, (lWo) 121.26 mbsf, (Image 16338)
11) ***Menardella* cf. *limbata* (Fornesini)**, 500 μm, (uTt) 212.32 mbsf, (Image 16356)
12) ***Menardella* cf. *limbata* (Fornesini)**, 250 μm, (lTt) 296.50 mbsf, (Image 16209)

13) ***Menardella* cf. *limbata* (Fornesini)**, 435 μm, (uTt) 212.32 mbsf, (Image 16357)
14) ***Truncorotalia* sp.**, 255 μm, (uTk) 130.29 mbsf, (Image 16242)
15) ***Truncorotalia* aff. *crassaconica* (Hornibrook)**, 250 μm, (lWo) 125.30 mbsf, (Image 16289)

Plate 1.38 – DSDP Site 593 (miscellaneous planktics)

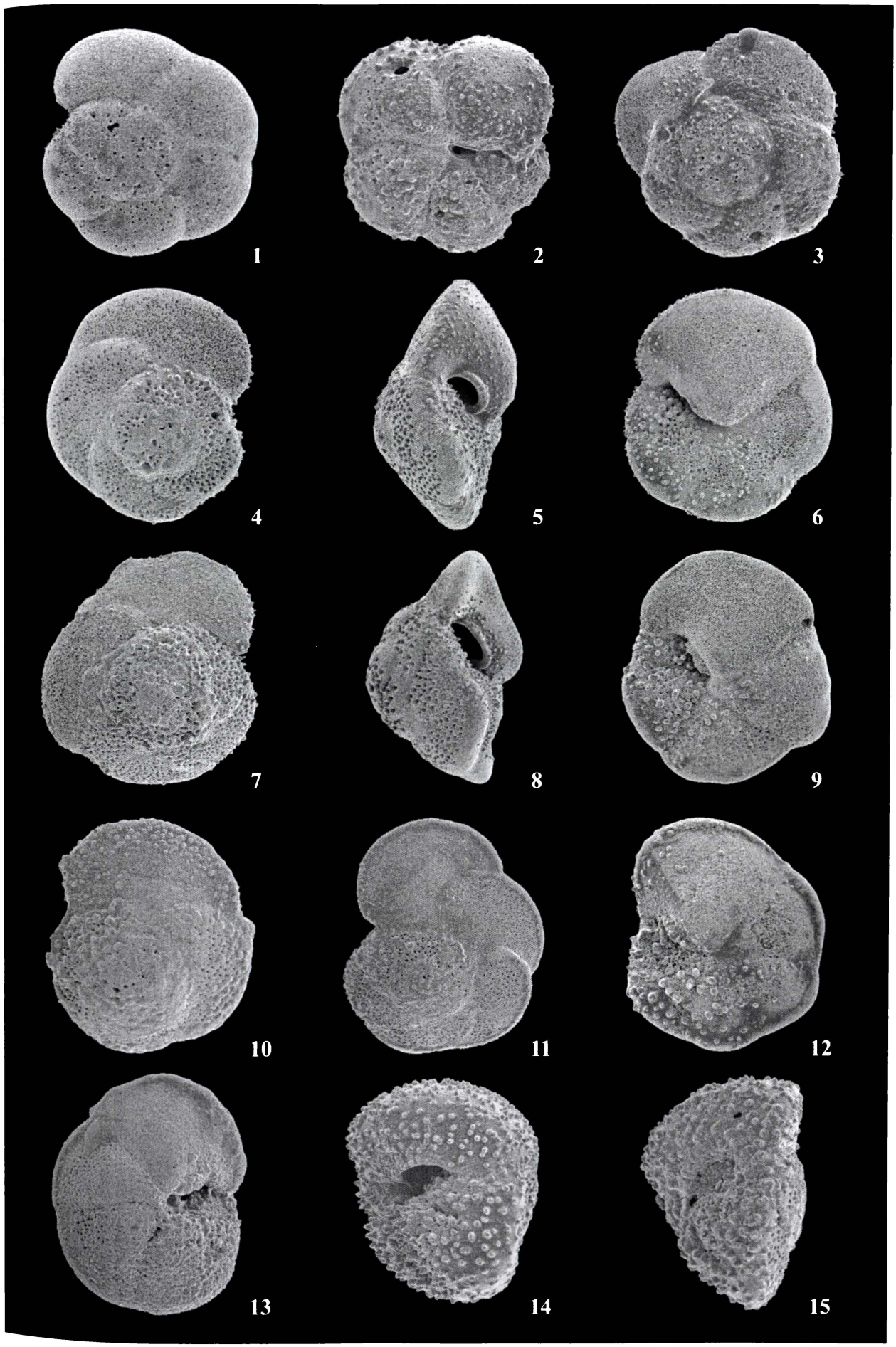


Plate 1.39

Miscellaneous Late Miocene planktic foraminifers

DSDP Site 593, various horizons

NB. The maximum dimension is given for each illustrated specimen, based on the orientation shown. This is followed by its age, stratigraphic horizon, and image file number. Specimens are not shown to the same scale.

1) ***Truncorotalia* aff. *crassaconica* (Hornibrook)**, 340 µm, (lWo) 122.26 mbsf, (Image 16373)
2) ***Truncorotalia* aff. *crassaconica* (Hornibrook)**, 290 µm, (lWo) 122.26 mbsf, (Image 16367)
3) ***Truncorotalia* aff. *crassaconica* (Hornibrook)**, 310 µm, (lWo) 122.26 mbsf, (Image 16374)

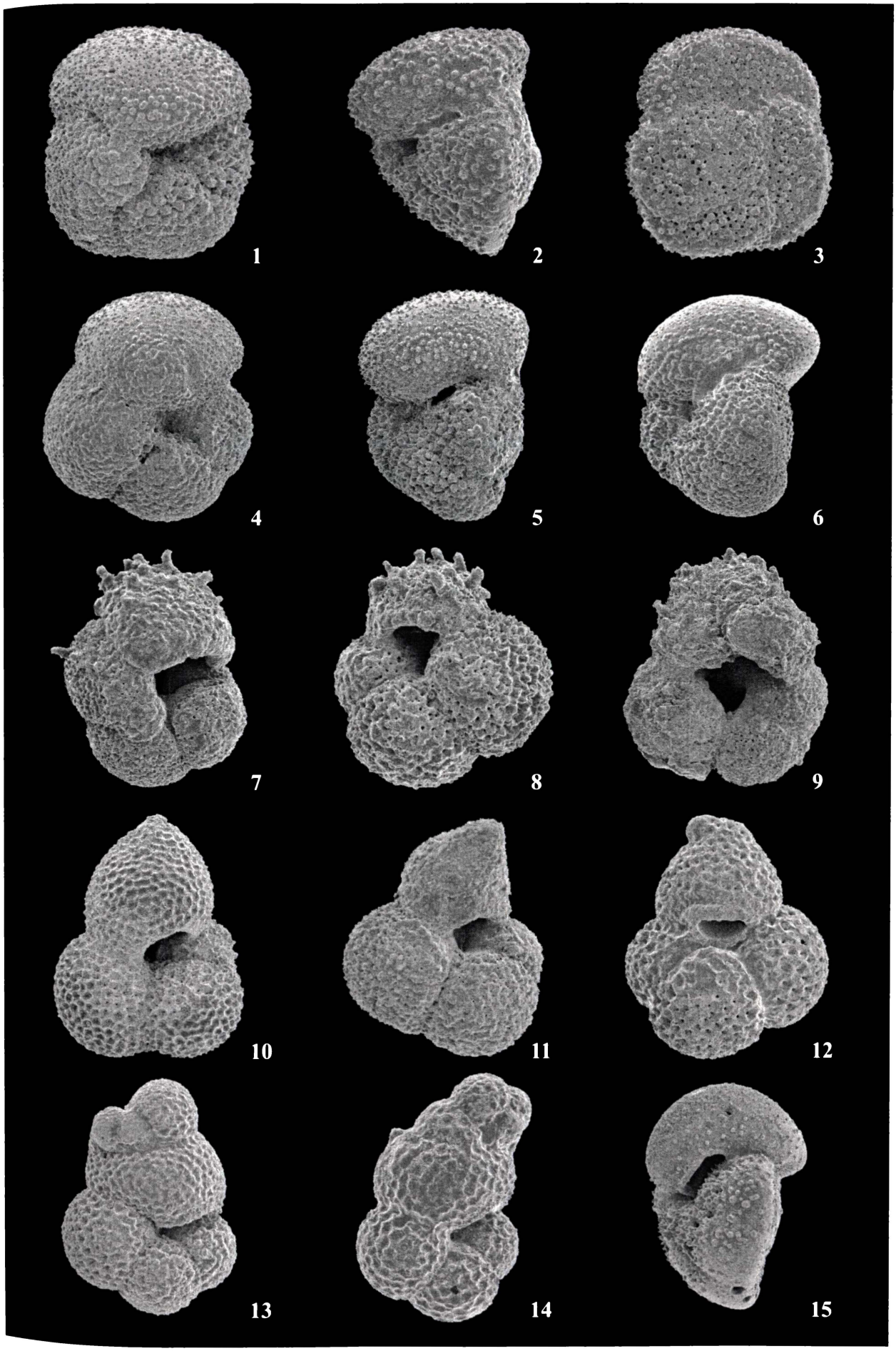
4) ***Truncorotalia crassaformis* (Galloway and Wissler)**, 375 µm, (lWo) 122.09 mbsf, (Image 16363)
5) ***Truncorotalia crassaformis* (Galloway and Wissler)**, 310 µm, (lWo) 122.09 mbsf, (Image 16364)
6) ***Truncorotalia crassaformis* (Galloway and Wissler)**, 325 µm, (lWo) 122.09 mbsf, (Image 16365)

7) ***Zeaglobigerina* sp.**, aberrant, 395 µm, 238.93 mbsf, uTt (Image 16188)
8) ***Zeaglobigerina* sp.**, aberrant, 195 µm, 296.50 mbsf, lTt (Image 16212)
9) ***Zeaglobigerina* sp.**, aberrant, 335 µm, 305.15 mbsf, lTt (Image 15466)

10) ***Globigerinoides sacculifer* (Brady)**, 235 µm, (uTt) 170.73 mbsf, (Image 16152)
11) ***Globigerina* sp.**, aberrant, 230 µm, (lTt) 255.91 mbsf, (Image 16193)
12) ***Zeaglobigerina nepenthes* (Brady)**, 195 µm, (lTt) 314.45 mbsf, (Image 16392)

13) ***Neogloboquadrina mayeri continuosa* (Blow)**, aberrant, 235 µm, (lTt) 290.51 mbsf, (Image 16195)
14) ***Neogloboquadrina pachyderma* (Ehrenberg)**, aberrant 215 µm, (lTk) 157.12 mbsf, (Image 16396)
15) ***Truncorotalia praecrassaformis* n. sp.**, aberrant, 285 µm, (uTt) 230.90 mbsf, (Image 15454)

Plate 1.39 – DSDP Site 593 (miscellaneous planktics)



Study 2

Important late Miocene planktic foraminiferal bioevents: DSDP Site 593, temperate Southwest Pacific (southern Tasman Sea)

Important late Miocene planktic foraminiferal bioevents: DSDP Site 593, temperate Southwest Pacific (southern Tasman Sea)

ABSTRACT: A high-resolution study of late Miocene (upper Waiauan to lower Opoitian) planktic foraminifers at DSDP Site 593, southern Tasman Sea, identifies at least 37 significant bioevents that are potentially useful for biostratigraphic correlation within the New Zealand and Tasman Sea regions. This represents a nine-fold improvement in resolution over the existing late Miocene land-based stage classification. Important bioevents include: narrow intervals of dextrally-coiled *Globoconella,* referred to as the *Gc*-593/A (Kaiti), *Gc*-593/B (Mapiri), *Gc*-593/C (Tukemokihi), *Gc*-593/D1, *Gc*-593/D2, and *Gc*-593/D3 (Palliser) Coiling Zones; intervals of dextrally-coiled *Neogloboquadrina Nq*-593/A1, *Nq*-593/A2 (Glomar), and *Nq*-593/B (Challenger) Coiling Zones; acme zones associated with *Truncorotalia juanai* and *Hirsutella panda*; biogeographically controlled disappearances, HCO *Neogloboquadrina mayeri* s.l., HO *Neogloboquadrina mayeri* s.l., LO *Neogloboquadrina pachyderma,* HO *Globoquadrina dehiscens,* and HO *Hirsutella* cf. *ichinosekiensis* (weakly keeled); and evolutionary appearances and disappearances, HO *Hirsutella panda* (strongly keeled), HO *Hirsutella* cf. *ichinosekiensis* (weakly keeled), LO *Globoconella conomiozea,* LO *Globoconella mons,* LO *Truncorotalia neojuanai* n. sp., LO *Globoconella sphericomiozea,* LO *Truncorotalia* aff. *crassaconica,* LO *Globoconella pliozea,* HO *Globoconella sphericomiozea,* LO *Globoconella puncticulata,* and LO *Truncorotalia crassaformis.*

These biostratigraphic events occur within the context of a staged withdrawal of warm-water taxa from the southern Tasman Sea – notably the disappearance of *Neogloboquadrina mayeri* s.l. in the early late Miocene (lowermost Tongaporutuan) and the disappearance of *Globoquadrina dehiscens* in the early late Miocene (Tongaporutuan). The appearance for the first time of hirsutellid populations with significant contributions of sinistrally-coiled shells in the middle late Miocene (upper Tongaporutuan) marks another important biological threshold and an extended period of evolutionary stasis. This ends with the disappearance of sinistrally-coiled hirsutellid populations in the latest Miocene (Kapitean) and the onset of major morphotypic expansions and evolutionary radiations in the clades *Globoconella* and *Truncorotalia.*

The greatest density of bioevents occurs in the early late Miocene (lower Tongaporutuan) and in the vicinity of the Miocene-Pliocene boundary (upper Kapitean). The intervening middle late Miocene (upper Tongaporutuan and lower Kapitean) interval has very few well defined events, and faunal variation is largely restricted to fluctuations in the relative proportions of common taxa and coiling reversals in *Hirsutella scitula*. These events offer little scope for significant biostratigraphic refinement and there is need to research other microfossil groups that might help resolve this interval.

Keywords: planktic foraminifers; biostratigraphy; late Miocene; DSDP Site 593; southern Tasman Sea region; cool subtropical (temperate) zonation.

INTRODUCTION

Despite the availability of modern high-resolution stratigraphic tools and our ability to calibrate and orbitally-tune sedimentary sequences, unique biostratigraphic events are still needed to tie regional sequences to global chronological time scales. To this end there is an ever-increasing demand for faunal events that refine regional correlations and improve temporal resolution. This is especially the case in late Miocene sequences prior to the Mediterranean salinity crisis, when global oceanic conditions appear to have been relatively stable and there is a paucity of events suitable for biostratigraphic correlation. Consequently, biostratigraphic units within the late Miocene typically have rather long durations (Figure 2.1): Tortonian Stage c. 4.1 m.y., tropical planktic foraminiferal Zone M13a c. 2.6 m.y., and transitional planktic foraminiferal Zone Mt9 c. 4.3 m.y. (Berggren et al. 1995). Similarly, in New Zealand the local late Miocene Tongaporutuan Stage occupies 4.7 m.y. (Morgans et al. 1996). These data highlight the need to examine the New Zealand late Miocene for events that will improve biostratigraphic correlation and temporal resolution, and probe the enigma of the relatively stable oceanic conditions and evolutionary stasis that appear to be associated with this period.

The classification of New Zealand late Miocene stages was originally based on an eclectic selection of molluscan and foraminiferal criteria (Finlay & Marwick 1940, 1947). In this sense the stages were suitable for uplifted marine sequences in onland New Zealand, and were only partially applicable to oceanic sequences deposited in deep water. Planktic foraminiferal studies of cored oceanic sequences at Deep Sea Drilling Project (DSDP) Site 284 (Jenkins 1975; Hornibrook 1982) and Site 593 (Jenkins & Srinivasan 1986; Hoskins

1990; Scott 1992) have extended the application of land-based stages, to offshore sequences. As a consequence, most late Miocene stage boundaries can now be related to planktic foraminiferal events distributed in latitudinally extensive water masses. These events allow the New Zealand stage classification to be used throughout the cool subtropical (temperate) Southwest Pacific region and they provide a robust low-resolution framework for regional syntheses.

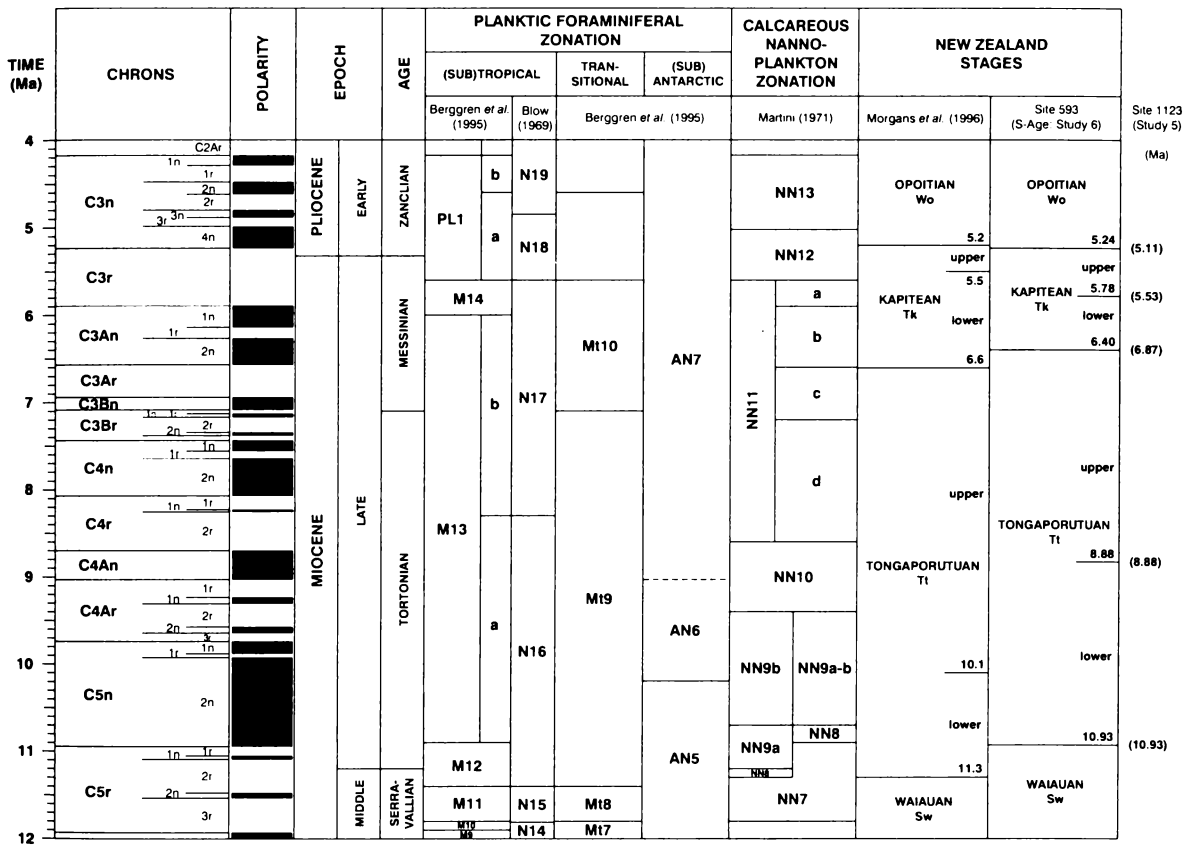


Figure 2.1 – Correlation of late Miocene planktic zonations from tropical-subtropical, temperate, and antarctic-subantarctic regions. New Zealand stages are reliably correlated, except for the Tongaporutuan-Kapitean boundary, using the magnetostratigraphically constrained chronology from Site 1123 (Study 5) and the S-Age model from Site 593 (Study 6).

Scope and material

This study documents in detail important late Miocene planktic foraminiferal events at Site 593 in the southern Tasman Sea that offer potential for improving biostratigraphic correlation and temporal resolution in the New Zealand region. It focuses on the uppermost Waiauan to lower Opoitian interval that extends from the base of core 593-36X (336.60 mbsf, metres below seafloor) to the top of 593-14X (120.30 mbsf), approximately 11.7-5.1 Ma. A total of 931 samples were examined from this interval at an average stratigraphic

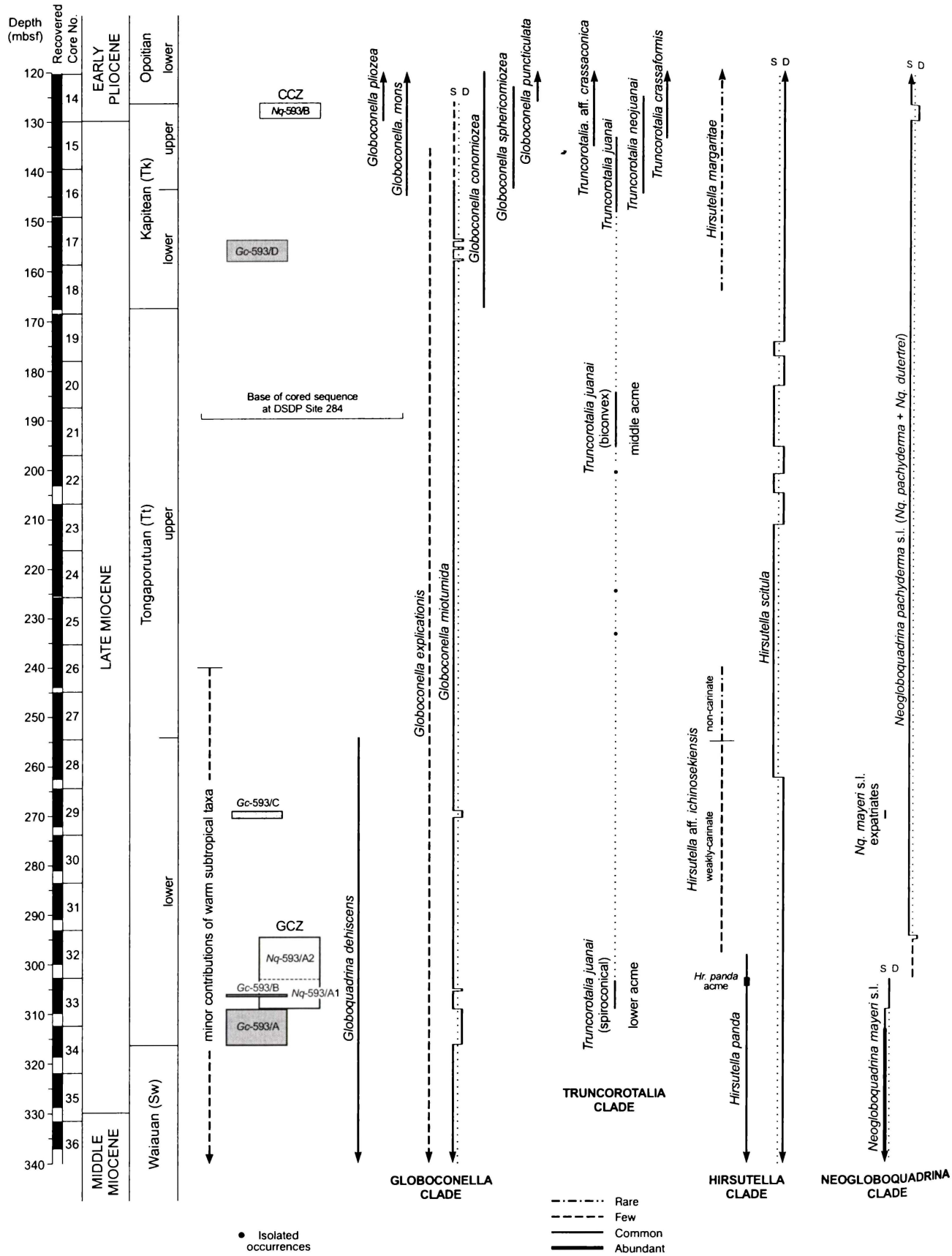


Figure 2.2 – Distribution of important late Miocene species associated with the clades *Globoconella* (*Gc.*), *Truncorotalia* (*Tr.*), *Hirsutella* (*Hr.*), and *Neogloboquadrina* (*Nq.*), intervals of dextrally-coiled *Globoconella* (*Gc*-593/A–D) and *Neogloboquadrina* (*Nq*-593/A–B), and *Globoquadrina dehiscens*. S = sinistral, D = dextral; GCZ = Glomar Coiling Zone (*Nq*-593/A1 and *Nq*-593/A2), CCZ = Challenger Coiling Zone (*Nq*-593/B). Minor contributions of warm subtropical taxa are a distinctive feature of early late Miocene assemblages, but they largely disappear from upper Miocene assemblages in the lowermost upper Tongaporutuan.

spacing of 20 cm (c. 7 k.y.). This represents a major improvement in resolution over previous biostratigraphic studies at the site which have been at reconnaissance level only (Jenkins & Srinivasan 1986; Hoskins 1990; Scott 1992). Procedures for the preparation of samples and the compilation of census and coiling data that underpin the adopted species distributions are outlined in Study 1 – the relevant census and coiling data are given in Data appendices 1.2-1.4. The positions of important biostratigraphic events were verified with supplementary scans of at least 5000 specimens in the >150 μm fraction of each sample. A summary of these events is shown in Figure 2.2 and reliability criteria are given in Appendix 2.1. Lowest and highest occurrences (LOs and HOs) are adopted in preference to first and last occurrences (FOs and LOs), as the former terms have an implicit stratigraphic meaning, and the latter have both a stratigraphic and time context. The phylogenetic classification that is employed here is based on Kennett & Srinivasan (1983), Cifelli & Scott (1986), and Scott et al. (1990). Details of the classification are outlined in Study 1 and abbreviations that are commonly used in the classification are listed in Table 2.1.

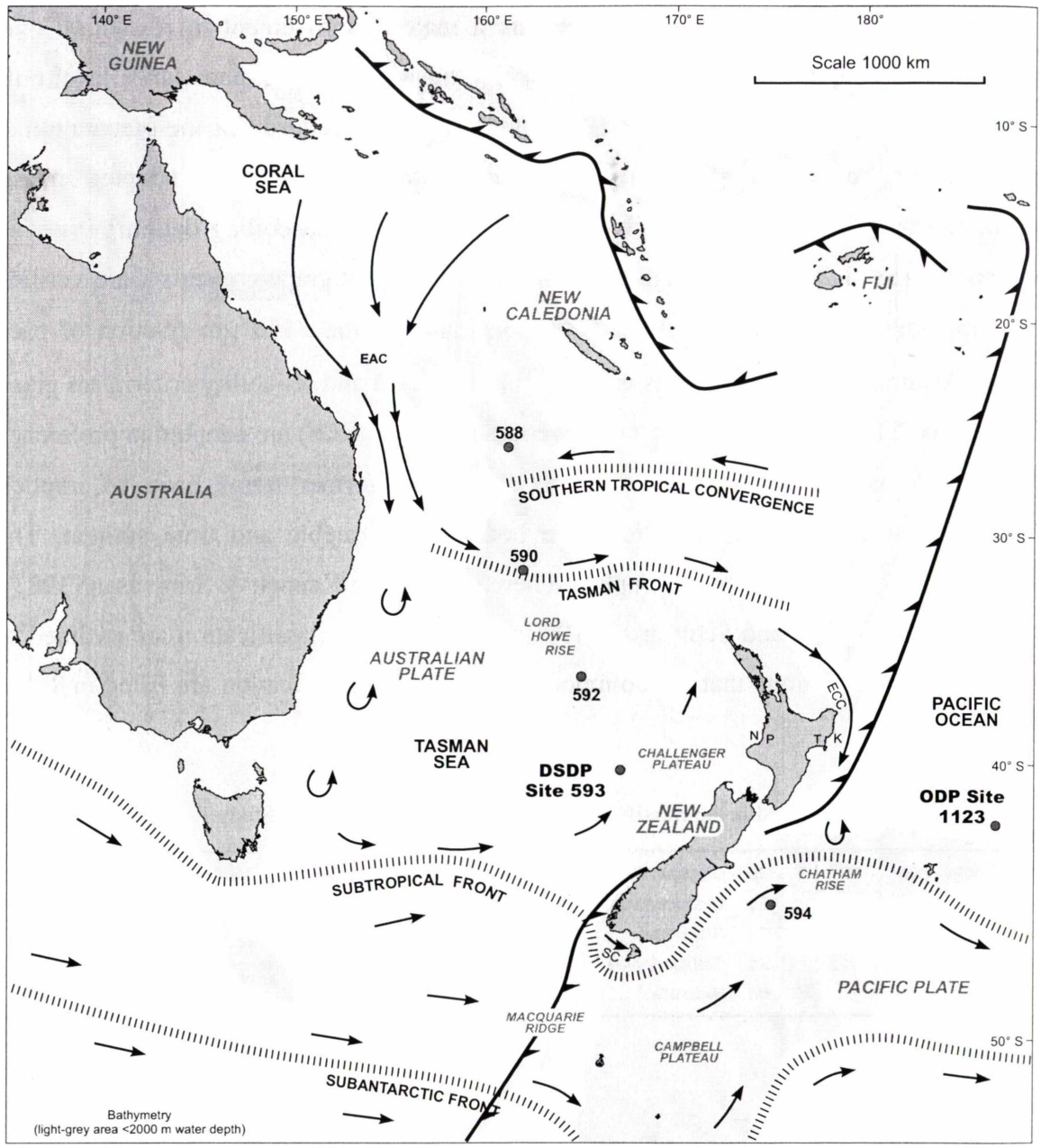
Table 2.1 – Abbreviations used in the classification of planktic foraminifers (see Study 1).

Ga.	*Globigerinita*	*Gp.*	*Globigerinopsis*	*Mn.*	*Menardella*	*Zg.*	*Zeaglobigerina*
Gc.	*Globoconella*	*Gq.*	*Globoquadrina*	*Nq.*	*Neogloboquadrina*	s.s.	*sensu stricto*
Gd.	*Globorotaloides*	*Gr.*	*Globorotalia*	*Ob.*	*Orbulina*	s.l.	*sensu lato*
Ge.	*Globigerinella*	*Gs.*	*Globigerinoides*	*Ss.*	*Sphaeroidinellopsis*	cf.	compare with
Gg.	*Globigerina*	*Hr.*	*Hirsutella*	*Tr.*	*Truncorotalia*	aff.	affinity with

DSDP SITE 593

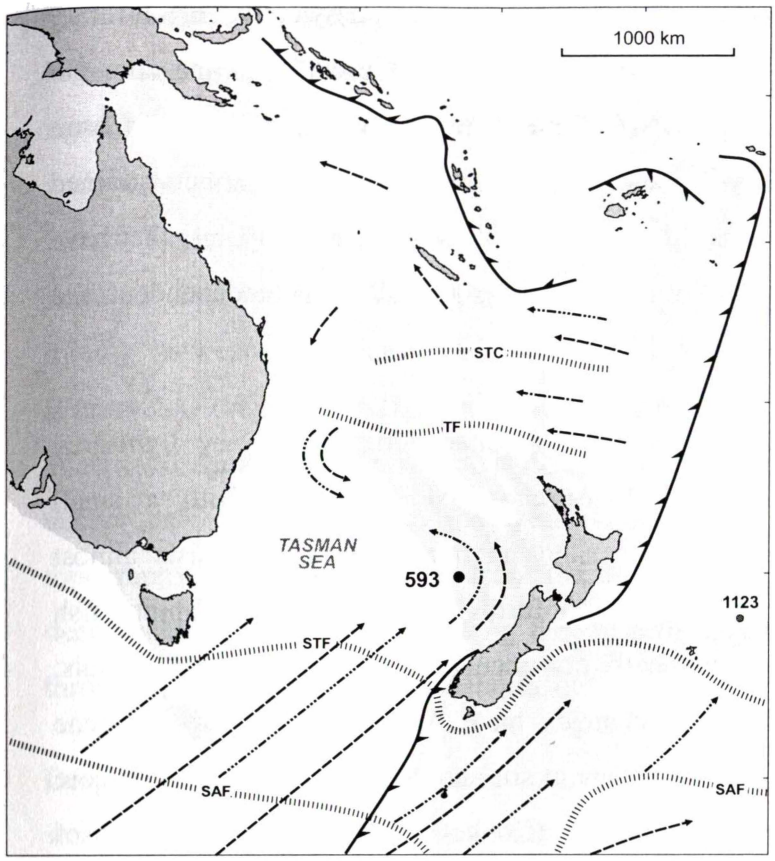
DSDP Site 593 was cored during Leg 90 of the Deep Sea Drilling Project as a reoccupation of DSDP Site 284. The site is located on the western margin of the Challenger Plateau in the southern Tasman Sea (Figure 2.3). It lies in 1068 m of water, at 40° 31' S latitude, 167° 41' E longitude, about 500 km north of the modern Subtropical Front and a 1000 km south of the Tasman Front. Since the Oligocene, thermal relaxation of the Challenger Plateau, an extension of the New Zealand continental platform on which the site sits, has allowed a relatively thick and continuous Neogene sequence to accumulate (Wood 1993). Sediment input appears to have kept pace with this subsidence and the site has remained relatively shallow (c. 1000 m) throughout the Neogene.

Employment of the newly developed hydraulic piston corer and extended core barrel systems at Site 593 greatly improved core recovery and provided a much longer and less



Modern oceanic fronts and surface water masses from Cooke (2002)	Abbreviation	Neogene biogeography Kennett & Srinivasan (1983)		Late Miocene biogeography (THIS STUDY)	Example
		Subtropical		Subtropical	Site 588
SOUTHERN TROPICAL CONVERGENCE	**- STC -**	**- STC -**	┐	**- STC -**	**- STC -**
Warm Subtropical Water	WSTW	Transitional	Cool		Site 590
TASMAN FRONT	**- TF -**	**- TF -**	subtropical	Temperate	**- TF -**
Cool Subtropical Water	CSTW	Temperate	assemblage		Sites 592, 593, 1123
SUBTROPICAL FRONT	**- STF -**	**- STF -**	┘	**- STF -**	**- STF -**
Subantarctic Surface Water	SASW				Site 594
SUBANTARCTIC FRONT	**- SAF -**	Subantarctic		Subantarctic	**- SAF -**
Circumpolar Surface Water	CSW				Site 278 (56°33.7'S; 160°04.5'E)

Figure 2.3 – Location map of Sites 593 and 1123, and important late Miocene sequences in onland New Zealand: N = North Taranaki Coast; P = Pukearuhe-1; T = Tukemokihi Stream; K = Kaiti Beach. Modern oceanic fronts and general circulation of surface water in the Tasman Sea region, after Wyrtki (1962) and Heath (1985). EAC = East Australian Current, ECC = East Cape Current, SC = Southland Current. The relationships between modern oceanic fronts and surface water masses, and biogeographic boundaries are given in the table beneath the location map.



INTERMEDIATE WATER CIRCULATION

Subantarctic Mode Water (SAMW)

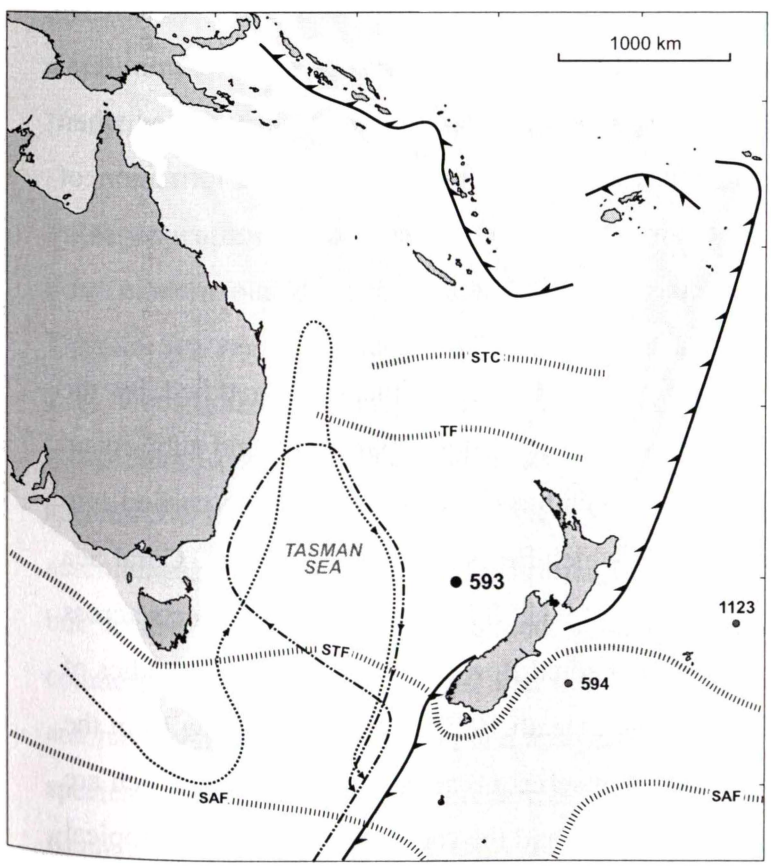
Antarctic Intermediate Water (AAIW)

STC = Subtropical Convergence
TF = Tasman Front
STF = Subtropical Front
SAF = Subantarctic Front

Water Mass	Abbrev.	Depth (m)
Circumpolar Surface Water	CSIW	0-400
Subantarctic Mode Water	SAMW	400-600
Antarctic Intermediate Water	AAIW	600-1450
Circumpolar Deep Water (upper)	u-CPDW	1450-2550
Circumpolar Deep Water (middle)	m-CPDW	2550-2900
Circumpolar Deep Water (lower)	l-CPDW	>3800
Antarctic Bottom Water	AABW	

after Shipboard Scientific Party (1999a)

Figure 2.4 – General circulation of Subantarctic Mode Water and Antarctic Intermediate Water in the Tasman Sea region, after Wyrtki (1961, 1973), Bingham & Lukas (1994), Fine et al. (1994), Tomczak and Godfrey (1994), and Hautala (1996). See Figure 2.3 for explanation of bathymetry and oceanic fronts.



DEEP WATER CIRCULATION

Cicumpolar Deep Water (CPDW)

Antarctic Bottom Water (AABW)

STC = Subtropical Convergence
TF = Tasman Front
STF = Subtropical Front
SAF = Subantarctic Front

Water Mass	Abbrev.	Depth (m)
Circumpolar Surface Water	CSIW	0-400
Subantarctic Mode Water	SAMW	400-600
Antarctic Intermediate Water	AAIW	600-1450
Circumpolar Deep Water (upper)	u-CPDW	1450-2550
Circumpolar Deep Water (middle)	m-CPDW	2550-2900
Circumpolar Deep Water (lower)	l-CPDW	>3800
Antarctic Bottom Water	AABW	

after Shipboard Scientific Party (1999a)

Figure 2.5 – General circulation of Circumpolar Deep Water and Antarctic Bottom Water in the Tasman Sea region, for an explanation of bathymetry and oceanic fronts see Figure 2.3, and for source references see Figure 2.4.

disturbed Quaternary to Oligocene section than had been recovered by conventional rotary drilling at Site 284. Although paleomagnetic studies were undertaken on the core, no tenable Miocene or early Pliocene magnetostratigraphic record was obtained below Chron C2An (Barton & Bloemendal 1986). The late Miocene chronology is largely constrained by biostratigraphy, although widely spaced strontium-87/strontium-86 tie points that have been calibrated to the global strontium reference curve provide some independent age control (Hess & Schilling 1986; Howarth & McArthur 1997).

The cored late Miocene sequence at Site 593 is characterized by very light-grey homogenous foraminifer-bearing nannofossil ooze (>90% carbonate) with a small siliciclastic clay content (Nelson 1986). The sand fraction (>63 um) consists almost entirely of foraminifera, with minor calcareous bolboforms, ostracods, echinoid spines, fish teeth, and mollusc fragments, as well as locally conspicuous pyrite and celestite crystals, and rare volcanic glass shards. Textural changes have been noted in late Miocene sediments at the site, including cyclical variations in silt and clay components, an up-core increase in sand, and significant textural shifts (Cooke 2002). The preservation of foraminifers is extremely good and carbonate dissolution proxies based on relative abundances and fragmentation ratios of planktic foraminifers (e.g. Dittert et al. 1999) suggest there was no significant post-mortem modification of assemblages caused by dissolution in any part of the studied section. However, the surfaces of some foraminiferal tests from the upper Waiauan and lower Tongaporutuan appear to be slightly etched when viewed under high magnification. This may be related to the diagenetic formation of pyrite, which is relatively common in the lower part of the studied core section.

Modern oceanography

At the present day the New Zealand subcontinent and landmass is straddled by the Subtropical Front – a major oceanic boundary that separates subantarctic and subtropical surface water masses (Figure 2.3). Most tropical/subtropical surface water is carried into the Tasman Sea by the East Australian Current which flows southwards from the Coral Sea along the eastern continental margin of Australia to 31° S latitude, where it deflects across the Tasman as the Tasman Front – a meandering zonal flow associated with large eddies of relatively warm subtropical water (Stanton 1981; Heath 1985). The residual flow from the East Australian Current continues southward as a series of slow-moving eddies, which are turned towards New Zealand by the west-wind-drift and the southern-bounding Subtropical

Front to form the westerly and north-westerly flowing Tasman Current (Heath 1985). When the Tasman Current encounters the New Zealand continental platform it splits into a northwards directed flow along the west coast of New Zealand as part of the Tasman Gyre, and the Southland Current, which flows northwards along the eastern margin of the South Island (Heath 1985). The seafloor at Site 593 is bathed by the core of southern-sourced Antarctic Intermediate Water (AAIW), close to the southern-edge of a broad zone of mixing between northwards and southwards flowing subsurface AAIW water masses (Figure 2.4) (Wyrtki 1962). Northwards directed flows of deep-water (Circumpolar Deep Water and Antarctic Bottom Water) enter the Tasman Sea region, but are restricted to the deeper part of the basin to the west of Site 593 (Figure 2.5). Because of seafloor topography they cannot escape from the northern part of the basin and return flows of deep-water travel southwards along the western edge of the Campbell Plateau and leak through the Macquarie Ridge (Osborne et al. 1983).

Despite seafloor spreading between Australia and Antarctic shifting Site 593 (and the western side of the New Zealand subcontinent and landmass) northwards, from 45° S latitude at the beginning of the late Miocene to its present-day latitude of 40° S (Weissel et al. 1977; Sutherland 1995), and there being substantial Neogene deformation of the New Zealand landmass, along the Alpine Fault (Sutherland 1995), a similar paleoceanographic regime to that of the modern setting appears to have existed at Site 593 throughout the late Neogene (Edwards 1975; Nelson & Cooke 2001).

Paleogeography and zonation

Four modern planktic foraminiferal (biogeographic) assemblages are recognized in the Tasman Sea region: subantarctic, temperate, transitional, and warm subtropical (Figure 2.3). Transitional assemblages are characterized by *Globoconella inflata,* the only species indigenous to the province, and a diverse fauna of mixed subtropical and subantarctic species (Bé 1977; Hayward 1983). Kennett & Srinivasan (1983) also recognize temperate assemblages that are similar to transitional assemblages and have common *Globoconella,* but a less diverse fauna of mixed subtropical and subantarctic species. Miocene counterparts of these assemblages that predate the appearance of the *Globoconella inflata* and have common *Globoconella* and a diverse fauna of mixed subtropical and subantarctic species are referred to here as temperate assemblages (i.e. cool subtropical assemblages of Kennett & Srinivasan 1983). This is because the distinction between temperate and

transitional assemblages is unclear in the Miocene (Jenkins 1992). The Tasman Front, which separates modern temperate and transitional assemblages, does not appear to have existed in the Miocene, at least not in its present-day form or location relative to New Zealand.

Biogeographic boundaries largely correspond to oceanic fronts that act as biological barriers to planktic organisms, at least those which live in the surface mixed-layer above the permanent thermocline (Parker & Berger 1971; Vincent & Berger 1981). The positions of these fronts are largely governed by the New Zealand subcontinent and landmass, which disrupts oceanic circulation and deflects Subantarctic Surface Water around the southern end of New Zealand and Subtropical Surface Water around the northern end of New Zealand (Figure 2.3). The fronts are not fixed, however, and their position may vary in response to seasonal and longer term changes in oceanic circulation (Wyrtki 1962; Stanton 1981). The biogeographic pattern in the vicinity of the New Zealand continental margin is also made more complicated by local currents that cause anomalous local biogeographic associations (e.g. Southland and East Cape Currents). Modern temperate faunas at Site 593 are typical of much of the southern Tasman Sea region (including New Zealand) between the Subtropical and Tasman Fronts (Figure 2.3). The development of these fronts in the Neogene has contributed significantly to the paleogeography, evolution and extinction of planktic foraminifers in the Tasman Sea region (e.g. Jenkins 1992; Nelson & Cooke 2001). The cool subtropical (temperate) zonation introduced by Kennett and Srinivasan (1983) and the transitional zonation of Berggren et al. (1995) provide useful low-resolution biostratigraphic frameworks for regional correlation and synthesis, but to date they have not been reliably correlated with the New Zealand land-based stage classification.

Previous work

The initial reports on DSDP Site 284, cored during Leg 29 of the Deep Sea Drilling Project, noted a magnificent late Neogene biostratigraphic sequence involving obvious climatic fluctuations (Kennett et al. 1975). Biostratigraphic studies of planktic foraminifers at this site (Jenkins 1975; Kennett & Vella 1975; Hornibrook 1982) contributed significantly to biostratigraphic correlation within the New Zealand region. Morphometric studies of the foraminiferal clade *Globoconella* (Malmgren & Kennett 1981, 1982; Wei 1987; Wei & Kennett 1988) also advanced understanding of the phylogeny and evolutionary radiation of this group, which is important for biostratigraphic subdivision of

late Neogene temperate sequences. Stable isotope studies at Site 284 (Shackleton & Kennett 1975; Kennett et al. 1979) provided valuable insights into paleoclimatic changes in the Neogene and their impact on the distribution of planktic foraminifers in the region.

The preliminary report on planktic foraminifers at Site 593 by Jenkins & Srinivasan (1986) noted a complete late Miocene sequence with abundant and well preserved assemblages throughout. They classified the interval into three planktic foraminiferal zones but did not relate them to New Zealand stages. Hoskins (1990) reviewed the late Neogene planktic foraminiferal biostratigraphy of Site 593 (Hole 593A) and established a correlation with Site 284 and New Zealand onland stages. Scott (1992) subsequently reviewed the Miocene (Altonian to Tongaporutuan) biostratigraphy of planktic foraminifers at Site 593 and established the first tenable correlation with New Zealand early and middle Miocene stages. Stable isotope studies on Site 593 have also examined aspects of paleoceanography (Head & Nelson 1994; Cooke 2002) and interspecies habitat differences within the clade *Globoconella* (Schneider & Kennett 1996).

BIOSTRATIGRAPHIC ERROR

Construction of a high-resolution biostratigraphic framework for late Miocene planktic foraminifers in New Zealand involves three primary sources of error – those due to sampling, those due to taxonomic uncertainty, and inherent errors associated with the nature of a bioevent. While biostratigraphers largely focus on taxonomic issues relating to the identification of events that maintain consistent stratigraphic order, they seldom give due consideration to the quality of biostratigraphic records or the biological and environmental factors that may adversely affect the reliability of biostratigraphic correlations.

Sampling error

The late Miocene section at Site 593 was cored entirely with the extended core barrel system. This provided a longer and less disturbed section than had been recovered by conventional rotary drilling at Site 284. Core recovery was very good in the upper part of the section between cores 593-14X and 593-25X, except for core 593-22X where there was gear failure and only 64% of the core was recovered (Table 2.2). The incomplete core recovery in the lower part of the sequence was largely due to core deformation and compaction during the core recovery operation and there is no evidence that section was

lost (Kennett & von der Borch 1986). Coring and logging techniques presently employed by the Ocean Drilling Program (e.g. Shipboard Scientific Party 1999) allow complete sedimentary sequences to be constructed from composite sections, where core compaction is routinely corrected, but this was not possible when Site 593 was drilled. Consequently, the section at Site 593 has core gaps where there are no data. This may adversely affect the stratigraphic spacing of some bioevents, but it does not impact on the order of bioevents.

Core no.	Type	Top (mbsf)	Bottom (mbsf)	Length cored (m)	Length recovered (m)	Percentage recoved
14X	X	120.3	129.9	9.6	9.45	98
15X	X	129.9	139.5	9.6	9.41	98
16X	X	139.5	149.1	9.6	9.38	98
17X	X	149.1	158.7	9.6	9.51	99
18X	X	158.7	168.3	9.6	8.93	93
19X	X	168.3	177.9	9.6	9.67	101
20X	X	177.9	187.5	9.6	9.52	99
21X	X	187.5	197.1	9.6	9.70	101
22X	X	197.1	206.7	9.6	6.13	64
23X	X	206.7	216.3	9.6	9.61	100
24X	X	216.3	225.9	9.6	9.18	96
25X	X	225.9	235.5	9.6	9.54	99
26X	X	235.5	245.1	9.6	8.48	88
27X	X	245.1	254.7	9.6	9.69	101
28X	X	254.7	264.3	9.6	7.87	82
29X	X	264.3	273.9	9.6	7.88	82
30X	X	273.9	283.5	9.6	7.12	74
31X	X	283.5	293.1	9.6	7.45	78
32X	X	293.1	302.7	9.6	6.8	71
33X	X	302.7	312.3	9.6	7.08	74
34X	X	312.3	321.9	9.6	6.36	66
35X	X	321.9	331.5	9.6	6.92	72
36X	X	331.5	341.1	9.6	5.53	58

Table 2.2 – Coring summary, DSDP Site 593. Equipment failure during the recovery of core 593-22X resulted in the loss of some section, but there is no other evidence for section being lost. The lower core recovery below 593-27X is largely due to core compaction during the drilling and core recovery operation (Kennett & von der Borch 1986).

Bioevent classification

On the basis of phylogenetic relationships (Kennett & Srinivasan 1983) and species distributions observed at Site 593, three main categories of planktic bioevents are recognized – evolutionary, biogeographic, and opportunistic. All have features which affect the reliability of biostratigraphic correlations and the construction of a high-resolution biostratigraphic framework.

Evolutionary events (EV): The classification of evolutionary events includes those where there is an observed morphological transformation linking one species with another. This may take the form of a bioseries where the morphological transformation is unidirectional or an evolutionary radiation where there are divergent morphological trends. While evolutionary events relating to a particular lineage are unique in stratigraphic space, it is often difficult to locate species appearances and disappearances in gradually evolving populations without detailed morphometric study. This is generally not a problem in biostratigraphic studies except where a high-level of precision is required, as for example where there is a need to calibrate and orbitally-tune sedimentological and isotopic data.

Biogeographic events (BG): The classification of biogeographic events includes those that are related to advances and retreats, or expansions and contractions, in species biogeographic ranges. By their very nature they are inherently diachronous, but not necessarily so within the region where they occur. At a single locality such as Site 593, biogeographic events are sometimes characterized by abrupt species appearances with no prior evolutionary sequence, and abrupt disappearances (extinctions). They are not necessarily unique either, as demonstrated by the repeated appearances and disappearances of some taxa, coiling reversals, abundance changes, and expatriate occurrences. While these attributes place a cautionary caveat on the use of some biogeographic events, they often occur in very distinctive closely spaced stratigraphic clusters and individual events can still be used reliably within the context of a robust biostratigraphic framework.

Opportunistic events (OP): Opportunist events are similar to some biogeographic events, although they primarily reflect a biological response to ecological factors such as niche availability and trophic resources. In the context of the stratigraphic record at Site 593, opportunistic events are represented by rapid expansions in the size of *in situ* populations to the point where specimen numbers markedly exceed long-term average abundances. Population increases of this type tend to be species specific and largely independent of other faunal signatures. They may also be linked to widespread changes in the water column and are potentially useful for regional correlation.

Stratigraphic position

The identification of a bioevent in stratigraphic space, and the extent to which it may be recognized consistently, are largely controlled by the abundance and distinctiveness of a species. For example, events associated with very distinctive taxa that occur in large numbers are more likely to be reliably located in sequences than those associated with taxa that are difficult to identify and occur in low numbers. The following categories 1-3 evaluate bioevents as criteria for stratigraphic boundaries:

1. Distinctive, well defined bioevents that are associated with common widely distributed taxa.
2. Well defined bioevents that are associated with small populations in pelagic sequences and may be difficult to locate reliably in facies with poor planktic representations.

3. Poorly defined bioevents that are potentially useful for correlating pelagic sequences, but may not necessarily be found in sequences with poor planktic representations.

The above criteria are used in the following discussion of important bioevents at Site 593 to provide a subjective guide as to reliability. The classification of bioevents based on these criteria is given in Appendix 2.1.

IMPORTANT BIOSTRATIGRAPHIC EVENTS

Globorotalid taxa form a very distinctive part of late Miocene planktic foraminiferal assemblages at Site 593, and they play a major role in the correlation and subdivision of the New Zealand stage classification (Kennett 1966a, b, 1967; Jenkins 1971; Hornibrook 1981, 1982; Hornibrook et al. 1989; Scott et al. 1990; Hornibrook & Jenkins 1994). This is particularly the case in the younger part of the late Miocene where there are evolutionary radiations in the temperate clades *Globoconella* and *Truncorotalia* (Kennett 1966a; Malmgren & Kennett 1981; Srinivasan & Kennett 1981; Cifelli & Scott 1986; Scott et al. 1990). The clades *Neogloboquadrina* and *Hirsutella* are also well represented throughout the late Miocene, and rare elements of the warm subtropical/tropical clades *Menardella* and *Globorotalia* occur in the Tongaporutuan. Important evolutionary events and distinctive biogeographic and opportunistic events that are associated with these clades and the genus *Globoquadrina* are examined in the following section.

As this study focuses on bioevents in the New Zealand region, the adopted taxonomic concepts and biostratigraphic definitions are largely based on studies from the cool subtropical (temperate) Southwest Pacific region, which differ from the criteria used by workers in the northern hemisphere (Scott 1980; Cifelli & Scott 1986). To facilitate local biostratigraphic correlation, changes to the classification of some species and the definitions of some bioevents are also introduced here based on the observed stratigraphic and morphological relationships of species at Site 593.

GLOBOCONELLA

The temperate clade *Globoconella* (Kennett & Srinivasan 1983) (Figures 2.6, 2.7, and 2.9) comprises a very important and sometimes dominant part of late Miocene assemblages at Site 593. A key feature of the clade is the *Gc. miotumida* bioseries, which involves a gradual morphological transformation from strongly keeled five-chambered forms to non-

carinate four-chambered forms. The successive appearances of species in the bioseries – *Gc. conomiozea* (base Kapitean), *Gc. sphericomiozea* (base upper Kapitean), and *Gc. puncticulata* (base Opoitian) – form an integral part of the New Zealand late Miocene stage classification (Kennett 1966a, 1967; Jenkins 1971; Hornibrook 1981, 1982; Hornibrook et al. 1989; Scott et al. 1990; Hornibrook & Jenkins 1994). A small divergent group of globoconellid species including *Gc. mons* and *Gc. pliozea,* evolves from the *Gc. miotumida* bioseries in the Kapitean (Hornibrook 1982; Scott et al. 1990). Most species within the clade are thick-walled and resistant to carbonate dissolution. This makes them particularly important for dating and correlating deep-water sequences that have been affected by carbonate dissolution.

Morphometric studies of the *Gc. miotumida* bioseries (Malmgren & Kennett 1981, 1982; Wei 1987; Wei & Kennett 1988) offer the potential for significant improvements in biostratigraphic resolution, although there is no consensus concerning the definitions and content of species. As a consequence, the criteria that are employed here to define species content are based on distinctive morphological features that can be identified consistently by a skilled operator with a stereomicroscope. Criteria used for the identification of species are discussed in Study 1.

***Globoconella miotumida* bioseries**

The early part of the bioseries is represented by *Gc. miotumida*, a species that embodies a wide range of morphotypic variation centred on strongly keeled, biconvex to ventroconical forms with a high-arched aperture and four and one-half to five chambers in the outer whorl. The most significant variation occurs in the shape of the axial profile. In order of decreasing relative abundance the various forms include: biconvex forms with moderate ventral extension and weakly inflated chamber walls (Figures 2.6A and C), ventroconical forms with relatively flat spiral sides (Figures 2.7E, 2.9C and D), ventroconical forms with gently domed spiral sides and weakly inflated chambers (Figure 2.7D upper), and compressed biconvex forms (Figure 2.7D lower). There appears to be no systematic change in the relative abundances of various morphotypes in the upper Waiauan and lower Tongaporutuan.

The first pervasive morphotypic trends are noted in the uppermost Tongaporutuan, where there is a general reduction in the number of chambers in the outer whorl. This change

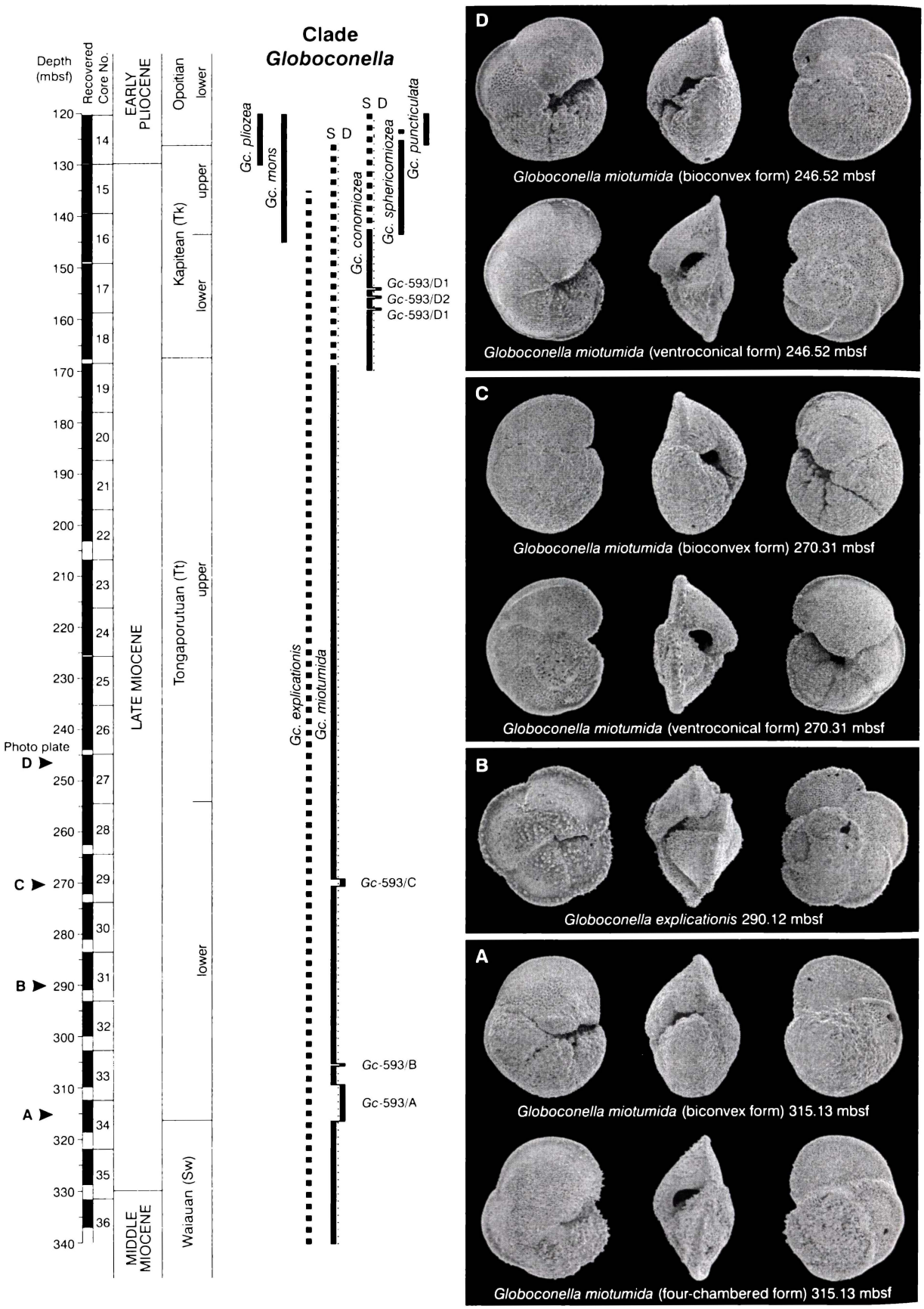


Figure 2.6 – Early late Miocene (lower Tongaporutuan) species of the planktic foraminiferal clade *Globoconella*. Includes the *Gc. miotumida* bioseries, which involves a morphological transformation from carinate forms with five chambers in the outer whorl to non-carinate four-chambered forms (*Gc. miotumida* – *Gc. conomiozea* – *Gc. sphericomiozea* – *Gc. puncticulata*). The most rapid evolutionary phase occurs in the vicinity of the Miocene-Pliocene boundary, where modern non-carinate forms first appear. *Gc*-593/A–D (intervals with sigificant contributions of dextrally-coiled *Globoconella*); S = sinistral; D = dextral. See Figure 2.10 for a more detailed history of coiling and abundance changes in the clade *Globoconella*.

coincides with a marked increase in the relative proportion of encrusted specimens. As the precise number of chambers in the outer whorl is difficult to determine accurately in heavily encrusted specimens with poor sutural definition, the biostratigraphic separation between *Gc. miotumida* s.s. and *Gc. conomiozea* s.s. is based here on lightly-crusted and crust-free specimens. On this basis, the highest occurrence of *Gc. miotumida* s.s. – the level where 90% or more of adult specimens have four and one-half or more chambers in the outer whorl – occurs in 593-18X-6, 66-68 cm (166.86 mbsf). Typical morphotypes of *Gc. miotumida* s.l. that have more than four and one-half chambers in the outer whorl are relatively common in assemblages up to 593-15X-1, 79-82 cm (130.69 mbsf), although rare morphotypes extend up to 593-14X-4, 111-114 cm (125.91 mbsf). Similar specimens that occur above the lowest occurrences of *Gc. conomiozea* s.s. and *Gc. sphericomiozea* s.s. are considered to be part of the morphological variation field associated with these species.

Globoconella explicationis has much the same stratigraphic distribution as *Gc. miotumida* and is considered to be a distinctive end-member of this species range of morphological variation.

Globoconella conomiozea: There is considerable confusion in the published records concerning the identification and nomenclatural status of *Gc. conomiozea*. For example, Kennett (1966a), Chaproniere (1973), Malmgren & Kennett (1981, 1982), and Hornibrook (1982) argue that *Gc. conomiozea* evolved from *Gc. miotumida* as a discrete taxonomic entity through a clinal increase in conicity and a gradual neotenic reduction in chambers in the outer whorl. Contrary to this, Scott (1979), Cifelli & Scott (1986), and Scott et al. (1990) have suggested *Gc. conomiozea* is a reduced-chambered intraspecific variant within the normal variation field of *Gc. miotumida*. Despite these two opposing views, it is widely accepted that there is a modal decrease in the number of chambers in the outer whorl in successively younger populations (Kennett 1966a; Scott 1975, 1976; Malmgren & Kennett 1981).

At Site 593, rare morphotypes of *Gc. conomiozea* sensu Kennett (1966a) occur in association with *Gc. miotumida* throughout the late Miocene. This supports the concept of *Gc. conomiozea* being an intraspecific variant of *Gc. miotumida*. However, the abundance of morphotypes with less than four and one-half chambers in the outer whorl increases

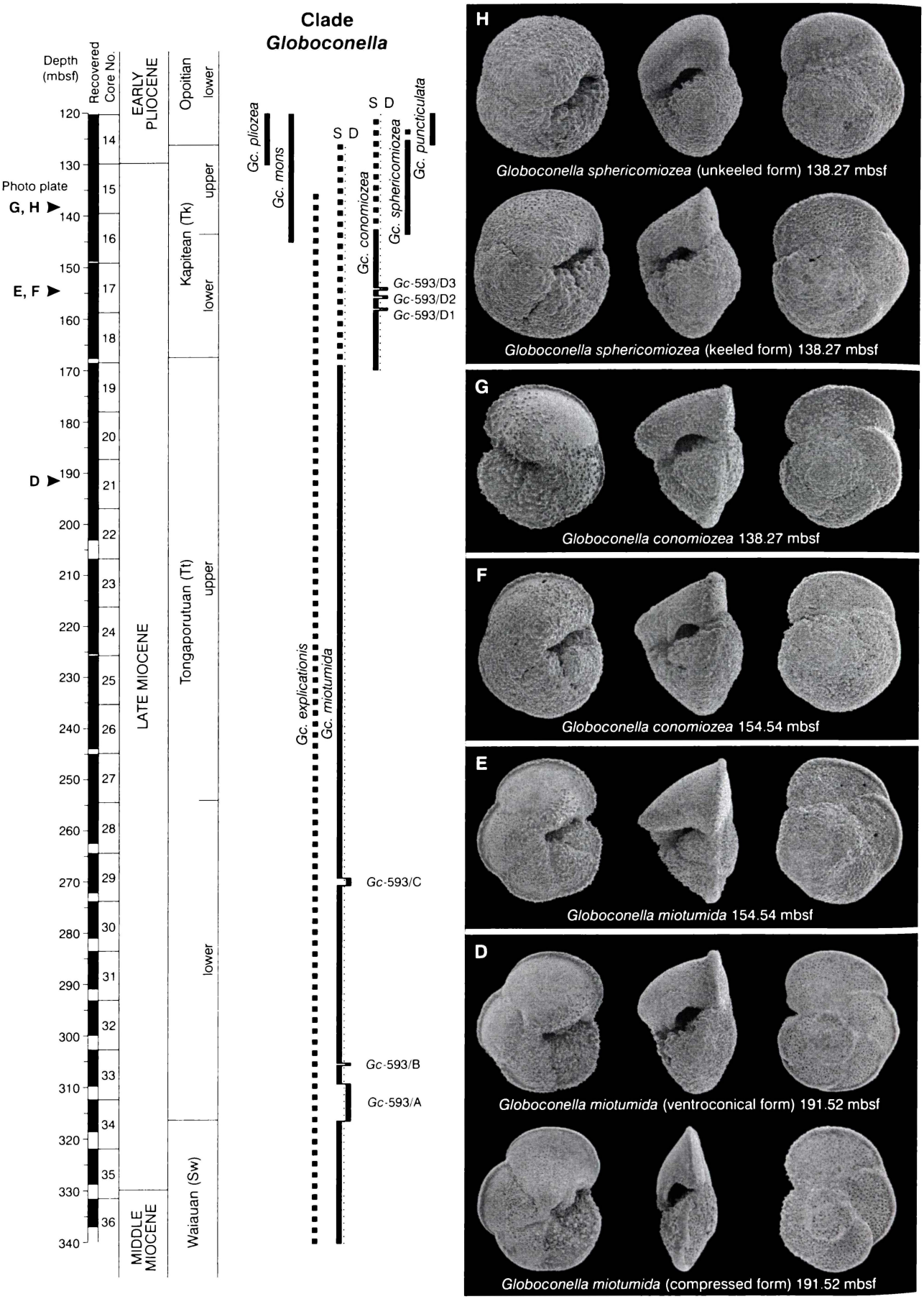


Figure 2.7 – Latest Miocene (upper Tongaporutuan to Kapitean) species of the planktic foraminiferal clade *Globoconella*. For further explanation see Figure 2.6 caption.

markedly above core 593-20X-2 (c. 180 mbsf) and is consistent with a modal shift in population character based on a general reduction in the number of chambers in the outer whorl (Figure 2.8). This trend towards a reduced number of chambers in the outer whorl has also been noted at Site 284 (Malmgren & Kennett 1981) and in sections in onland New Zealand (Kennett 1966a, 1967; Scott 1979). Modal changes have also been noted in the shape of the umbilical side and shape of the aperture (Kennett 1966a; Scott 1975, 1976; Malmgren & Kennett 1981), although trends associated with these morphological features are not as clearly defined as those associated with the reduction in chamber number (Malmgren & Kennett 1981).

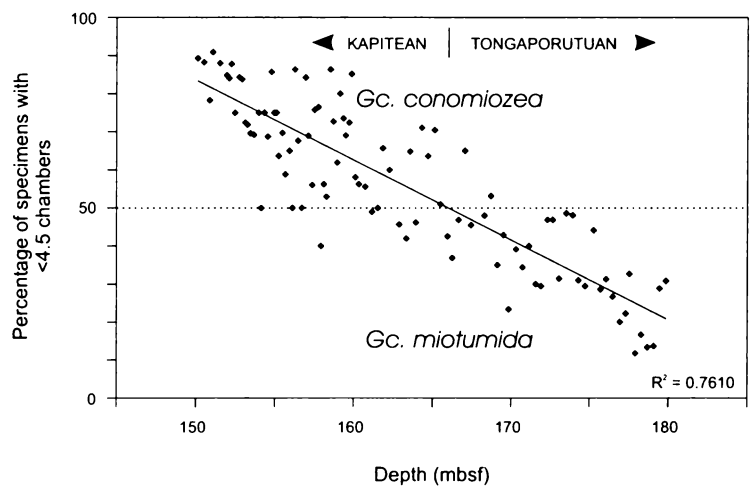


Figure 2.8 – Graph showing the proportion of specimens in the *Globoconella miotumida* bioseries at Site 593 that have less than four and one-half chambers in the outer whorl. Low specimen counts of lightly-crusted and crust-free individuals in some samples contribute to the scatter of the data. A linear trendline is used to locate the lowest occurrence of *Globoconella conomiozea* and the Tongaporutuan-Kapitean boundary (i.e. where the trendline intercepts the 50% level and half of the specimens have less than four and one-half chambers in the outer whorl and the other half have more chambers).

To stabilize the taxonomic concept of *Gc. conomiozea* and improve its biostratigraphic utility in the New Zealand region, the entry of *Gc. conomiozea* is emended and set here as the level where 50% or more of adult specimens within the *Gc. miotumida* bioseries have less than four and one-half chambers in the outer whorl. This 50% threshold is an easy criterion to apply and occurs at the base of core-section 593-18X-5 (166 mbsf). This is very close to the stratigraphic level at Site 284 where Malmgren & Kennett (1981) noted the entry of *Gc. conomiozea*. The emphasis on chamber number rather than degree or angle of conicity within individual specimens, results in morphotypes with a reduced number of chambers and elevated ventroconical profiles being grouped with morphotypes which have less elevated profiles. The wide tolerance in umbilical shape is consistent with the original species concept of Kennett (1966a), but differs from other workers who assign a greater

taxonomic weighting to the development of highly conical axial profiles (Vincent 1981; Cifelli & Scott 1986).

Kennett (1967) located the base of the Kapitean Stage above the entry of *Gc. conomiozea* at a stratigraphic level where 80-90% of specimens in the *Gc. miotumida* bioseries have less than four and one-half chambers in the outer whorl, although the species entry has subsequently been used as a criterion for the base of the Kapitean in deep-water sequences without age diagnostic molluscs (Malmgren & Kennett 1981; Hornibrook et al. 1989). This usage is followed here. Significantly, Kennett (1966a, text-figure 7) shows populations of *Gc. conomiozea* at the base of the Kapitean stratotype to have a conical-angle of 60° – the same conical-angle that Malmgren and Kennett (1981) use for the morphometrically defined entry of the species at Site 284. Kennett (1966a) also records the entry of *Gc. conomiozea* at Blind River in Marlborough at a stratigraphic level where populations are dominated by specimens with a conical-angle of 60° – the same stratigraphic level in the section where 25% of specimens have less than four and one-half chambers in the outer whorl. In the context of the above, the emended entry of *Gc. conomiozea* which is adopted here would appear to be above the stratigraphic level where Malmgren & Kennett (1981) locate the entry of *Gc. conomiozea,* but below the Kapitean stratotype sensu Kennett (1967). This loss of stratigraphic precision for the base of the stage is more than outweighed by the improvements in reliability, although there is still a need to determine more precisely the relationship between *Gc. conomiozea* and entry of Kapitean mollusca.

***Globoconella sphericomiozea*:** Subsequent morphological changes in the *Gc. miotumida* bioseries include a further reduction in chamber number and the loss of a peripheral keel. The lowest occurrence of *Gc. sphericomiozea* s.s. is defined in terms of this anagenetic morphological transformation, at a level where at least 5% of adult specimens lack a keel (Scott 1980). This occurs in 593-16X-3, 103-106 cm (143.53 mbsf). Scott (1982) considered the lowest occurrence of *Gc. sphericomiozea* s.s. to be a suitable candidate for the Kapitean-Opoitian boundary, although it has subsequently been adopted as the primary faunal criterion for the base of the upper Kapitean (Hornibrook 1982; Hornibrook et al. 1989; Scott et al. 1990). This latter usage is followed here.

Globoconella puncticulata: Peripheral keels are usually weak and infrequent in upper populations of *Gc. sphericomiozea,* and the criteria proposed by Scott (1980) for the lowest

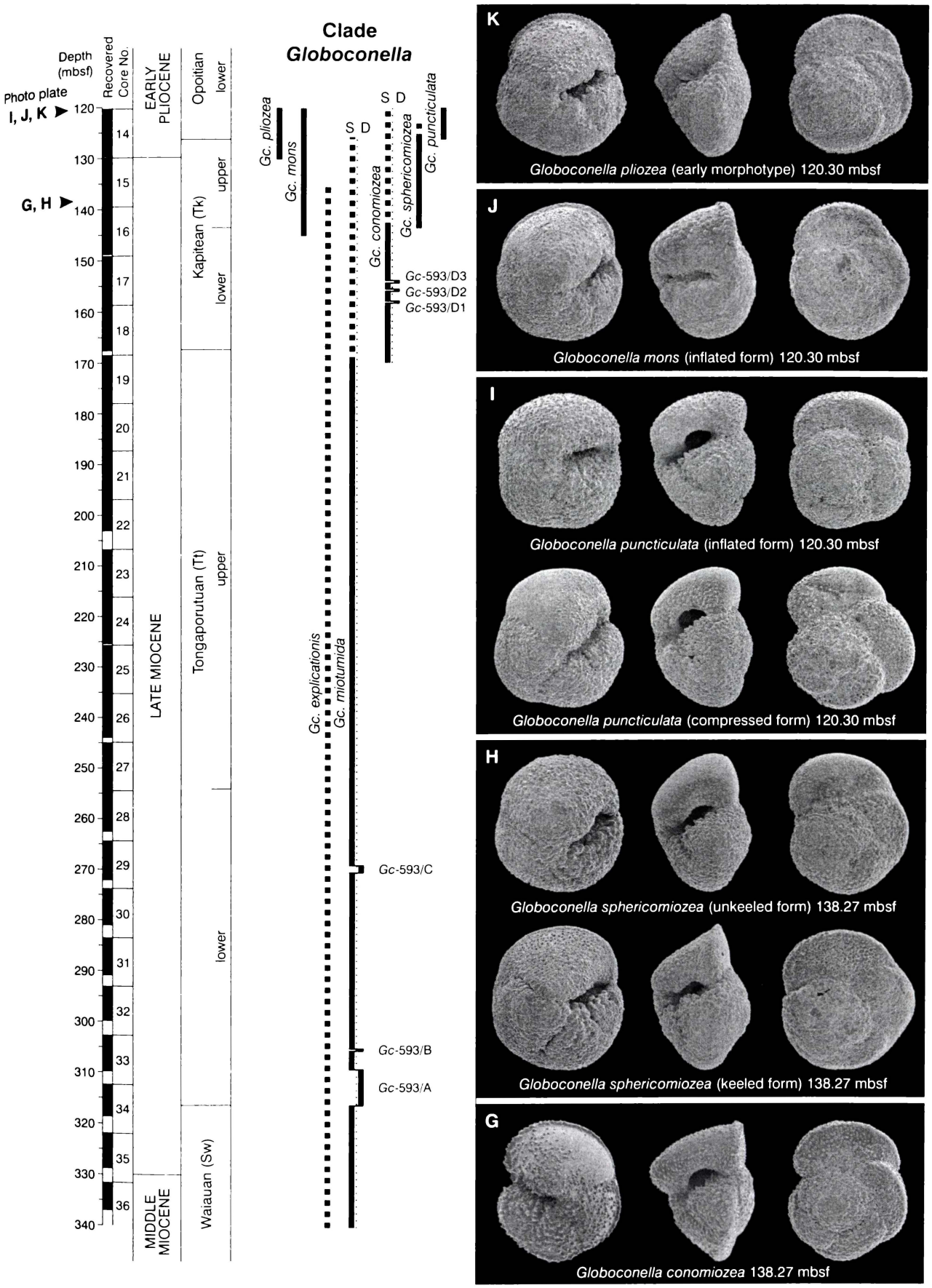


Figure 2.9 – Early Pliocene (upper Kapitean to lower Opoitian) species of the planktic foraminiferal clade *Globoconella*. For further explanation see Figure 2.6 caption.

occurrence of *Gc. puncticulata* – the level where all specimens in the *Gc. miotumida* bioseries lack a keel – are difficult to apply. The entry of *Tr. crassaformis* is also poorly defined and it occurs at least 9.2 m below the lowest totally non-carinate populations of *Gc. puncticulata* (see later). The uncertainty concerning the lowest occurrences of these species and their wide stratigraphic separation makes it difficult to locate the Kapitean-Opoitian boundary at Site 593, based on the current stage usage – the lowest joint occurrence of *Gc. puncticulata* and *Truncorotalia crassaformis* (Hornibrook 1982; Hornibrook et al. 1989; Scott et al. 1990). Scott (1982) noted these problems when reviewing the Kapitean stratotype, although the reliability of the biostratigraphic criteria only affects studies requiring a high-level of biostratigraphic precision.

In order to improve the reliability of the Opoitian Stage boundary the lowest occurrence of *Gc. puncticulata* is redefined here as the level where 95% or more of specimens in the *Gc. miotumida* bioseries lack a keel. The stage boundary is well defined on the basis of the emended faunal criterion and it occurs in 593-14X-2, 112-115 cm (122.92 mbsf). This is at least 3 m below the highest occurrence of weakly keeled specimens of *Gc. puncticulata*.

Divergent globoconellid group

Morphological trends in globoconellid populations that are distinct from those of the *Gc. miotumida* bioseries, specifically the appearance of compactly coiled forms with a closed umbilicus, and a low-arched aperture, are first noted in the lower Kapitean. These divergent morphological trends are associated with the evolutionary appearances of at least two species – *Gc. mons* and *Gc. pliozea*.

Globoconella mons: *Globoconella mons* does not form a part of the *Gc. miotumida* bioseries, but evolves from *Gc. conomiozea* in the lower Kapitean (Hornibrook 1982). The emergence of early forms of *Gc. mons* cannot be fully resolved at Site 593 without detailed morphometric study, although typical morphotypes with a compactly coiled ventroconical test and an elongated low-arched aperture are first noted in 593-16X-5, 0-3 cm (145.50 mbsf), slightly below the lowest occurrence of the upper Kapitean marker species *Gc. sphericomiozea*. As such, the lowest occurrence of *Gc. mons* serves as a useful low-resolution biostratigraphic marker.

In describing the taxon as a subspecies of *Gc. conomiozea,* Hornibrook (1982) restricted the name to strongly conicotruncate morphotypes with a prominent angular peak on the umbilical side. Scott et al. (1990) also included compact heavily encrusted morphotypes with less prominent ventroconical profiles within *Gc. mons* – the unifying factors being the four chambers in the outer whorl, the narrow or closed umbilicus, and the slit-like aperture. The broader taxonomic concept introduced by Scott et al. (1990) overlaps the variation field of *Gc. conomiozea* sensu Hornibrook (1982). This places a significant caveat on the use of the lowest occurrence of *Gc. mons*, especially where different operators are involved.

Globoconella pliozea: The evolutionary appearance of *Globoconella pliozea* is poorly defined in terms of the census data. Early ventroconical morphotypes that are assigned to *Gc. pliozea* are first noted in the upper Kapitean in 593-15X-2, 93-96 cm (132.33 mbsf), and typical morphotypes with a compactly coiled biconvex test and an elongated low-arched aperture appear in the vicinity of the Kapitean-Opoitian boundary, in 593-14X-3, 0-3 cm (123.30 mbsf). Such forms appear to evolve from *Gc. mons* via a gradual reduction in ventral elevation. The lowest occurrence of *Gc. pliozea* serves as a useful proxy for the Miocene-Pliocene boundary, although the species is poorly represented for some time after its appearance and it first becomes common in the vicinity of the Kapitean-Opoitian boundary

Early populations of *Gc. pliozea* are randomly coiled while latter populations have majorities of sinistrally-coiled specimens. Hornibrook (1982) noted similar coiling perturbations at Site 284 in the lowermost part of the species range.

Late Miocene coiling history of globoconellids

Globoconella has a strong preference for sinistral coiling throughout the Miocene (Walters 1965; Jenkins 1971; Scott 1995), except for narrow intervals of dextrally-coiled *Gc. miotumida* near the middle-late Miocene boundary, as seen in expanded clastic sequences in onland New Zealand and in offshore pelagic sequences, including Site 593 (Scott 1992, 1995). Scott (1995) considered these intervals were part of a unique biostratigraphic interval, which he named the Kaiti Coiling Zone (KCZ). In establishing the KCZ, Scott (1995) suggested other intervals of dextrally-coiled *Gc. miotumida* may be found in the late Miocene, but not on a scale similar to the KCZ. The present study identifies several

narrow late Miocene intervals at Site 593 where there are significant increases in the contributions of dextral shells in populations of *Gc. miotumida* and *Gc. conomiozea* (Figure 2.10), including at least three early late Miocene intervals of dextrally-coiled *Gc. miotumida*. This clearly demonstrates the KCZ is not a unique zone. In this respect, it is important to use the KCZ and similar intervals of dextrally-coiled *Globoconella* in conjunction with other faunal events that provide a robust biostratigraphic framework. This was not possible before this study, but correlations based on the KCZ are reassessed in Study 7, particularly those relating to the Tongaporutuan Stage.

To facilitate the following discussion each interval of dextrally-coiled *Globoconella* at Site 593 is given an alphanumeric code that identifies the genus (e.g. Gc = *Globoconella*), Site, and interval number. The *Gc*-593/A and *Gc*-593/B intervals were considered by Scott (1995) to be part of a single zone which he correlated with the KCZ, near the base of the Tongaporutuan. The succeeding *Gc*-593/C interval that is associated with *Gc. miotumida* in the upper part of the lower Tongaporutuan, and the *Gc*-593/D1, *Gc*-593/D2, and *Gc*-593/D3 intervals that are associated with *Gc. conomiozea* in the lower Kapitean, have not been recognized before. New names are introduced here for intervals not previously described – *Gc*-593/B (Mapiri), *Gc*-593/C (Tukemokihi), and *Gc*-593/D1, *Gc*-593/D2, *Gc*-593/D3 (Palliser) – see Study 7. The correlation of these intervals is shown in Table 2.3.

Intervals *Gc*-593/A and *Gc*-593/B: The first increased contributions of dextrally-coiled *Globoconella miotumida* are noted in the *Gc*-593/A interval, which extends upwards from 593-34X-2, 139-142 cm (315.19 mbsf) to 593-33X-5, 41-43 cm (309.11 mbsf) (Figure 2.10). Assuming that no section was lost from the base of core 593-33X and that the incomplete length of this core was due to compaction during the core recovery operation (Shipboard Scientific Party 1986), the *Gc*-593/A interval has a nett thickness of 3.58 m. The base of the interval corresponds to an abrupt, almost four-fold increase in the proportion of dextral shells, from 7 to 26%. This occurs 1.49 m below the highest common occurrence of *Neogloboquadrina mayeri* s.l. (see later). The interval is represented by a total of 26 samples and the top is marked by an abrupt decrease in the proportion of dextral shells. As a whole, the interval is informally subdivided into a lower part (315.22-313.50 mbsf) that has variable proportions of dextral shells in the range 7-37%, and an upper part (313.50-309.11 mbsf) that includes dextral majorities of shells in the range 50-89% (Data appendix 1.4).

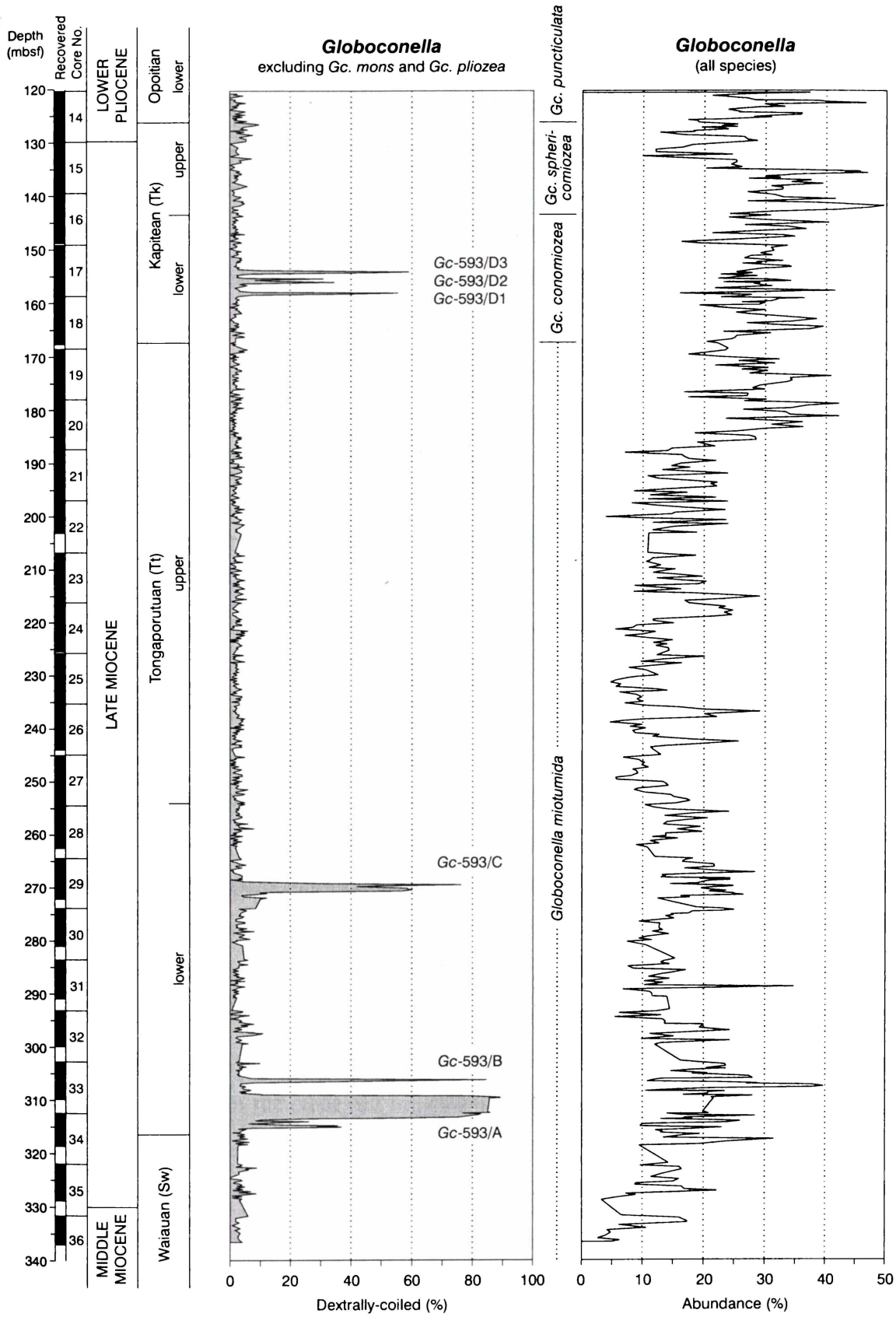


Figure 2.10 – Late Miocene changes in coiling and abundance associated with the planktic foraminiferal clade *Globoconella* (Figures 2.6, 2.7, and 2.9). Coiling data based on *Gc. miotumida* bioseries (*Gc. miotumida* – *Gc. conomiozea* – *Gc. sphericomiozea* – *Gc. sphericomiozea* – *Gc. puncticulata*), excluding *Gc. mons* and *Gc. pliozea*. Narrow intervals with significant contributions of dextrally-coiled shells (*Gc*-593/A–D) offer potential for biostratigraphic refinement.

The *Gc*-593/B interval occurs 2.74 m above the top of the *Gc*-593/A interval. It is a very narrow interval with increased contributions of dextral shells of *Gc. miotumida* that extends upwards from 593-33X-3, 84-86 cm (306.54 mbsf) to 593-33X-3, 41-43 cm (306.11 mbsf). It is represented by only three samples and the maximum proportion of dextral shells reaches 85%. The top of the *Gc*-593/B interval occurs 3.14 m below the lowest occurrence of *Neogloboquadrina pachyderma* (see later). Scott (1995) included both *Gc*-593/A and *Gc*-593/B intervals in a single zone, which he correlated with the KCZ. It is considered here, however, that these intervals have the potential to be mapped and correlated separately (see Study 7).

Table 2.3 – Correlation of late Miocene coiling zones associated with the planktic foraminifer *Globoconella miotumida* (Study 7). Magnetostratigraphic correlations based on Site 1123 (Study 5). *The Tukemokihi Coiling Zone does not maintain a consistent homotaxial position with respect to bioevents at Sites 1123 and 593, but is not significantly diachronous.

Oceanic sequences		Onland sequences				Coiling Zones	Magnetostratigraphic correlation		Age (Ma)
DSDP 593	ODP 1123	Kaiti Beach	Tukemokihi Stream	North Taranaki Coast	Pukearuhe-1				
Gc-593/C	*Gc*-1123/B	no age equivalent section	*Gc*-TS/B	*Gc*-TT	*Gc*-PK	Tukemokihi (TCZ)	Top	C4Ar.2r(0.41)*	9.62
							Base	C4Ar.2n(0.71)*	9.42
Gc-593/B	?		*Gc*-TS/A	missing	missing	Mapiri (MCZ)	Top	C5n.2n (lower)	?
							Base	C5n.2n (lower)	?
Gc-593/A	*Gc*-1123/A	KCZ	missing	missing	missing	Kaiti (KCZ)	Top	C5n.2n(0.87)	10.82
							Base	C5n.2n(0.98)	10.93

Interval *Gc*-593/C: The *Gc*-593/C interval occurs substantially above the *Gc*-593/A and *Gc*-593/B intervals (Figure 2.10). It is a narrow and very well defined interval with increased contributions of dextrally-coiled *Gc. miotumida* that extends upwards from 593-29X-5, 43-44 cm (270.72 mbsf) to 593-29X-4, 48-50 cm (269.28 mbsf). It is represented by a total of eight samples and the proportions of dextral shells are variable, in the range 31-76%, whereas the late Miocene average is 5%. The top of the interval occurs 14.79 m below the highest occurrence of *Globoquadrina dehiscens*. This locates the *Gc*-593/C interval near the top of the lower Tongaporutuan.

Intervals *Gc*-593/D1, *Gc*-593/D2, and *Gc*-593/D3: These intervals are all associated with significant contributions of dextrally-coiled *Globoconella conomiozea* and they all occur in the lower Kapitean in the lower part of core 593-17X (Figure 2.10). The *Gc*-593/D1 interval extends from 158.10-157.93 mbsf. It is represented by only two samples and the maximum proportion of dextral shells is 56%. The *Gc*-593/D2 interval extends from 155.94-155.24 mbsf. It includes four samples and the proportion of dextral shells is variable, in the range 8-34%. The *Gc*-593/D3 interval extends from 154.13-153.97 mbsf. It

includes only two samples and the proportion of dextral shells reaches a maximum of 58%. Because these intervals are very narrow and difficult to identify they are expected to be of limited use for correlating condensed oceanic sequences, although they have the potential to be used in expanded clastic sequences exposed on land in New Zealand.

Causes of coiling changes: The biostratigraphic and paleoenvironmental potential of coiling changes in planktic foraminiferal populations have long been recognized (Bolli 1950; Ericson et al. 1954; Bandy 1960, 1972b; Walters 1965; Jenkins 1971; Kennett & Vella 1975; Vella et al. 1975), although the causal mechanism for coiling changes is poorly understood. Historical studies have linked coiling changes to various environmental controls such as water temperature, salinity, oxygenation, and nutrients (Ericson 1959; Bandy 1960, 1964; Theide 1971), although the conflicting and equivocal nature of these data suggest a more complex causal mechanism. Lohmann & Schweitzer (1990) and Lohmann (1992) have more recently linked changes in coiling to the depth of the thermocline and differences in the reproductive success of sinistral and dextral forms. Genetic coding of extant species appears to support this view and suggests sinistral and dextral forms may represent genetically divergent subpopulations that are distinguished in terms of their biological requirements (Darling et al. 2000). Cooke (2002) suggests there may be a similar biological relationship at Site 593 between the depth of the thermocline and coiling changes in late Miocene populations of *Globoconella,* but finds no reliable isotopic evidence for separate sinistral and dextral subpopulations.

Summary of globoconellid events

Important bioevents associated with the clade *Globoconella* are shown in Figures 2.6, 2.7, and 2.9. Evolutionary sequences associated with the morphotypic expansion and evolutionary radiation in the clade are important for the correlation and subdivision of the Kapitean in the New Zealand region (Kennett 1966a, b; Hornibrook 1981; Scott et al. 1990; Scott 1992). At present, biostratigraphic subdivision of this interval is largely based on the successive appearances of *Gc. conomiozea* (base Kapitean), *Gc. sphericomiozea* (base upper Kapitean), and *Gc. puncticulata* (base Opoitian). Because the taxonomic concepts associated with these species are not always applied consistently, particularly by different stratigraphers, morphometric studies are needed to improve the reliability of species interpretations and biostratigraphic precision.

Changes in the dominant coiling direction of late Miocene globoconellid populations offer several abrupt, well defined biostratigraphic events that are potentially useful for correlation, particularly when used in conjunction with other bioevents. The utility of intervals of dextrally-coiled *Globoconella* appears to be coextensive with the clades biogeographic distribution, at least within the cool subtropical (temperate) Southwest Pacific region (Scott 1995). Importantly, the lowest of these intervals, the Kaiti Coiling Zone (*Gc*-593/A), serves as a useful criterion for the base of the Tongaporutuan Stage – see Study 7.

Table 2.4 – Bioevents associated with the clade *Globoconella*. Events: HO = Highest occurrence; HCO = Highest common occurrence; LO – Lowest Occurrence; LCO – Lowest common occurrence. Nature of events: BG = Biogeographic event; OP = Opportunistic event; EV = Evolutionary event. Reliability criteria: 1 = Distinctive, well defined, widely distributed events; 2 = Moderately well defined events, useful for correlation of pelagic sequences but difficult to located in sequences with poor planktic representations; 3 = Poorly defined events, largely restricted to pelagic sequences.

Lower Opoitian

- LO *Globoconella puncticulata*, ≥95% non-carinate morphotypes (*Gc. miotumida* bioseries)
  593-14X-4, 130-133 cm (126.10 mbsf) – EV2: defines base Opoitian

Upper Kapitean

- HO *Globoconella sphericomiozea*, <95% non-carinate (*Gc. miotumida* bioseries)
  593-14X-3, 0-3 cm (126.30 mbsf) – EV2
- LO *Globoconella pliozea*
  593-15X-1, 0-3 cm (129.90 mbsf) – EV2
- LO *Globoconella sphericomiozea*, >5% non-carinate (*Gc. miotumida* bioseries)
  593-16X-3, 103-106 cm (143.53 mbsf) – EV2: defines base upper Kapitean

Lower Kapitean

- LO *Globoconella mons*
  593-16X-5, 0-3 cm (145.50 mbsf) – EV2
- *Gc*-593/D3 interval, >20% dextral *Globoconella conomiozea*
  593-17X-4, 53-56 cm (154.13 mbsf) to 593-17X-4, 37-39 cm (153.97 mbsf) – OP2
- *Gc*-593/D2 interval, >20% dextral *Globoconella conomiozea*
  593-17X-5, 84-87 cm (155.94 mbsf) to 593-17X-5, 14-17 cm (155.24 mbsf) – OP2
- *Gc*-593/D1 interval, >20% dextral *Globoconella conomiozea*
  593-17X-7, 0-3 cm (158.10 mbsf) to 593-17X-6, 133-136 cm (157.93 mbsf) – OP2
- LO *Globoconella conomiozea*, >50% with <4.5-chambers (*Gc. miotumida* bioseries)
  593-18X-5, 125-127 cm (165.95 mbsf) – EV2: base Kapitean?

Lower Tongaporutuan

- Top *Gc*-593/C interval, >20% dextral *Globoconella miotumida*
  593-29X-4, 48-50 cm (269.28 mbsf) – OP1
- Base *Gc*-593/C interval, >20% dextral *Globoconella miotumida*
  593-29X-5, 42-44 cm (270.72 mbsf) – OP1

- Top *Gc*-593/B interval, >20% dextral *Globoconella miotumida*
  593-33X-3, 41-43 cm (306.11 mbsf) – OP1
- Base *Gc*-593/B interval, >20% dextral *Globoconella miotumida*
  593-33X-3, 84-86 cm (306.54 mbsf) – OP1
- Top *Gc*-593/A interval, >20% dextral *Globoconella miotumida*
  593-33X-5, 41-43 cm (309.11 mbsf) – OP1
- Base *Gc*-593/A interval, >20% dextral *Globoconella miotumida*
  593-34X-2, 139-142 cm (315.19 mbsf) – OP1: base Tongaporutuan

TRUNCOROTALIA

Pliocene conicotruncate and quadrate forms with pustulose test surfaces similar to *Tr. crassaformis* have generally been included in the clade *Truncorotalia* (Kennett & Srinivasan 1983), although the derivation of *Tr. crassaformis* is poorly understood. Blow (1969 postscript, p. 421) was the first to suggest *Tr. crassaformis* evolved from a group of inflated late Miocene scituline forms, a view subsequently shared by Kaneps (1975) and Berggren (1977). Scott (1983) compared the South Atlantic succession that Berggren (1977) studied with successions from DSDP Sites 284 and 208 in the Southwest Pacific and concurred with the derivation of *Tr. crassaformis* from inflated scituline forms with a pustulose surface ultrastructure. The general consensus amongst southern hemisphere stratigraphers is that *Tr. crassaformis* evolved from such a group, which is supported by the observed evolutionary succession at Site 593.

In order to highlight the phylogenetic link between pustulose late Miocene scituline forms and pustulose conicotruncate Pliocene forms of *Truncorotalia*, the definition of *Truncorotalia* sensu Kennett & Srinivasan (1983) is emended to include unkeeled biconvex and spirally domed forms as well as conicotruncate forms. The finely perforate pustulose surface ultrastructure is considered to be the common factor linking all truncorotalids. The origin of the pustulose surface ultrastructure is uncertain, although some middle Miocene specimens of *Globoconella amuria* figured by Scott et al. (1990, p. 122 figure 80D-F) have a distinctly pustulose surface ultrastructure. They also have four inflated chambers in the outer whorl, the same number as late Miocene truncorotalids. This does not appear to support the late Miocene derivation of *Truncorotalia* from a hirsutellid ancestor (Stainforth et al. 1975; Kennett & Srinivasan 1983; Cifelli & Scott 1986).

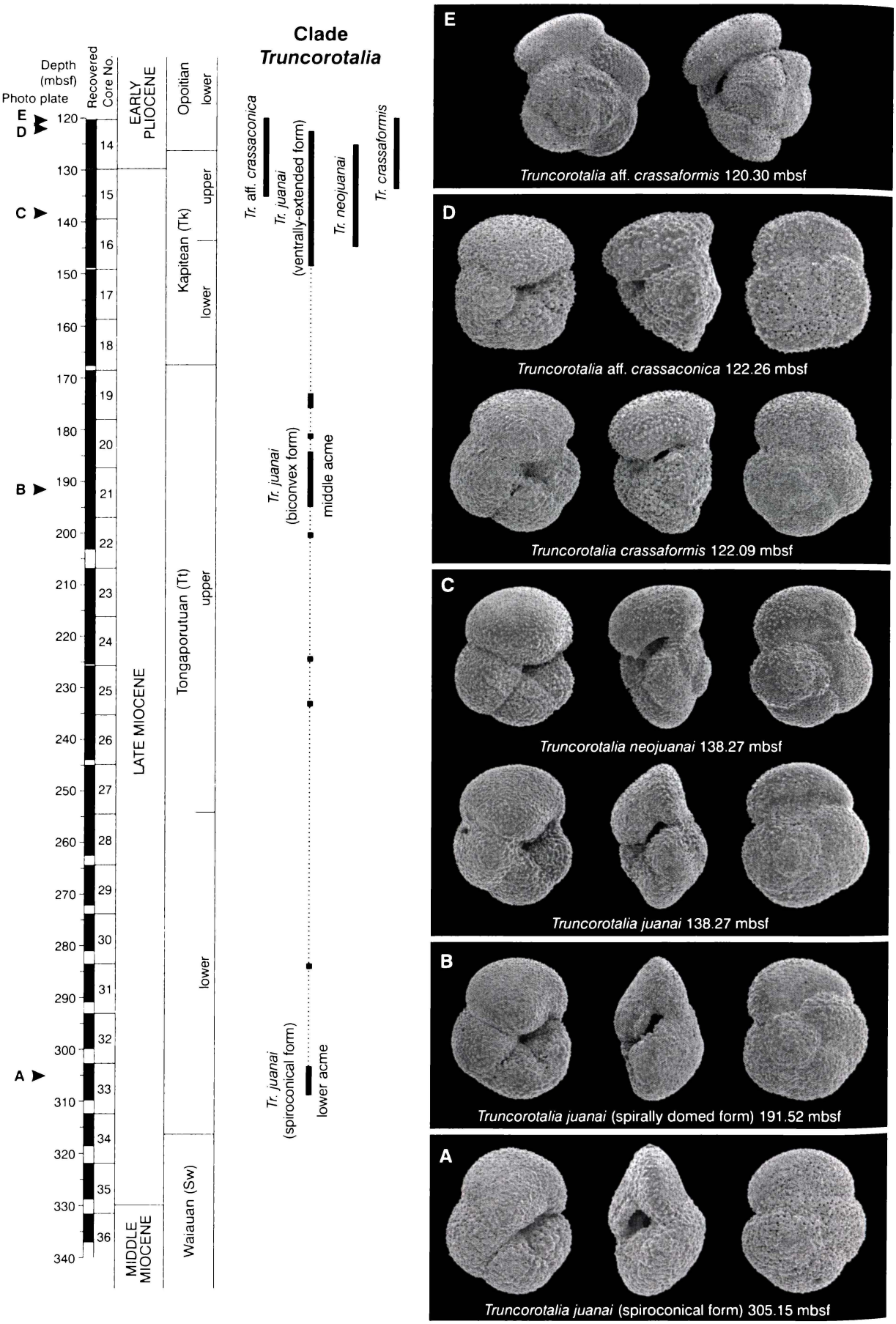


Figure 2.11 – Late Miocene species associated with the clade *Truncorotalia*. The main changes within the clade include a morphological transformation from spiroconical to ventrally-extended and conicotruncate forms. The most rapid evolutionary phase occurs in the vicinity of the Miocene-Pliocene boundary, where modern conicotruncate forms first appear.

Truncorotalia crassaformis bioseries

The observed morphological transformation at Site 593, involving *Tr. juanai* (Bermudez and Bolli) (= *Hirsutella cibaoensis* sensu Kennett & Srinivasan (1983)), *Tr. neojuanai* n. sp. Crundwell (= *Hirsutella juanai* sensu Kennett & Srinivasan (1983)), and *Tr. crassaformis* (Galloway and Wissler) is referred to here as the *Tr. crassaformis* bioseries (Figure 2.11). The underlying evolutionary themes in this late Neogene bioseries include a marked increase in the ventral extension of chambers and the dissipation of spiral convexity. Such morphological changes ultimately lead to the development of the quintessential conicotruncate Pleistocene species, *Tr. truncatulinoides*.

The late Miocene emergence of distinctly inflated and ventrally extended forms in the clade *Truncorotalia* is marked by a rapid expansion of the morphological variation field associated with *Tr. juanai*. It is perhaps significant that this occurs near the Miocene-Pliocene boundary, where there is a similar morphotypic expansion and evolutionary radiation within the clade *Globoconella*. Hodell & Kennett (1986), Wei & Kennett (1986), and Malmgren & Berggren (1987) have postulated that these changes in *Globoconella* may be linked to a strengthening of thermoclinal gradients and increased habitat stratification. These changes may also have contributed to the observed morphotypic expansion and evolutionary radiation in *Truncorotalia*.

***Truncorotalia juanai*:** Scott (1983) rejected use of the name *'Globorotalia' cibaoensis* sensu Berggren (1977) on the grounds that illustrations of the holotype (Cifelli & Belford 1977, Plate I, 19-21) show the presence of a keel. He followed Hornibrook (1982) who adopted the name *'Globorotalia' juanai* for all pustulose ventrally inflated scituline forms which occur prior to the entry of *Tr. crassaformis*, a view subsequently followed by Cifelli & Scott (1986), Hornibrook et al. (1989), and Scott et al. (1990). In contrast, Kennett & Vella (1975) and Kennett & Srinivasan (1983) used the name *'Hirsutella' juanai* for ventrally inflated scituline forms that precede the entry of *Tr. crassaformis*, and restricted use of the name *'Hirsutella' cibaoensis* to less inflated scituline forms with a pustulose surface ultrastructure and biconvex tests. A similar taxonomic concept was followed by Norris et al. (1994).

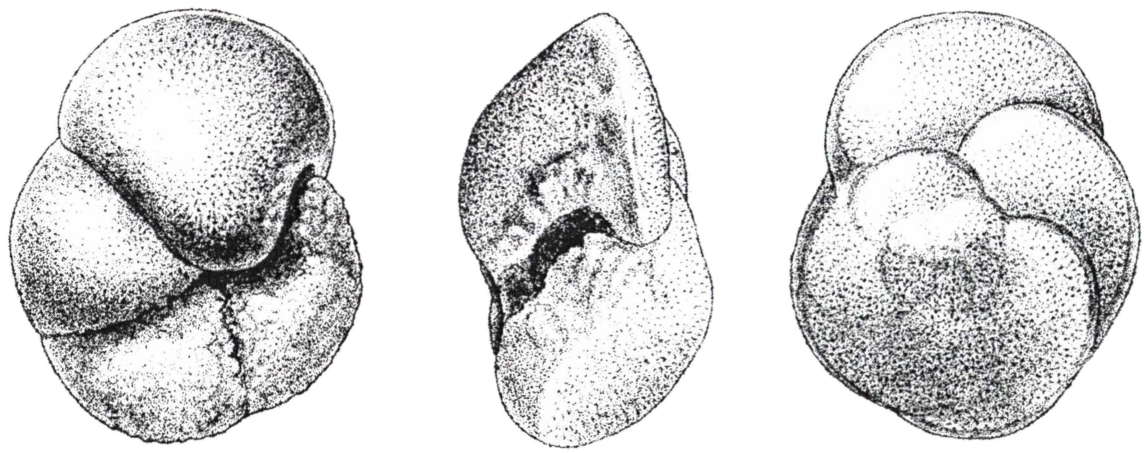


Figure 2.12 – Holotype *Globorotalia cibaoensis* (Cushman collection no. 63458) refigured by Ron Brazier – a former paleoartist with New Zealand Geological Survey. The holotype was refigured in October 1977 while on loan from the Smithsonian Institute, courtesy of Dr Richard Cifelli. The illustrations have not been published previously.

The new illustrations of the refigured holotype of *Globorotalia cibaoensis* show it to have crescentic spiral chamber outlines with well developed trailing sections, five chambers in the outer whorl, an acutely rounded imperforate peripheral margin that is non-carinate, and relatively smooth and perforate wall surfaces. These features are very similar to those of *Globoconella* and are very unlike the pustulose scituline forms that have sometimes been attributed to *Globorotalia cibaoensis* (e.g. Kennett & Srinivasan 1983). The latter pustulose forms are reassigned here to *Truncorotalia juanai* (Bermudez and Bolli), following the usage of Cifelli & Scott (1986), Hornibrook et al. (1989), and Scott et al. (1990). The species name, however, is used in a more restricted sense, with ventrally extended forms that are intermediate between *Tr. crassaformis* and biconvex specimens of *Tr. juanai* being included in *Tr. neojuanai* n. sp. (see later).

Unpublished illustrations of the *'Globorotalia' cibaoensis* holotype, prepared by Ron Brazier – a former paleo-artist with New Zealand Geological Survey – reveal detail of the surface ultrastructure that could not be discerned in the original illustration of the holotype (Bermudez 1949) and refigured illustrations of the holotype published by Cifelli & Belford (1977). The new illustrations, reproduced here in Figure 2.12, show the walls to be finely perforate and relatively smooth, except for conspicuous granulations – partially fused pustules – on the umbilical sides of early-formed chambers. The surface ultrastructure is distinct from the pustulose wall texture of *Truncorotalia* and suggests a closer affinity to *Globoconella*. This view concurs with Blow (1969, p. 366) who considers *'Globorotalia' cibaoensis* to be conspecific with *'Globorotalia' miozea* s.l. – a key species in the clade *Globoconella*. In this respect, the pustulose scituline forms that Kennett & Srinivasan (1983) illustrate do not appear to be related to *'Globorotalia' cibaoensis,* but they show a close affinity to *Tr. juanai* (Bermudez and Bolli). As a consequence, the name *Tr. juanai* is adopted here for all spirally domed and moderately inflated biconvex, pustulose scituline forms that are a part of the *Tr. crassaformis* bioseries. This follows the usage of Cifelli &

Scott (1986), Hornibrook et al. (1989), and Scott et al. (1990), albeit in a more restricted sense (see *Tr. neojuanai*).

Specimens of *Tr. juanai* are largely restricted to acme zones in the lowermost Tongaporutuan, uppermost Tongaporutuan, and Kapitean where they form a conspicuous part of assemblages (Figure 2.13). The lower acme is confined to a short interval in core 593-33X, where populations are dominated by biconvex forms with distinctive spiroconical profiles (Figure 2.11A). *Truncorotalia juanai* is then extremely rare up until the middle acme in cores 593-21X and 593-20X, where populations are dominated by forms with biconvex axial profiles (Figure 2.11B). It is then relatively rare once more, until the upper acme in cores 593-16X and 593-15X, where populations include biconvex and ventrally extended forms (Figure 2.11C). Biconvex forms with subequal ventral- and spiral-extension dominate the lower part of the upper acme, although there are trends towards greater ventral extension and the dissipation of spiral convexity in the upper part of the acme. This leads to a significant overlap between advanced morphotypes of *Tr. juanai* and the variation fields attributed to species that evolve from *Tr. juanai – Tr. neojuanai* and *Tr. crassaformis.*

The lowest occurrence of *Tr. juanai* in 593-33X-5, 29-31 cm (308.99 mbsf) is relatively well defined and potentially useful as a biostratigraphic datum. The subsequent disappearances and reappearances of the species may also be useful as low-resolution bioevents.

***Truncorotalia neojuanai*:** The new species *Tr. neojuanai* is introduced here for ventrally inflated forms that are intermediate in character between *Tr. juanai* (Bermudez and Bolli) and *Tr. crassaformis* (Galloway and Wissler) – forms of *Globorotalia (Hirsutella) juanai* that Kennett & Srinivasan (1983) had previously distinguished from *Globorotalia (Hirsutella) cibaoensis.* In the past such forms also have been included in a wider range of morphotypic variation associated with *Tr. juanai* (Hornibrook 1982; Scott et al. 1990) and they have been identified as primitive *Tr. crassaformis* (Cifelli & Scott 1986).

Species diagnosis: Test moderate sized, low trochospiral, biconvex. Equatorial periphery, subquadrate and slightly lobate. Axial periphery bluntly rounded. Chambers increase rapidly in size as added, usually four in outer whorl, moderately inflated and extended on

umbilical side. Sub-symmetrical spiral chamber outlines, with sutures slightly depressed. Umbilical sutures radial to slightly curved, depressed. Chamber walls densely perforate, peripheral chamber margin less perforate. Pustules on spiral and umbilical sides, conspicuous granulations – partially fused pustules – on early formed chambers of umbilical sides. Umbilicus open but narrower in encrusted specimens. Aperture an elongated low arch inclined obliquely to the coiling-axis and bordered by a distinct lip.



Paratype (TF1663/2) Holotype (TF1663/1) Paratype (TF1663/3)

Types: Holotype (TF 1663/1), 2 figured paratypes (TF1663/2-3), and 17 paratypes (TF 1663/4-20) lodged in the New Zealand national micropaleontological collections, maintained and curated by Geological and Nuclear Sciences, Lower Hutt.

Holotype dimensions: Axial height 260 µm, greatest spiral dimension 365 µm.

Type locality and level: DSDP Site 593, southern Tasman Sea, 470 km west of central New Zealand, 40° 30.47' S; 167° 40.47' E, 1068 m water depth. Core sample 593-15X-6, 12-15 cm (137.52 mbsf), upper Kapitean (earliest Pliocene).

Distribution: New Zealand upper Kapitean to lower Opoitian stages (early Pliocene). Cool subtropical (temperate) to tropical.

Remarks: Very rare inflated and ventrally extended *Tr. neojuanai*-like morphotypes occur sporadically in latest Miocene populations of *Tr. juanai*, although they tend to have less inflated chambers and more acute umbilical-spiral wall junctions than *Tr. neojuanai*. Typical *Tr. neojuanai* morphotypes, which show marked ventral extension and vertical-rotation and elongation of the aperture, first appear near the top of core-section 593-16-5 (145.50 mbsf) and become increasingly common prior to the entry of *Tr. crassaformis*.

Truncorotalia neojuanai is primarily distinguished from *Tr. juanai* on the basis of its inflated and obtusely rounded axial profile and the less convex shape of its spiral side. The aperture also tends to be more elongated and less obliquely rotated. Only inflated non-carinate forms of *Truncorotalia,* where the ratio of the axial height of the last formed chamber (H) versus the maximum spiral diameter (D) is between 0.6 and 0.7, are included in *Tr. neojuanai.* Forms where the (H/D) ratio is equal or less than 0.6 are assigned to *Tr. juanai* and those where the (H/D) ratio is equal or greater than 0.7 are assigned to *Tr. crassaformis.* While these criteria are useful for the identification of individual specimens, the lowest occurrence of *Tr. neojuanai* is a poorly defined event. Ventrally inflated forms of *Tr. neojuanai* first appear as very rare variants in upper Tongaporutuan populations associated with the middle *Tr. juanai* acme zone, although there is a marked increase in such forms in the upper Kapitean – in the vicinity of the Miocene-Pliocene boundary. This increase in abundance is taken here to be the lowest occurrence of *Tr. neojuanai,* although there is a need to examine more complete sequences of *Truncorotalia* that span the gap between the middle and upper acmes of *Tr. juanai.*

***Truncorotalia crassaformis*:** The entry of *Tr. crassaformis* has been well documented in New Zealand (Jenkins 1971; Collen & Vella 1973; Kennett & Watkins 1974; Kennett & Vella 1975; Hornibrook 1977, 1981). Its sudden appearance, presumed incorrectly to be an invasion from outside of the region, has been cited as a criterion for the base of the Opoitian Stage (Hornibrook 1981). In many New Zealand onland sections, however, its entry coincides with a Miocene-Pliocene unconformity which cuts-out the earliest stratigraphic record of the species (Hornibrook 1981, 1984; Crundwell 1987).

At DSDP Sites 284 and 593, where there is a continuous record spanning the species entry, there are conflicting and equivocal data regarding the entry of *Tr. crassaformis* (Jenkins 1975; Kennett & Vella 1975; Hornibrook 1982; Jenkins & Srinivasan 1986; Hoskins 1990). However, the highly resolved record from Site 593 provides evidence of a continuous morphological transformation between *Tr. crassaformis* and *Tr. juanai* – a species that invaded the New Zealand region at least three times in the late Miocene before permanently colonizing the region. The gradual morphological transformation in truncorotalid populations that gives rise to *Tr. crassaformis* occurs in the upper Kapitean, in the vicinity of the Miocene-Pliocene boundary. The rarity of the species in early populations, and the wide morphotypic variation field that is associated with

Truncorotalia, make it difficult to identify the entry of *Tr. crassaformis* precisely. Considerable biostratigraphic refinement could be achieved, however, by adopting a population concept for the entry of *Tr. crassaformis* based on morphometric considerations.

The early history of *Tr. crassaformis* at Site 593 is marked by a significant degree of intraspecific variability, although there appears to be no systematic pattern to the variation on a level that could be used for biostratigraphic refinement. Morphotypic variants with lobate equatorial outlines and a tendency for late formed chambers to be progressively offset due to a higher rate of whorl translation in late ontogeny – *Tr.* cf. *crassaformis* – occur in similar numbers to typical specimens of *Tr. crassaformis.* Very rare inflated variants with a distinctly rounded equatorial outline resembling *Tr. ronda* (Blow) were also noted in at least two samples (Data appendix 2.1).

Divergent truncorotalid group

The *Tr. crassaformis* bioseries forms a conspicuous part of late Miocene assemblages at Site 593, although divergent morphological trends are noted in the lower Kapitean. The trends are associated with the appearance of slightly angular ventroconical forms that appear to be early forms of *Tr. crassaconica.*

***Truncorotalia* aff. *crassaconica*:** Prior to the introduction of the name *Tr. crassaconica* (Hornibrook 1982), keeled ventroconical truncorotalids from the early Pliocene with quadrate tests and four chambers in the outer whorl were generally viewed as part of the natural variation field of *Tr. crassaformis* (Jenkins 1971; Scott 1980). A similar, but less marked, dimorphism is noted in upper Kapitean and lower Opoitian truncorotalid populations at Site 593, at least 40 m below the lowest occurrence of *Tr. crassaconica* recorded by Hoskins (1990). These early populations include typical inflated forms of *Tr. crassaformis* with well rounded non-carinate peripheries, as well as less inflated angular forms that show greater ventral extension and have very poorly defined rudimentary keels – imperforate bands or slightly raised pustulose ridges around the peripheral margin (Figure 2.11D upper). The angular forms also tend to have a narrower umbilicus and a comparatively flat apertural-face that projects as a distinct peak above earlier formed chambers. Such forms are assigned here to *Tr.* aff. *crassaconica.*

The lowest occurrence of *Tr.* aff. *crassaconica* is noted in 593-15X-4, 90-93 cm (135.30 mbsf), just prior to the entry of typical rounded specimens of *Tr. crassaformis.* Scott (1980) has noted similar truncorotalids at Blind River in Marlborough with angular ventroconical profiles, 300 m below the first typical rounded forms of *Tr. crassaformis.* There appears to be no continuity of morphological variation between the angular and rounded forms and they are considered here to represent divergent morphotypic taxa. An authenticated evolutionary sequence has yet to be established, although *Tr.* aff. *crassaconica* and *Tr. crassaconica* would appear to represent early elements of a divergent truncorotalid bioseries. *Truncorotalia* aff. *crassaconica* extends at least up to the top of the studied section – the top of core 593-14X (120.30 mbsf) – and the lowest occurrence of *Tr. crassaconica* is noted by Hoskins (1990) in 593A-11X-1, 40 cm (94.50 mbsf). The above data highlight the need to reassess the lowest occurrence of *Tr. crassaconica* and possibly introduce criteria that identify early morphotypes as a separate species or subspecies.

Late Miocene coiling history of truncorotalids

Late Miocene populations of *Truncorotalia* are dominated almost exclusively by sinistrally-coiled specimens (Figure 2.13). Small contributions of dextrally-coiled shells are noted in the lower and upper *Tr. juanai* acme zones, although there are no significant intervals with majorities of dextrally-coiled shells, at least in the late Miocene. Pliocene intervals of dextrally-coiled *Tr. crassaformis* have been noted by Hornibrook (1982) at Site 284, the lowest of which occurs in core 284-11X. This is at a higher stratigraphic level than the present study reaches.

Summary of truncorotalid events

Important bioevents associated with the clade *Truncorotalia* are shown in Figure 2.11. The discontinuous stratigraphic record of *Tr. juanai* at Site 593, and the lack of an evolutionary sequence leading to its first appearance in the early late Miocene, suggest it originated outside the cool subtropical (temperate) Southwest Pacific region. The clade appears to have invaded New Zealand waters at least three times before permanently colonizing the region in the latest Miocene. This places a cautionary caveat on the use of late Miocene truncorotalid events, but it does not necessarily imply that they are significantly diachronous within the New Zealand region. Subsequent evolutionary events within the clade offer potential for refining correlations in the vicinity of the Miocene-Pliocene boundary, although detailed morphometric studies are needed.

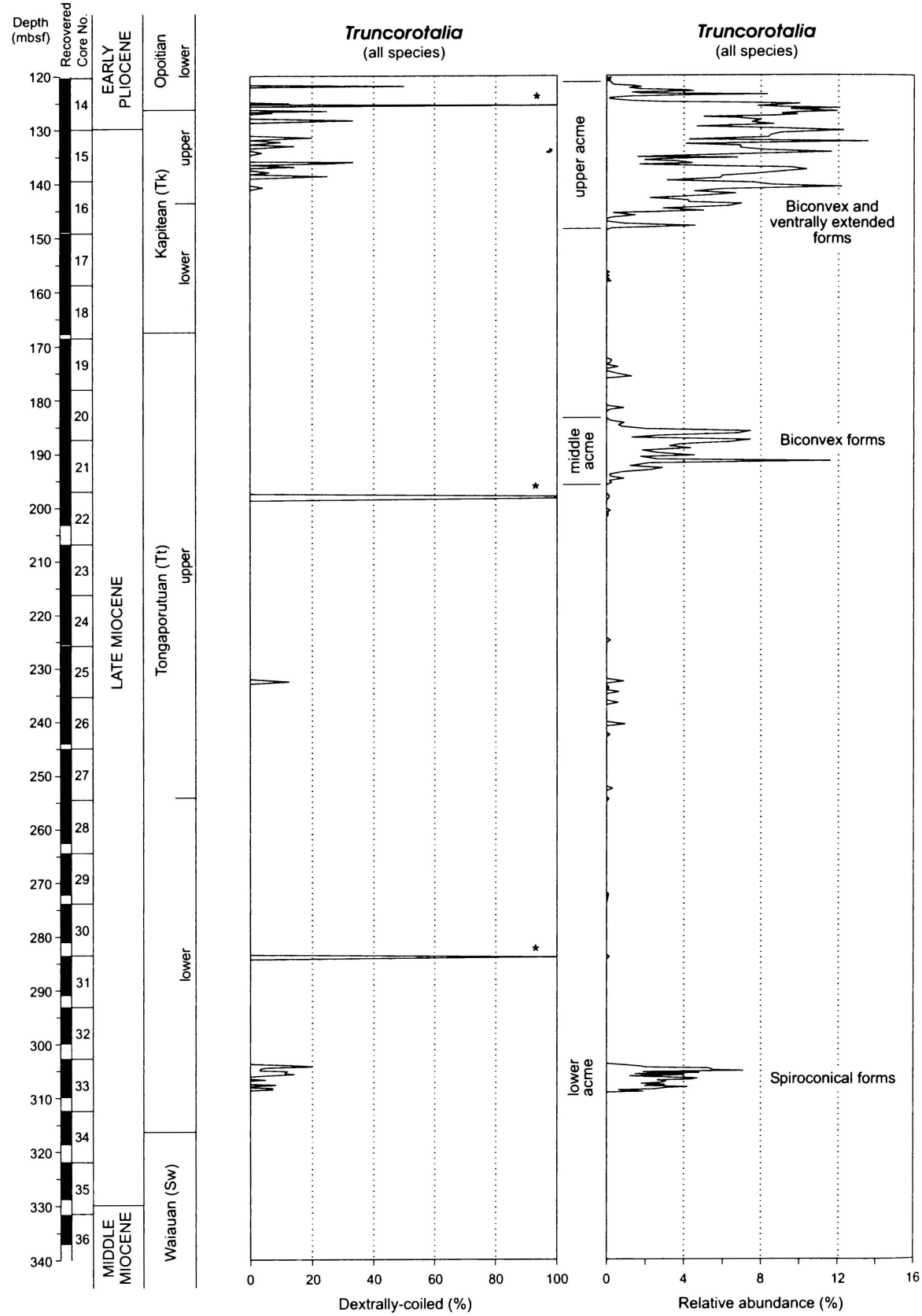


Figure 2.13 – Late Miocene changes in coiling and abundance associated with the planktic foraminiferal clade *Truncorotalia* (Figure 2.11). Three late Miocene acmes of *Truncorotalia* are noted at Site 593: a very narrow interval with spiroconical forms in the lower Tongaporutuan, a narrow interval in the upper Tongaporutuan with biconvex forms, and an extended interval in the upper Kapitean and lowermost Opoitian – across the Miocene-Pliocene boundary – where there is a rapid morphotypic expansion and evolutionary radiation in the clade. The principal morphological transformation involves a change from biconvex to ventrally-extended and conicotruncate forms. *Unreliable coiling determinations based on very low specimen counts.

Table 2.5 – Bioevents associated with the clade *Truncorotalia*. See Table 2.4 (page S2-28) for an explanation of Events, the Nature of events, and Reliability criteria.

Lower Opoitian

- LO *Truncorotalia crassaformis*
  593-14X-2, 46-49 cm (122.26 mbsf) – EV3
- Top upper *Truncorotalia juanai* acme
  593-14X-2, 71-75 cm (122.51 mbsf) – BG2

Upper Kapitean

- LO *Truncorotalia* aff. *crassaconica*
  593-15X-4, 90-93 cm (135.30 mbsf) – EV3

Lower Kapitean

- LO *Truncorotalia neojuanai* n. sp.
  593-16X-5, 0-3 cm (145.50 mbsf) – EV2
- Base upper *Truncorotalia juanai* acme
  593-16X-6, 47-50 cm (147.47 mbsf) – BG2

Upper Tongaporutuan

- Top middle *Truncorotalia juanai* acme
  593-20X-5, 117-119 cm (185.07 mbsf) – BG2
- Base middle *Truncorotalia juanai* acme
  593-21X-5, 0-2 cm (193.50 mbsf) – BG2

Lower Tongaporutuan

- Top lower *Truncorotalia juanai* acme
  593-33X-1, 59-61 cm (303.29 mbsf) – BG2
- LO *Truncorotalia juanai*, base lower *Truncorotalia juanai* acme
  593-33X-5, 29-31 cm (308.99 mbsf) – BG2

HIRSUTELLA

The clade *Hirsutella* (Figure 2.14) comprises a relatively small but persistent part of late Miocene assemblages at Site 593 (Figure 2.15). Two distinct groups of hirsutellids are recognized, the most common being slightly inflated scituline forms (e.g. *Hr. scitula*) and a spiroconical group with keeled or sharp edged peripheries (e.g. *Hr. margaritae*). Species associated with both groups have very similar smooth densely perforate test ultrastructures and they are separated primarily on the basis of their axial test shape.

Hirsutella panda bioseries

The origin of *Hr. panda* is poorly understood. Kennett & Srinivasan (1983) included it with the globoconellids and suggested it may have evolved from *Globoconella praescitula*

in the middle Miocene. Cifelli & Scott (1986) also suggested it evolved from an early globoconellid ancestor, but that it was more closely allied to menardine species. It is considered here, however, on the basis of its low-arched aperture, smooth densely perforate test ultrastructure, and sharp-edged spiroconical axial profile, to be more closely allied with the hirsutellids. This view is supported by the observed continuum of morphological variation at Site 593 between strongly keeled specimens of *Hr. panda* and weakly keeled and sharp-edged non-carinate specimens of *Hr.* cf. *ichinosekiensis* – a form that appears to be an early morphotypic variant of *Hr. margaritae* (Jenkins & Srinivasan 1986). These species are included here in what is provisionally termed the *Hr. panda* bioseries. Sharp-edged spiroconical hirsutellids are very poorly represented in the upper Tongaporutuan and Kapitean and it is not possible to identify a complete record of the morphological transformation between *Hr.* cf. *ichinosekiensis* and *Hr. margaritae,* at least within the New Zealand region.

***Hirsutella panda*:** Strongly keeled specimens of *Hr. panda* comprise a small part of lower Tongaporutuan and upper Waiauan assemblages, except for a very narrow acme zone near the top of the *Gc*-593/A interval of dextrally-coiled *Globoconella miotumida,* where the species forms a major part of assemblages (Figure 2.15). This occurs between 593-33X-5, 41-43 cm (309.11 mbsf) and 593-33X-3, 1-3 cm (305.71 mbsf). The high abundance of *Hr. panda* is a distinctive feature of the acme zone, but is variable in the range 0.2-20%. The acme appears to represent a unique interval, at least on a scale not repeated in the late Miocene. Scott (1995) has noted similar spikes in the abundance of *Hr. panda* in several expanded sections in onland New Zealand, near the Kaiti Coiling Zone. This suggests the *Hr. panda* acme zone may serve as a useful criterion for the KCZ.

The highest occurrence of *Hr. panda* is noted by Scott (1992) to be a well defined event in the lower Tongaporutuan prior to the highest occurrence of *Globoquadrina dehiscens.* The present study, however, identifies equivocal data regarding the species disappearance. Strongly keeled forms that are typical of *Hr. panda* are noted up to 593-32X-4, 48-50 cm (298.08 mbsf), close to the level recorded by Jenkins & Srinivasan (1986) and Scott (1992). Weakly keeled morphotypes *Hr.* cf. *ichinosekiensis* are also noted in the same populations and they appear to gradually replace strongly keeled forms at higher stratigraphic levels. Similar weakly keeled forms also occur above the highest occurrence of strongly keeled *Hr. panda.* The significant stratigraphic overlap between these

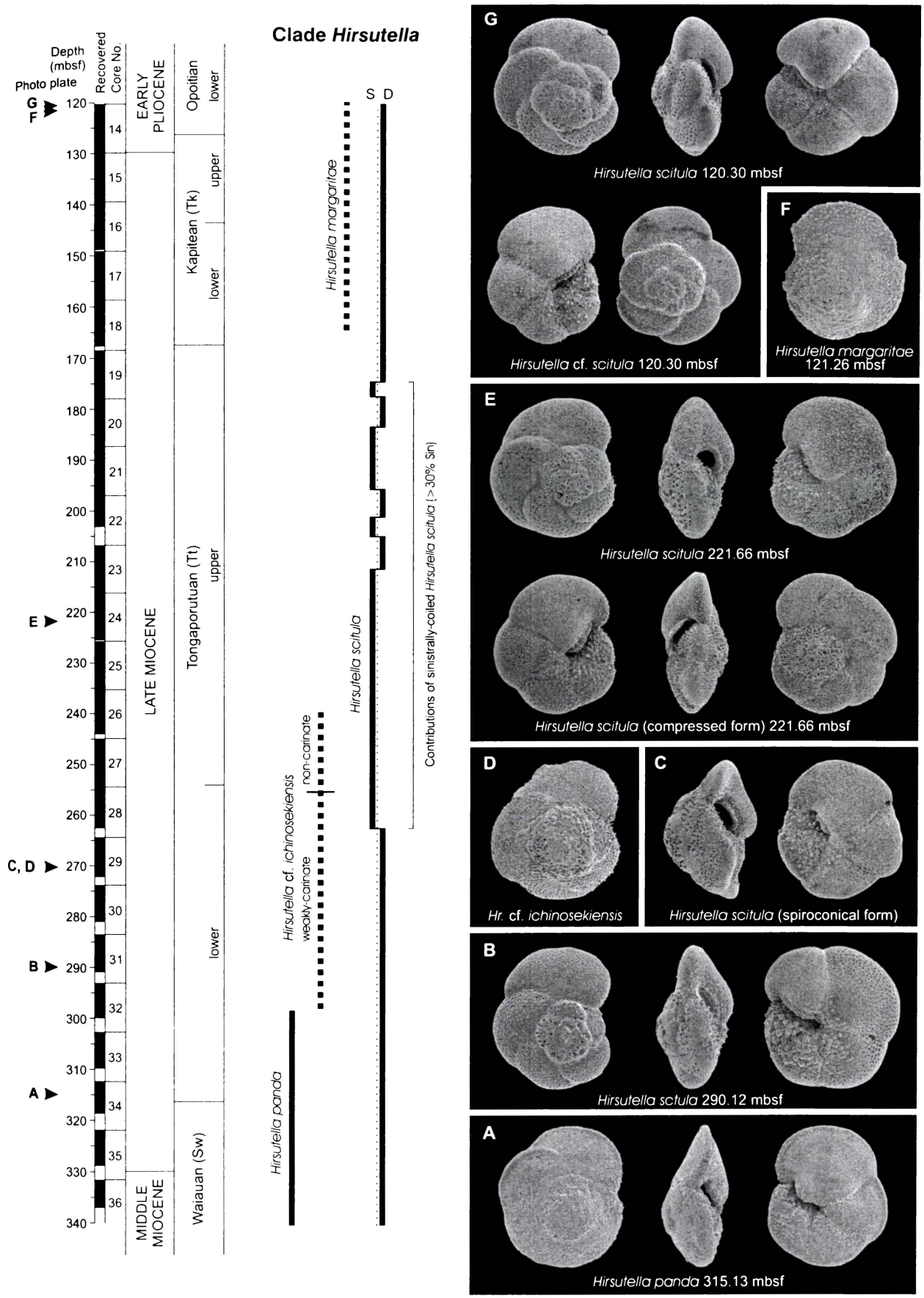


Figure 2.14 – Late Miocene elements of the planktic foraminiferal clade *Hirsutella*, which includes the early part of the *Hirsutella hirsuta* lineage (*Hirsutella panda* – *Hr.* cf. *ichinosekiensis* – *Hr. margaritae*) which is poorly represented at Site 593. *Hirsutella scitula* does not form a part of the lineage, but is included in the clade on the basis of its smooth, densely perforate surface ultrastructure. Increased contributions of sinistrally-coiled *Hirsutella scitula* occur in the upper Tongaporutuan. S = sinistral; D = dextral.

morphotypes, and the gradual replacement of strongly keeled forms by weakly keeled forms, appears to represent a modal shift in the morphotypic variation field of *Hr. panda* and has features of an evolutionary sequence. The disappearance of *Hr. panda,* which is marked by the highest occurrence of strongly keeled specimens of *Hr. panda*, is poorly defined, and a population concept for the highest occurrence of *Hr. panda* based on morphometric considerations may provide a more reliable datum for correlation.

***Hirsutella* cf. *ichinosekiensis*:** Jenkins & Srinivasan (1986) were the first to record sharp-edged spiroconical specimens of *Hr.* cf. *ichinosekiensis* at oceanic sites in the Tasman Sea region, including Site 593. The abundance of *Hr.* cf. *ichinosekiensis* decreases above the highest occurrence of *Hr. panda* and the weakly keeled forms are gradually replaced in higher horizons by sharp-edged spiroconical forms that are non-carinate. The stratigraphic overlap between weakly keeled and non-carinate forms and the gradual upward increase in the number of specimens without keels represent a continuation of the evolutionary sequence that gives rise to *Hr.* cf. *ichinosekiensis,* and is considered here to be part of the same bioseries. Sharp-edged specimens of *Hr.* cf. *ichinosekiensis* are extremely rare in the upper Tongaporutuan, and specimens in the Kapitean and lower Opoitian have the appearance of being intermediate morphotypic variants between *Hr.* cf. *ichinosekiensis* and *Hr. margaritae.*

Very weakly keeled morphotypes of *Hr.* cf. *ichinosekiensis* are last noted in 593-28X-1, 58-60 cm (255.28 mbsf), immediately below the highest occurrence of *G. dehiscens,* although non-carinate forms with highly acute peripheral margins persist upwards to 593-26X-3, 117-117 cm (240.07 mbsf). These new data place a cautionary caveat on the use of the highest occurrence of *Hr. panda* and highlight the need for a more detailed investigation of late Miocene sharp-edged spiroconical hirsutellids to improve their utility in biostratigraphy.

***Hirsutella margaritae*:** The lowest occurrence of *Hr. margaritae* is often used as a biostratigraphic marker in tropical regions for the base of the Pliocene (Bolli & Saunders 1985). Typical morphotypes of *Hr. margaritae* that are weakly keeled have not been found in the present study, but sharp-edged non-carinate morphotypes are noted very rarely in the Kapitean and lower Opoitian. They appear to be intermediate morphotypic variants between *Hr. margaritae* and the Tongaporutuan species *Hr.* cf. *ichinosekiensis.* Typical

specimens of *Hr. margaritae* are first recorded by Hornibrook (1982) at Site 284 in the lower part of core 284-13, at a stratigraphic level that is very close to the top of the present study.

Scituline hirsutellids

Late Miocene hirsutellid populations from Site 593 largely comprise biconvex scituline forms (Figure 2.14) that encompass a wide range of morphotypic variation, which extends to compressed biconvex forms (Figure 2.14E, lower) and spirally domed forms (Figure 2.14C). There appears to be no systematic pattern to the distribution of these morphotypes in stratigraphic space and they are all included here in *Hr. scitula.*

Hirsutella scitula dominates hirsutellid populations at Site 593, but it comprises a relatively minor part of late Miocene assemblages at the same site, except for an extended interval in the upper Tongaporutuan and lower Kapitean where it maintains an average abundance of 4.8%. This is significant in terms of the species much lower abundances both above and below this interval, and it is also significant in terms of modern assemblages where the relative abundance of *Hr. scitula* rarely exceeds 2% (Hilbrecht 1996).

Late Miocene coiling history of hirsutellids

The coiling signature of *Hirsutella* (Figure 2.15), which is largely based on *Hr. scitula,* shows several upper Tongaporutuan intervals where there are significant contributions and sometimes majorities of sinistrally-coiled shells. These intervals largely occur in the vicinity of an extended interval of increased hirsutellid abundance, although there appears to be no direct correlation between influxes of sinistrally-coiled *Hirsutella* and perturbations in the abundance signature (Figure 2.15). The intervals of increased contributions of sinistrally-coiled shells represent significant departures from the dextral coiling trend that is most commonly associated with hirsutellid species (Kennett 1969; Jenkins 1971; Bolli & Saunders 1985; Scott et al. 1990), and they offer potential biostratigraphic refinement, a suggestion first mooted by Scott (1992). Similar coiling reversals in *Hr. scitula* have been noted in Tortonian and Messinian (late Miocene) sections in the Mediterranean and northeast Atlantic (Sierro et al. 1993), although the utility of these bioevents for correlation is unlikely to extend beyond a regional level.

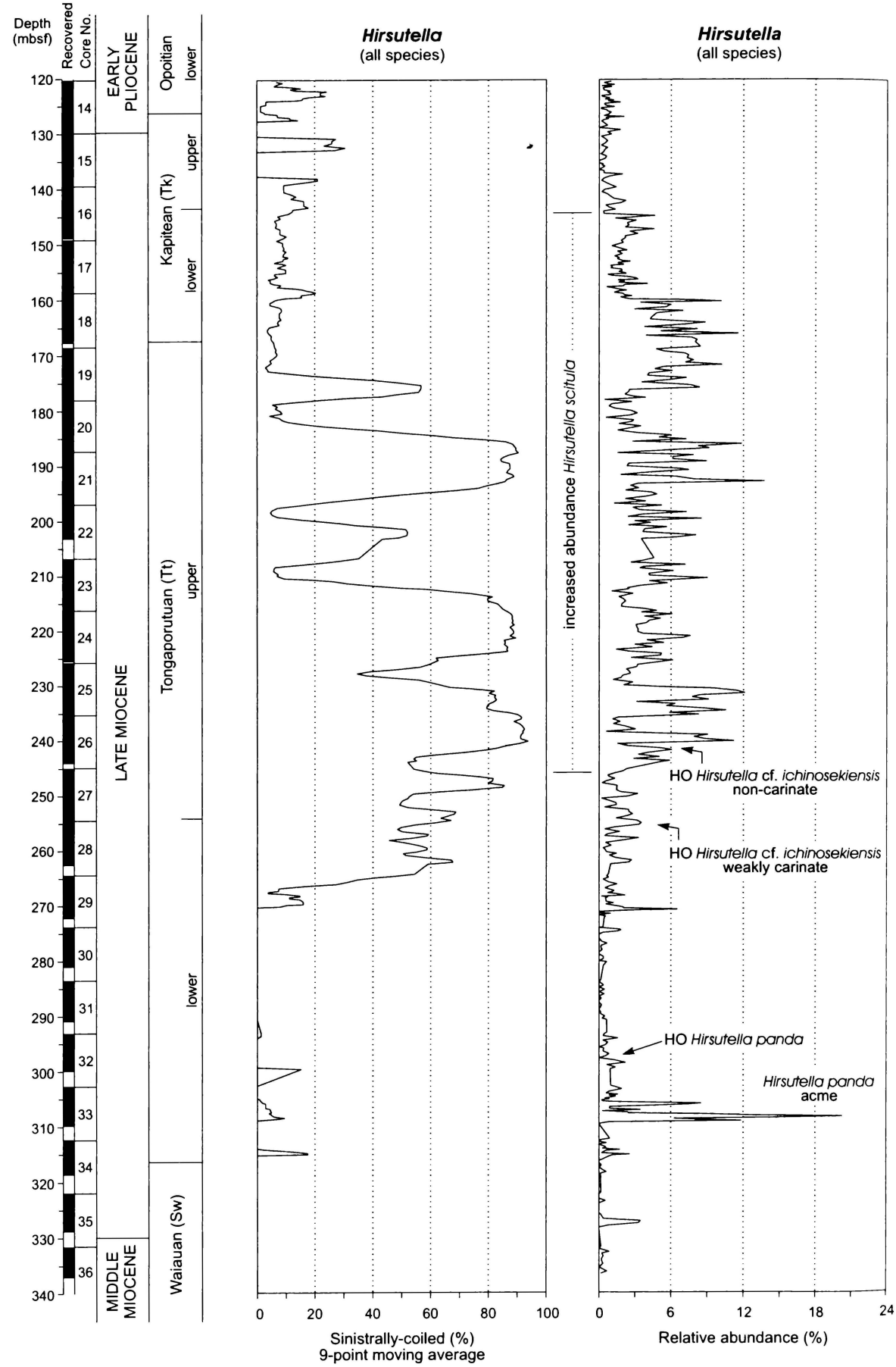


Figure 2.15 – Late Miocene changes in coiling and abundance associated with the planktic foraminiferal clade *Hirsutella*. The increased abundance of hirsutellids in the upper Tongaporutuan and lower Kapitean is largely due to increased representations of sinistrally-coiled *Hirsutella scitula*.

Summary of hirsutellid events

Important bioevents associated with the clade *Hirsutella* are shown in Figure 2.14. Evolutionary events associated with keeled and sharp-edged spiroconical species within the clade are potentially useful for late Miocene correlation, although the utility of these events is limited by the group's decrease in abundance in the upper Tongaporutuan (middle late Miocene). This appears to be associated with a gradual withdrawal of sharp-edged spiroconical hirsutellids from the New Zealand region, presumably to lower latitudes where the extant species *Hr. hirsuta* is most common (Hilbrecht 1996). Significantly, the withdrawal of sharp-edged spiroconical hirsutellids coincides with an increase in the abundance of scituline hirsutellids and the first of several late Miocene coiling reversals in *Hr. scitula.* These changes in hirsutellid populations are distinct from those in any other part of the late Miocene and appear to represent a major threshold in local planktic biogeography. The withdrawal of warm-water planktic species prior to these changes in hirsutellid populations suggests they may be linked to relatively cool paleoceanographic conditions at the onset of Miocene isotope event Mi7 (Miller et al. 1991).

Table 2.6 – Bioevents associated with the clade *Hirsutella.* See Table 2.4 (page S2-28) for an explanation of Events, the Nature of events, and Reliability criteria.

Upper Tongaporutuan

- HO *Hirsutella* cf. *ichinosekiensis,* non-carinate morphotypes
  593-26X-4, 7-9 cm (240.07 mbsf) – EV3

Lower Tongaporutuan

- HO *Hirsutella* cf. *ichinosekiensis,* weakly carinate morphotypes
  593-28X-1, 58-60 cm (255.28 mbsf) – EV3
- HO *Hirsutella panda,* strongly keeled morphotypes
  593-32X-4, 48-50 cm (298.08 mbsf) – EV2
- Top *Hirsutella panda* acme, >10% abundance
  593-33X-2, 135-137 cm (305.55 mbsf) – OP2
- Base *Hirsutella panda* acme, >10% abundance
  593-33X-5, 41-43 cm (309.11 mbsf) – OP2

NEOGLOBOQUADRINA

Neogloboquadrina mayeri continuosa (Blow) is generally considered to be the ancestor of the extant species *Nq. pachyderma* (Jenkins 1966, 1967, 1971; Bandy 1972a; Srinivasan & Kennett 1976, 1981; Kennett & Srinivasan 1980; Stott & Webb 1989), although the phylogenetic relationships concerning *Nq. mayeri continuosa* remain somewhat enigmatic

and controversial. Jenkins (1971) suggests *'Globorotalia' mayeri mayeri* gave rise to *'Globorotalia' mayeri continuosa* in the middle Miocene, which in turn gave rise to *Nq. pachyderma*. Bolli & Saunders (1982) have also suggested *'Globorotalia' continuosa* is a reduced-chambered intraspecific variant of *'Globorotalia' mayeri* and that it evolved into *Nq. pachyderma* in the early late Miocene. In contrast, Kennett & Srinivasan (1983) have postulated *Nq. continuosa* had no intraspecific or direct phylogenetic link with *'Globorotalia' mayeri*, although they supported the widely held view that *Nq. continuosa* evolved into *Nq. pachyderma*. The high-resolution sequence at Site 593 supports the view of Bolli & Saunders (1982) that *Nq. mayeri continuosa* and *Nq. mayeri nympha* are intraspecific variants of *Nq. mayeri* s.s., although there is no evidence at the site of an evolutionary sequence leading to the appearance of *Nq. pachyderma* (Figure 2.16)

***Neogloboquadrina mayeri* s.l.**

Neogloboquadrina mayeri s.l. (Figure 2.16A) forms a major part of most uppermost Waiauan and lowermost Tongaporutuan assemblages at Site 593 (Figure 2.17). The range of intraspecific morphotypic variation extends to forms with four and one-half full-sized chambers in the outer whorl [*Nq. mayeri continuosa* (Blow)], kummerforms with less than four and one-half chambers in the outer whorl [*Nq. mayeri nympha* (Jenkins)], and forms with four and one-half or more chambers in the outer whorl [*Nq. mayeri* s.s. (Cushman and Ellisor)]. Apart from the disparate number of chambers in the outer whorl, these subspecies all have compact low trochospiral tests, inflated globular chambers, distinctly cancellate surface textures, open umbilicuses, and slightly elongated arched apertures. They also show similar changes in abundance and coiling, and are viewed here as intraspecific morphotypic variants of *Nq. mayeri* s.l.

The abundances of all three subspecies remain relatively high throughout the lowermost part of the studied core section, although total combined abundances decrease rapidly to less than 5% above 593-34X-1, 1-3 cm (312.31 mbsf) (Figure 2.17). This well defined horizon, which occurs within the lowermost part of the *Gc*-593/A interval of dextrally-coiled *Globoconella miotumida*, marks the highest occurrence of *Nq. mayeri* s.l. This occurs slightly below the level of the first significant contributions of dextrally-coiled *Nq. mayeri* s.l. (see later) and the level where *Nq. mayeri* s.l. becomes very rare.

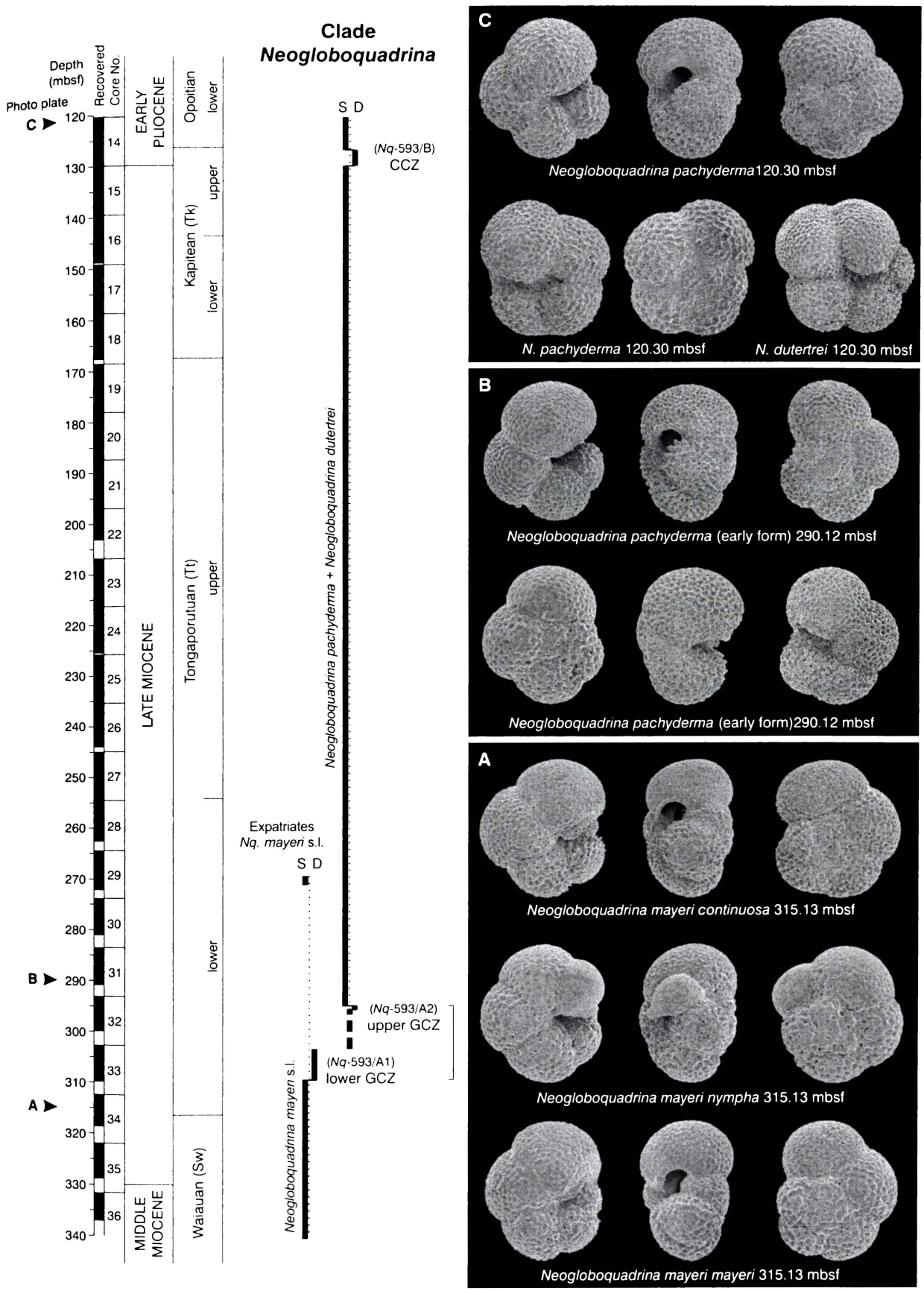


Figure 2.16 – Late Miocene species associated with the clade *Neogloboquadrina*. *Neogloboquadrina mayeri* s.l. is replaced by *Nq. pachyderma* s.l. in the vicinity of the base of core 593-32X, where there is a significant increase in the contribution of dextrally-coiled specimens (Figure 2.17). Rare expatriates of *Nq. mayeri* s.l. (mostly *Nq. mayeri continuosa*) occur in core 593-29X. Intervals with significant relative contributions of dextrally-coiled specimens, *Nq*-593/A1 and *Nq*-593/A2 = GCZ (Glomar Coiling Zone), *Nq*-593/B = CCZ (Challenger Coiling Zone). S = sinistral; D = dextral.

The highest occurrence of *Nq. mayeri* s.l. is marked by the simultaneous disappearance of all three subspecies in 593-33X-1, 27-29 cm (302.97 mbsf). This occurs in the immediate vicinity of the top of the lower *Truncorotalia juanai* acme zone (Figure 2.2). The disappearance of *Nq. mayeri* s.l. is reliably located at Site 593, although it occurs in an interval where *Neogloboquadrina* is extremely rare and there are significant contributions of dextrally-coiled specimens (see later). The datum is unlikely to be reliably located in sequences with poor planktic representations, because of the rarity of *Neogloboquadrina*.

Significantly, a narrow interval of rare expatriates of *Nq. mayeri* s.l. is noted in core 593-29X in the vicinity of the *Gc*-593/B interval of dextrally-coiled *Globoconella miotumida* (Figure 2.2). This is substantially above the highest persistent occurrence of *Nq. mayeri* s.l. and the expatriates occur jointly with *Nq. pachyderma*. All three subspecies of *Nq. mayeri* s.l. are represented as expatriates, although *N. mayeri continuosa* is the most common. The subsequent reappearance of expatriates suggests the disappearance of the species is biogeographically controlled.

***Neogloboquadrina pachyderma* s.l.**

Neogloboquadrina pachyderma s.l. (Figure 2.16B and C) includes forms with less than four and one-half chambers in the outer whorl (*Nq. pachyderma*) and forms with four and one-half or more chambers in the outer whorl (*Nq. dutertrei*). The first rare specimens of *Nq. pachyderma* s.l. are noted in 593-33-1, 1-3 cm (302.71 mbsf) immediately above the highest occurrence of *Nq. mayeri* s.l. These early forms are morphologically distinct from the upper specimens of *Nq. mayeri* s.l. and there is no evolutionary sequence between them at Site 593, contrary to widely held views concerning the evolutionary origin of *Nq. pachyderma* from *Nq. mayeri* (Jenkins 1966, 1967, 1971, Bandy 1972; Srinivasan & Kennett 1976, 1981; Kennett & Srinivasan 1980; Stott & Webb 1989). The observed morphological discontinuity suggests the sequence may be incomplete, although this is unlikely given the changes in neogloboquadrinid abundance and coiling near the lowest occurrence of *Nq. pachyderma* s.l. These features suggest the stratigraphic juxtaposition of *Nq. mayeri* s.l. and *Nq. pachyderma* is a biogeographically controlled event. The mounting weight of evidence for contemporary biogeographically restricted populations of *Nq. mayeri* s.l. and *Nq. pachyderma* suggests the latter species evolved outside the cool subtropical (temperate) Southwest Pacific region.

Late Miocene coiling history of neogloboquadrinids

Late Miocene populations of *Neogloboquadrina* are largely dominated by sinistrally-coiled specimens, although at least three narrow intervals are noted with significant contributions of dextrally-coiled specimens, at least several times above average background values (Figure 2.17).

The lower *Nq*-593/A1 and *Nq*-593/A2 intervals, which are respectively associated with the species *Nq. mayeri* s.l. and *Nq. pachyderma,* occur in the lowermost Tongaporutuan where *Neogloboquadrina* is extremely rare (Figure 2.17). These intervals represent a single zone of dextrally-coiled *Neogloboquadrina* that extends upwards from 593-33X-5, 41-43 cm (309.11 mbsf) to 593-32X-1, 141-143 cm (294.51 mbsf). Synchronous changes in coiling and the abundance of *Neogloboquadrina,* in combination with the stratigraphic juxtaposition of *Nq. mayeri* s.l. and *Nq. pachyderma,* suggest there are common biogeographic controls on all of these events.

The *Nq*-593/B interval, which is associated with *Nq. pachyderma,* occurs in the uppermost Kapitean. It is a narrow well-defined interval that extends upwards between 593-14X-7, 20-23 cm (129.50 mbsf) and 593-14X-5/26-29 cm (126.56 mbsf). The proportion of dextrally-coiled shells is variable throughout the *Nq*-593/B interval, in the range 9-87%, but averages 43%, seven-times the average baseline proportion of dextrally-coiled *Neogloboquadrina.*

To facilitate the use of these very distinctive intervals of dextrally-coiled *Neogloboquadrina* in biostratigraphy, the approach of Scott (1995) is followed and they are defined here as coiling zones.

Glomar Coiling Zone (GCZ): The *Nq*-593/A1 and *Nq*-593/A2 intervals of dextrally-coiled *Neogloboquadrina* are included in the newly named Glomar Coiling Zone (GCZ). The lower Tongaporutuan core section that is inclusive of 593-33X-5, 41-43 cm (309.11 mbsf) and 593-32X-1, 141-143 cm (294.51 mbsf) is designated as the reference section for the GCZ. The name is taken from the drillship Glomar Challenger, which cored Site 593. The GCZ is subdivided into the lower-GCZ for that part which is associated with *Nq. mayeri* s.l., and the upper-GCZ for that part which is associated with *Nq. pachyderma* (Figure 2.16).

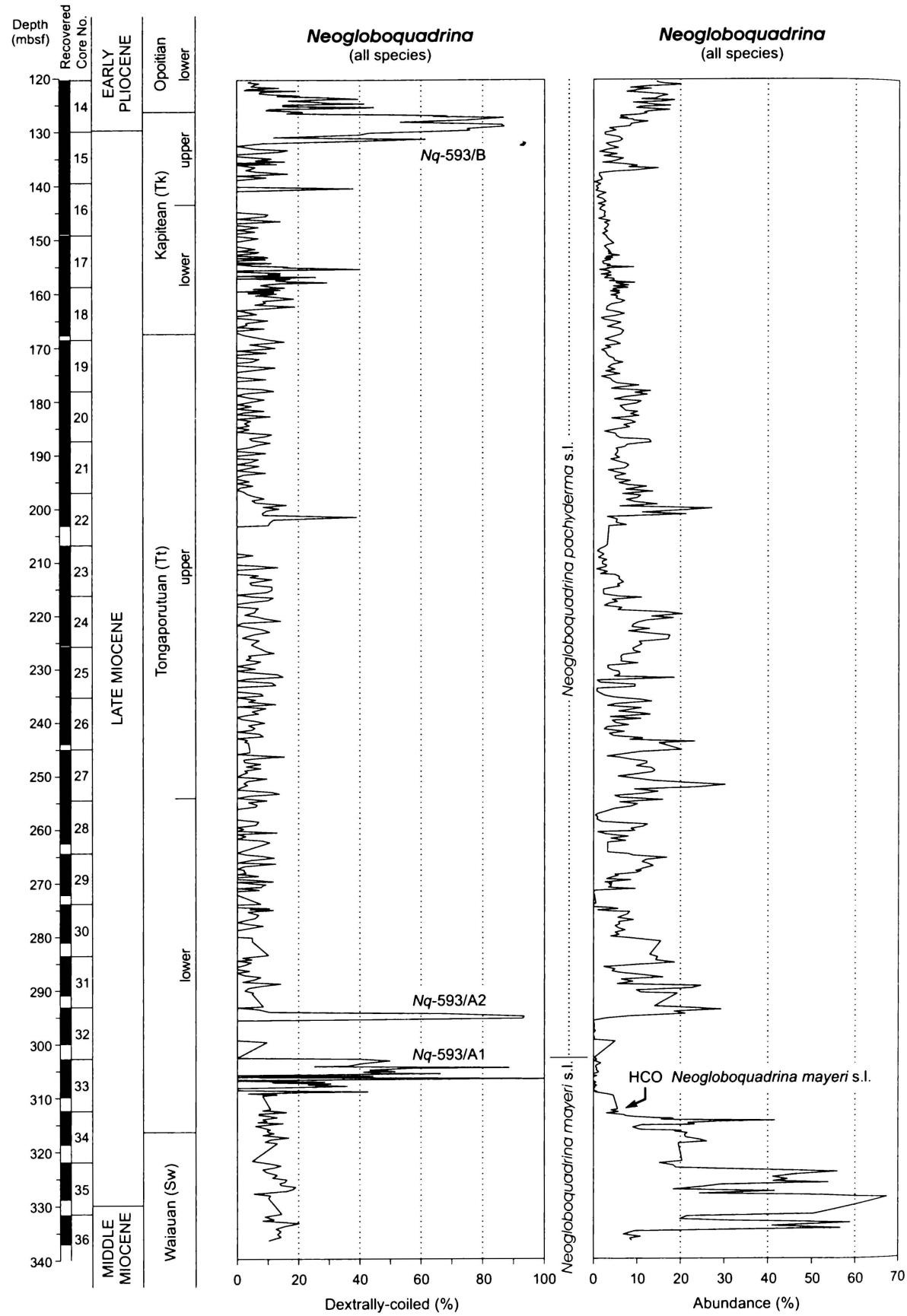


Figure 2.17 – Late Miocene changes in coiling and abundance associated with the clade *Neogloboquadrina* (Figure 2.16). *Neogloboquadrina mayeri* s.l. is replaced by *Nq. pachyderma* in the vicinity of the base of core 593-32X. This coincides with an interval where *Neogloboquadrina* is extremely rare and there are significant relative contributions of dextrally-coiled *Neogloboquadrina*. Intervals with significant contributions of dextrally-coiled specimens, *Nq*-593/A1 and *Nq*-593/A2 = GCZ (Glomar Coiling Zone), *Nq*-593/B = CCZ (Challenger Coiling Zone).

The base of the GCZ occurs immediately below the top of the *Gc*-593/A interval of dextrally-coiled *Globoconella miotumida* and serves as a useful criterion for distinguishing the *Gc*-593/A and *Gc*-593/B intervals. The top of the GCZ occurs a short distance above the highest occurrence of strongly keeled *Hirsutella panda.*

Challenger Coiling Zone (CCZ): The uppermost Kapitean interval of dextrally-coiled *Nq. pachyderma,* between 593-14X-7, 20-23 cm (129.50 mbsf) and 593-14-5, 26-29 cm (126.56 mbsf), is defined here as the Challenger Coiling Zone (CCZ). The name is taken from the Challenger Plateau where Site 593 was drilled. Kennett & Vella (1975) appear to have noted the same interval in the earliest Pliocene section of Site 284, between cores 284-15 and 284-14. Similar intervals of dextrally-coiled *Nq. pachyderma* have also been noted in Plio-Pleistocene sections from onland New Zealand (Jenkins 1967, 1971; Collen & Vella 1973; Kennett & Watkins 1974), although the CCZ appears to be the only such interval associated with the upper Kapitean index species *Globoconella sphericomiozea.*

The base of the CCZ occurs immediately below the lowest occurrence of *Globoconella pliozea,* and the top of the CCZ occurs in very close proximity to the lowest occurrence of *Gc. puncticulata* – a species that defines the base of the Opoitian Stage. In this respect, the top of the CCZ is useful as a proxy for the Kapitean-Opoitian boundary.

Summary of neogloboquadrinid events

Important bioevents associated with the clade *Neogloboquadrina* are shown in Figure 2.16. The clade comprises a major part of late middle Miocene assemblages, and occurs throughout the late Miocene. A key feature of the clade is the replacement of warm-water forms (*Nq. mayeri* s.l.) by species that have a tolerance for colder water (*Nq. pachyderma*) (Kennett & Srinivasan 1983). This occurs in the vicinity of the base of the Tongaporutuan Stage and is preceded by a marked decrease in the abundance of *Nq. mayeri* s.l. and a significant increase in the relative contribution of dextrally-coiled shells. These changes within the clade occur near the base of the late Miocene and they appear to represent a major biological threshold in the transition from relatively warm middle Miocene climates to cooler late Miocene climates. The stepwise nature of these changes is indicative of a paleoceanographically-forced withdrawal of *Nq. mayeri* s.l. from the cool subtropical (temperate) Tasman Sea region and a coeval invasion by *Nq. pachyderma.* In this respect, the highest occurrence of *Nq. mayeri* s.l. and the lowest occurrence of *Nq. pachyderma* are

likely to be diachronous events, but not necessarily so within the southern Tasman Sea region.

Coiling reversals in earliest Pliocene populations of *Neogloboquadrina* may also be linked to expansions and contractions in the clades biogeographic range, and are potentially useful for correlation in the southern Tasman Sea region (including the New Zealand region).

Table 2.7 – Bioevents associated with the clade *Neogloboquadrina*. See Table 2.4 (page S2-28) for an explanation of Events, the Nature of events, and Reliability criteria.

Upper Kapitean

- Top *Nq*-593/B interval, >30% dextral *Neogloboquadrina pachyderma*
  593-14X-3, 23-26 cm (123.53 mbsf) – BG2
- Base *Nq*-593/B interval, >30% dextral *Neogloboquadrina pachyderma*
  593-15X-2, 11-14 cm (131.51 mbsf) – BG2

Lower Tongaporutuan

- Top *Nq*-593/A interval, >30% dextral *Neogloboquadrina pachyderma*
  593-32X-1, 141-143 cm (294.51 mbsf) – BG2
- LO *Neogloboquadrina pachyderma*
  593-32CC, 2-4 cm (299.67 mbsf) – BG3
- HO *Neogloboquadrina mayeri* s.l., excludes rare expatriates near *Gc*-593/C interval
  593-33-1, 1-3 cm (302.71 mbsf) – BG2
- Base *Nq*-593/A interval, >30% dextral *Neogloboquadrina mayeri* s.l.
  593-33X-5, 29-31 cm (308.99 mbsf) – BG3
- HCO *Neogloboquadrina mayeri* s.l., >5% abundance
  593-34X-1, 87-89 cm (313.17 mbsf) – BG2

MISCELLANEOUS WARM-WATER TAXA

Taxa other than those already described with preferences for tropical and warm subtropical water, including *Globigerinoides, Globoquadrina, Menardella, Globorotalia, Globorotaloides, Sphaeroidinellopsis,* and *Globigerinella* (Kennett & Srinivasan 1983; Jenkins 1992) (Figure 2.18), are most commonly found in the lower part of the studied section, below core 593-24X, although they generally comprise a small part (<5%) of planktic assemblages (Figure 2.19). These same taxa are very rare in the upper part of the section. The up-core decrease in the abundance of warm-water taxa appears to be indicative of a gradual biogeographic withdrawal of such forms from the southern Tasman Sea, and is potentially useful as a general indicator of stratigraphic position when trying to

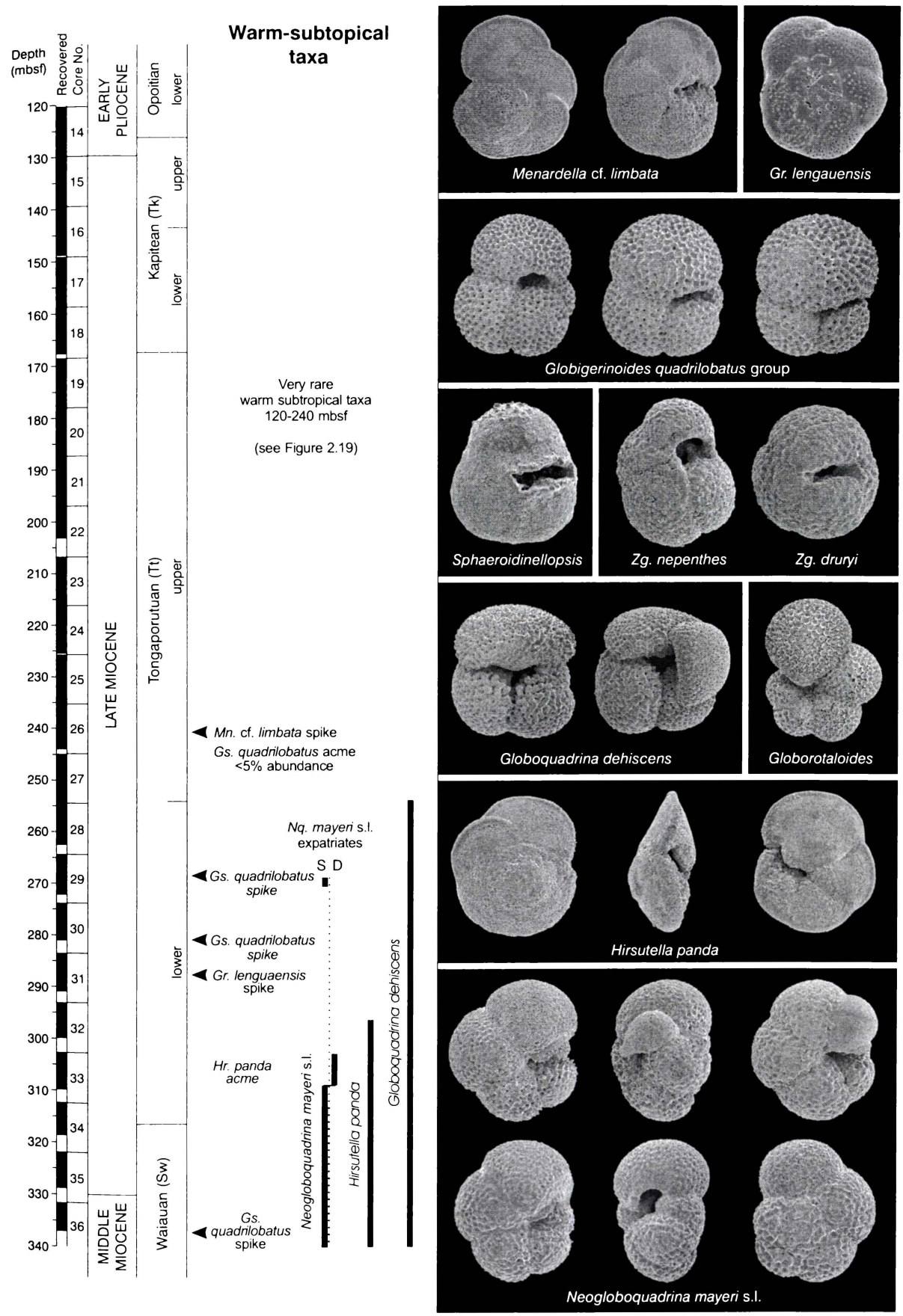


Figure 2.18 – Distinctive abundance spikes, acme zones, coiling, and highest occurrences associated with late Miocene warm-subtropical taxa. Abundance spikes and acmes associated with *Menardella* cf. *limbata*, *Globorotalia lenguaensis*, and the *Globigerinoides quadrilobatus* group are poorly defined events with maximum abundances of <5%, but are potentially useful for biostratigraphic refinement, particularly when used in conjunction with other bioevents.

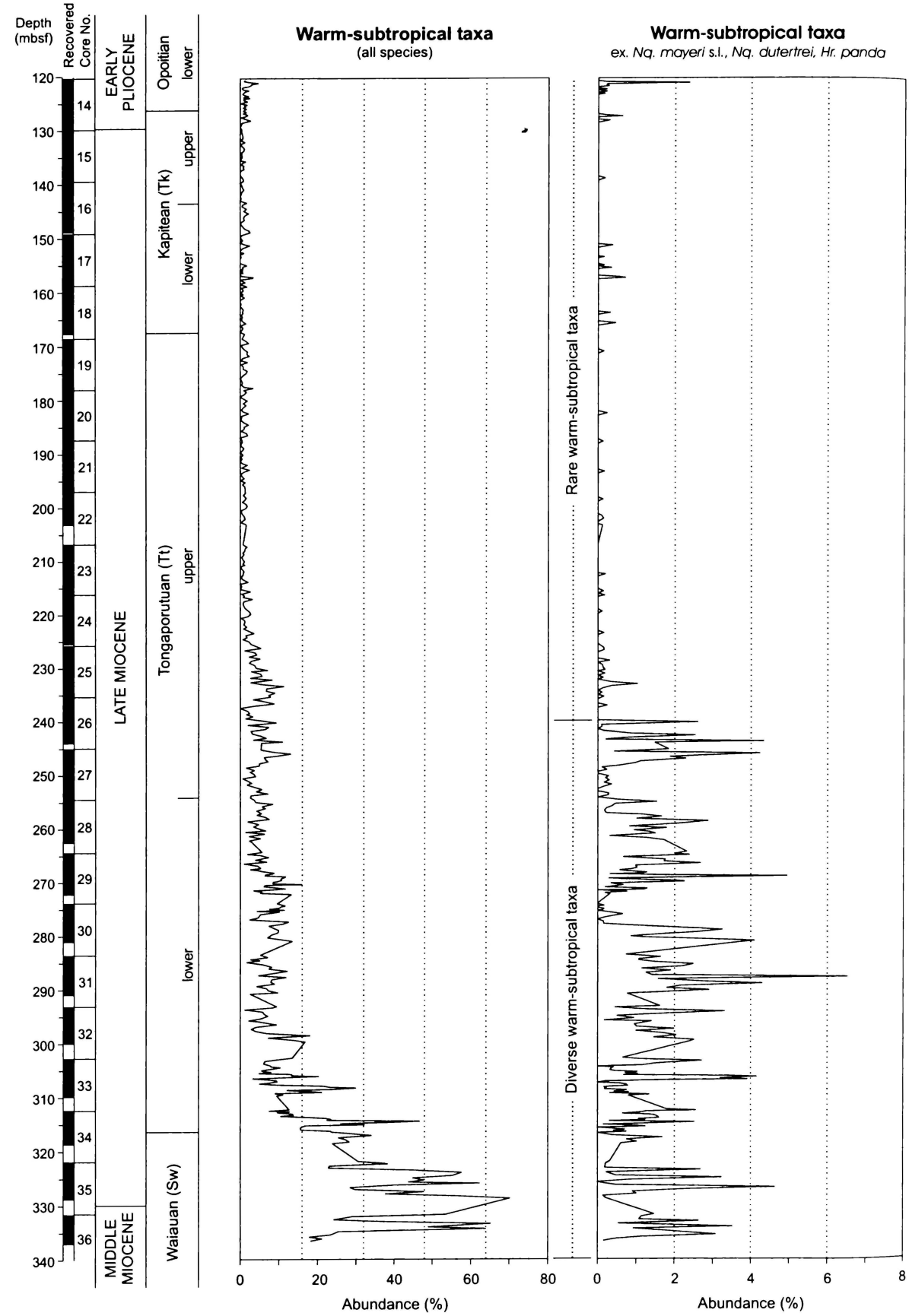


Figure 2.19 – Changes in abundance associated with warm-subtropical taxa (see Figure 2.18). The very rapid decrease in warm-subtropical taxa near the middle-late Miocene boundary is largely associated with a decrease in the abundance of *Neogloboquadrina mayeri* s.l. The abundance and diversity of warm-subtropical taxa also decrease markedly in the lowermost part of upper Tongaporutuan.

differentiate between lower and upper Tongaporutuan faunas. This has particular relevance for the correlation of neritic faunas where the intra-Tongaporutuan marker species *Globoquadrina dehiscens* is often absent, but subtropical species that dwell in the shallow mixed-layer may still be found.

Scott (1992) alluded to the potential of using late Miocene incursions of *Menardella, Globorotalia,* and *Globigerinoides* for correlation in the New Zealand region. These taxa are very poorly represented at Site 593 and have discontinuous ranges, although distinctive abundance spikes are noted in *Menardella* cf. *limbata* and *Globorotalia lenguaensis,* and several abundance spikes and a narrow poorly defined acme zone are noted in association with the *Globigerinoides quadrilobatus* group (Table 2.8). These influxes of warm-water taxa all occur in the lower part of the studied core section and are potentially useful for biostratigraphic refinement, particularly in eastern North Island sequences where warm-water taxa are generally more common (Scott 1991).

Warm-water subtropical taxa	Sample	mbsf
Menardella cf. *limbata*	593-26X-4, 7-9	240.07
HO *Globoquadrina dehiscens**	593-27CC, 10-12	254.49
Globigerinoides quadrilobatus gp	593-29X-4, 6-8	268.86
Top *Globigerinoides quadrilobatus* gp acme	593-26X-5, 102-104	242.13
Base *Globigerinoides quadrilobatus* gp acme	593-27X-2, 107-109	247.67
Globigerinoides quadrilobatus gp	593-29X-4, 6-8	268.86
Globigerinoides quadrilobatus gp	593-30X-5, 102-104	280.92
Globorotalia lengauensis	593-31X-3, 117-119	287.67
HO *Hirsutella panda**	593-32X-4, 48-50	298.08
HO *Neogloboquadrina mayeri* s.l.*	593-33X-1, 1-3	302.71
Top *Hirsutella panda* acme*	593-33X-2, 135-137	303.29
Base *Hirsutella panda* acme*	593-33X-5, 41-43	309.11
HCO *Neogloboquadrina mayeri* s.l.*	593-34X-1, 87-89	313.17
Globigerinoides quadrilobatus gp	593-36X-3, 97-99	335.47

Table 2.8 – Distinctive abundance spikes, acmes, and highest occurrences of warm subtropical taxa that are potentially useful for biostratigraphic correlation. Based on census data (Contribution 1). *Well defined bioevents associated with common and persistent taxa (see previous discussions).

Globoquadrina dehiscens (Chapman, Parr and Collins)

The highest occurrence of the warm-subtropical species *Globoquadrina dehiscens* is well documented globally and is considered to be highly diachronous (Kennett & Srinivasan 1975, 1983; Hodell & Kennett 1986). Edwards (1987) and Jenkins (1992) relate this to a contraction in the species biogeographic range during the late Miocene, as it retreated towards lower latitudes. In this respect, the species highest occurrence is substantially older in the New Zealand region than at lower latitudes, where it disappears near the Miocene-Pliocene boundary.

In the New Zealand region, the highest occurrence of *Gq. dehiscens* is generally an abrupt and well defined Tongaporutuan event in oceanic and marginal oceanic sequences (Jenkins 1960, 1971; Hornibrook et al. 1989). For this reason the species disappearance has been commonly used as the principal criterion for a two-fold subdivision of the Tongaporutuan Stage (Scott 1992). At ODP Site 1123 where there is an excellent magnetostratigraphic record, the highest Tongaporutuan occurrence of *Gq. dehiscens* is recorded near the middle of Chron C4r.2r and is assigned an age of 8.88 Ma (Study 5). This is significantly younger than the 10.1 Ma age that is reported for the disappearance of the species (Morgans et al. 1996) and it results in a more-or-less equal subdivision of the Tongaporutuan, into lower and upper parts. This ameliorates the paradox whereby most onland sections appeared to have a much greater thickness of strata deposited in the lower Tongaporutuan than in the upper Tongaporutuan (i.e. sedimentary thicknesses that were disproportionate to the duration of these intervals).

At Site 593, where there is a very detailed record of *Gq. dehiscens*, typical specimens such as those illustrated in Figure 2.18 disappear in 593-27CC, 10-12 cm (254.49 mbsf), about 15 m above the top of the *Gc*-593/C interval of dextrally-coiled *Globoconella miotumida*. This is slightly higher than was noted by Jenkins & Srinivasan (1986) and Scott (1992). *Globoquadrina dehiscens* comprises a relatively minor part of early late Miocene assemblages, although it is a persistent species and it maintains an average abundance of about 1% prior to its disappearance. Very rare specimens that are assigned questionably to *Globoquadrina* in the census are noted above the highest occurrence of *Gq. dehiscens*, although supplementary scans of these samples did not find typical *Globoquadrina*, except for a single specimen of *Gq. venezuelana* which was noted at 593-22X-1, 122-124 cm (198.32 mbsf).

Edwards (1987) has noted enigmatic early Pliocene records of *Gq. dehiscens* in uplifted marine sections in eastern North Island, New Zealand, and new records from Site 1123 (1000 km east of central New Zealand) identify rare atypical specimens of *Gq.* cf. *dehiscens* in the earliest Pliocene (see Study 5). These records are too few and too poorly understood to be useful in regional correlation, although they provide evidence of biogeographic instability during the earliest Pliocene and suggest incursions of warm-water subtropical water reached New Zealand at this time. Despite a comprehensive search for *Gq. dehiscens* in the upper Tongaporutuan to lower Opoitian of Site 593, no expatriate

specimens were found. This suggests incursions of warm-water similar to those recorded on the eastern side of New Zealand may not have reached Site 593. This appears to be indicative of a pattern of oceanic circulation similar to that of the modern, where the East Cape Current, an offshoot of the Tasman Front, carries relatively warm subtropical water down the eastern side of New Zealand (Figure 2.3). Based on the distribution of *Gq. dehiscens* at Site 593 and our improved knowledge of the species stratigraphic range in onland New Zealand and at ODP Site 1123 (Studies 5 and 7), the disappearance of *Gq. dehiscens* in the lower Tongaporutuan would appear to be a widespread isochronous regional event. Expatriate occurrences, however, place a cautionary caveat on the use of the species disappearance in eastern regions.

Summary of bioevents associated with warm-water taxa

Important bioevents associated with warm-water taxa are shown in Figure 2.18. Following the withdrawal of *Neogloboquadrina mayeri* s.l. from the southern Tasman Sea region in the earliest late Miocene there are few well defined events associated with warm-water taxa other than the extinction of *Hirsutella panda* (see earlier) and the regional disappearance of *Globoquadrina dehiscens* (Table 2.8). Distinctive abundance spikes associated with the species *Menardella* cf. *limbata, Globorotalia lenguaensis,* and the *Globigerinoides quadrilobatus* group are potentially useful for correlation, although the reliability of these events has not been tested. The paucity of warm-water taxa above core-section 593-26-4 (240 mbsf) appears to be indicative of a general withdrawal of warm-water taxa from the southern Tasman Sea region (including New Zealand) in the Tongaporutuan, presumably as the biogeographic ranges of warm-water taxa contracted towards low-latitudes.

Table 2.9 – Bioevents associated with warm-water taxa. See Table 2.4 (page S2-28) for an explanation of Events, the Nature of events, and Reliability criteria.

Lower Tongaporutuan
• HO *Globoquadrina dehiscens* 593-27CC, 10-12 cm (254.49 mbsf) – BG1

CONCLUSIONS

This study provides for the first time a highly refined New Zealand late Miocene planktic foraminiferal framework. Bioevents recorded at Site 593 are useful for the correlation of pelagic sequences, although many of these events are also potentially useful for refining

correlations in expanded clastic sequences in onland New Zealand. The close spacing of many of the events, particularly in the lower Tongaporutuan, provides a robust biostratigraphic framework suitable for rigorously testing molluscan and benthic foraminiferal events for maintenance of homotaxial order – something that has not been possible before this study. The use of these bioevents is expected to improve the reliability of onland biostratigraphy and sequence stratigraphy, and improve our understanding of petroleum systems associated with the early late Miocene Mount Messenger Formation in Taranaki. The middle late Miocene (upper Tongaporutuan) has few reliable planktic foraminiferal events and there is a need to research other microfossil groups that will resolve this interval. Coiling excursions in the clade *Globoconella* may help to refine latest Miocene correlations, although the greatest potential for biostratigraphic refinement lies in detailed morphometrically-based taxonomic studies of the clades *Globoconella* and *Truncorotalia.*

Distinct biological thresholds associated with the withdrawal of warm-water taxa from the southern Tasman Sea in the lower Tongaporutuan, the appearance of distinctive sinistrally-coiled populations of *Hirsutella* in the upper Tongaporutuan, and the onset of evolutionary radiations in the clades *Globoconella* and *Truncorotalia* in the Kapitean provide a useful tripartite subdivision for the New Zealand late Miocene. This compares with the existing land-based stage classification (Finlay & Marwick 1940, 1947) with only two stages – a relatively long Tongaporutuan Stage and a much shorter Kapitean Stage. With the ever increasing need for greater stratigraphic resolution it is perhaps time to re-examine the New Zealand late Miocene and possibly introduce a new late Miocene stage or consider reintroducing the Urenuian Stage that was suppressed by Finlay & Marwick (1947) because faunal criteria then available could not reliably distinguish between the Tongaporutuan and Urenuian.

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Appendices

APPENDIX 2.1: Important planktic foraminiferal events.

Summary of late Miocene planktic foraminiferal events that are potentially useful for the correlation of sequences in the New Zealand sector of the cool subtropical (temperate) Southwest Pacific.

Event:

HO = Highest occurrence

HCO = Highest common occurrence

LCO = Lowest common occurrence

LO = Lowest occurrence

Nature of event:

BG = Biogeographic events (see below)

OP = Opportunistic events (see below)

EV = Evolutionary events

Reliability criteria:

1 = Distinctive, well defined, widely distributed events.

2 = Moderately well defined events, useful for the correlation of pelagic sequences but difficult to locate in sequences with poor planktic representations.

3 = Poorly defined events, largely restricted to pelagic sequences.

The above criteria are used in this study for the classification and assessment of bioevent reliability. Biogeographic events include abrupt appearances and disappearances of species and significant changes in abundance and preferred coiling directions. These events are principally controlled by changes in oceanic circulation and their utility is largely restricted to the water mass in which they are found. Opportunistic events are similar to biogeographic events, although they exhibit features of a biological nature and show very distinctive increases and decreases in population size. Such events tend to be species specific and largely independent of other faunal signatures.

Lowermost Opoitian events

- LO *Truncorotalia crassaformis*
  593-14X-2, 46-49 cm (122.26 mbsf) – EV3
- Top upper *Truncorotalia juanai* acme
  593-14X-2, 71-75 cm (122.51 mbsf) – BG2
- LO *Globoconella puncticulata*, ≥95% non-carinate (*Gc. miotumida* bioseries)
  593-14X-4, 130-133 cm (126.10 mbsf) – EV2: base Opoitian

Lower Kapitean events

- LO *Truncorotalia neojuanai* n. sp.
  593-16X-5, 0-3 cm (145.50 mbsf) – EV2
- LO *Globoconella mons*
  593-16X-5, 0-3 cm (145.50 mbsf) – EV2
- Base upper *Truncorotalia juanai* acme
  593-16X-6, 47-50 cm (147.47 mbsf) – BG2
- PCZ subzone *Gc*-593/D3, >30% dextral *Globoconella conomiozea*

593-17X-4, 53-56 cm (154.13 mbsf) to 593-17X-4, 37-39 cm (153.97 mbsf) – OP2

- PCZ subzone *Gc*-593/D2, >30% dextral *Globoconella conomiozea*
  593-17X-5, 84-87 cm (155.94 mbsf) to 593-17X-5, 14-17 cm (155.24 mbsf) – OP2
- PCZ subzone *Gc*-593/D1, >30% dextral *Globoconella conomiozea*
  593-17X-7, 0-3 cm (158.10 mbsf) to 593-17X-6, 133-136 cm (157.93 mbsf) – OP2
- LO *Globoconella conomiozea*, >50% with <4.5-chambers (*Gc. miotumida* bioseries)
  593-18X-6, 86-89 cm (167.06 mbsf) – EV2: base Kapitean?

Upper Tongaporutuan events

- Top middle *Truncorotalia juanai* acme
  593-20X-5, 117-119 cm (185.07 mbsf) – BG2
- Base middle *Truncorotalia juanai* acme
  593-21X-5, 0-2 cm (193.50 mbsf) – BG2
- HO *Hirsutella* cf. *ichinosekiensis,* non-carinate morphotypes
  593-26X-4, 7-9 cm (240.07 mbsf) – EV3 Base middle *Truncorotalia juanai* acme

Lower Tongaporutuan events

- HO *Globoquadrina dehiscens*
  593-27CC, 10-12 cm (254.49 mbsf) – BG1: marks top lower Tongaporutuan
- HO *Hirsutella* cf. *ichinosekiensis*, weakly carinate morphotypes
  593-28X-1, 58-60 cm (255.28 mbsf) – EV3
- Top *Gc*-593/C, >20% dextral *Globoconella miotumida*
  593-29X-4, 48-50 cm (269.28 mbsf) – BG1
- Base *Gc*-593/C interval, >20% dextral *Globoconella miotumida*
  593-29X-5, 42-44 cm (270.72 mbsf) – BG1
- Top *Nq*-593/A2 interval, >30% dextral *Neogloboquadrina pachyderma*
  593-32X-1, 141-143 cm (294.51 mbsf) – BG2
- Top *Nq*-593/A2 interval, >30% dextral *Neogloboquadrina pachyderma*
  593-32X-1, 141-143 cm (294.51 mbsf) – BG2
- HO *Hirsutella panda,* strongly keeled morphotypes
  593-32X-4, 48-50 cm (298.08 mbsf) – EV2
- LO *Neogloboquadrina pachyderma*
  593-32CC, 2-4 cm (299.67 mbsf) – BG3
- HO *Neogloboquadrina mayeri* s.l., excludes rare expatriates near *Gc*-593/C interval
  593-33X-1, 1-3 cm (302.71 mbsf) – BG2
- Top lower *Truncorotalia juanai* acme
  593-33X-1, 59-61 cm (303.29 mbsf) – BG2
- Top *Hirsutella panda* acme, >10% abundance
  593-33X-2, 135-137 cm (305.55 mbsf) – OP2
- Top *Gc*-593/B interval, >20% dextral *Globoconella miotumida*
  593-33X-3, 41-43 (306.11 mbsf) – OP1
- Base *Gc*-593/B interval, >20% dextral *Globoconella miotumida*
  593-33X-3, 84-86 cm (306.54 mbsf) – OP1
- Base *Nq*-593/A1 interval, >30% dextral *Neogloboquadrina mayeri* s.l.
  593-33X-5, 29-31 cm (308.99 mbsf) – BG3
- LO *Truncorotalia juanai,* base lower *Truncorotalia juanai* acme
  593-33X-5, 29-31 cm (308.99 mbsf) – BG2

- Base *Hirsutella panda* acme, >10% abundance
  593-33X-5, 41-43 cm (309.11 mbsf) – OP2
- Top *Gc*-593/A interval, >20% dextral *Globoconella miotumida*
  593-33X-5, 41-43 cm (309.11 mbsf) – OP1
- HCO *Neogloboquadrina mayeri* s.l., >5% abundance
  593-34X-1, 87-89 cm (313.17 mbsf) – BG2
- Base *Gc*-593/A interval, >20% dextral *Globoconella miotumida*
  593-34X-2, 139-142 cm (315.19 mbsf) – OP1: base Tongaporutuan

Upper Kapitean events

- LO *Globoconella sphericomiozea*, >5% non-carinate (*Gc. miotumida* bioseries)
  593-16X-3, 103-106 cm (143.53 mbsf) – EV2: base upper Kapitean
- LO *Truncorotalia* cf. *crassaconica*
  593-15X-4, 90-93 cm (135.30 mbsf) – EV3
- Base CCZ (*Nq*-593/B), >30% dextral *Neogloboquadrina pachyderma*
  593-15X-2, 11-14 cm (131.51 mbsf) – BG2
- LO *Globoconella pliozea*
  593-15X-1, 0-3 cm (129.90 mbsf) – EV2
- Top CCZ (*Nq*-593/B), >30% dextral *Neogloboquadrina pachyderma*
  593-14X-3, 23-26 cm (123.53 mbsf) – BG2.
- HO *Globoconella sphericomiozea*, <95% non-carinate (*Gc. miotumida* bioseries)
  593-14X-3, 0-3 cm (126.30 mbsf) – EV2

NB. Coiling reversals associated with late Miocene populations of *Hirsutella scitula* are not listed, but they are potentially useful for low-resolution biostratigraphic correlation (see Figure 2.15).

Study 3

Biostratigraphy of late Miocene *Bolboforma* (enigmatic marine protophyta) DSDP Site 593, southern Tasman Sea

Biostratigraphy of late Miocene *Bolboforma* (enigmatic marine protophyta): DSDP Site 593, southern Tasman Sea

ABSTRACT: High-resolution bolboform distribution data from the very well preserved older part of the late Miocene section (12 to 8 Ma) of DSDP Site 593, in the southern Tasman Sea, are described and integrated with the planktic foraminiferal zonation from the same site. Contrary to most bolboform studies, this one adopts a population approach and takes size-related intraspecific morphologic variability into account when interpreting species and species ranges.

The record consists of a well defined sequence of narrow bolboform subzones punctuated by intervals without bolboforms. Lower subzonal occurrences from the upper Waiauan to lowermost Tongaporutuan (593-36X to 593-33X) are mainly heterogeneous and include morphotypes of *Bolboforma subfragoris* s.l., which are described under open nomenclature: *B.* sp. spirospinosa, *B.* sp. serrata, *B.* sp. echinus, and *B.* sp. spinulosa. The pattern of morphotypic variation is poorly resolved in this part of the bolboform sequence, although the punctuated record includes at least five subzones that are potentially useful for correlation. They are collectively included in the BBs-Range Zone. Zonal occurrences from the lower to lowermost upper Tongaporutuan (593-32X to 593-26X) are largely monospecific. They comprise a well defined succession of distinct bolboform species that are restricted to eight zones and subzones. In ascending species order, the succession includes *Bolboforma gruetzmacheri* n. sp., *B. capsula, B. pentaspinosa, B. gracilireticulata* s.l., *B. metzmacheri* s.s. (subzones BBm-593/A and C), *B. metzmacheri ornata,* and *B. praeintermedia.* Another subzone, BBm-593/B comprising small smooth-walled phases of uncertain affinity, also occurs between subzones BBm-593/A and C.

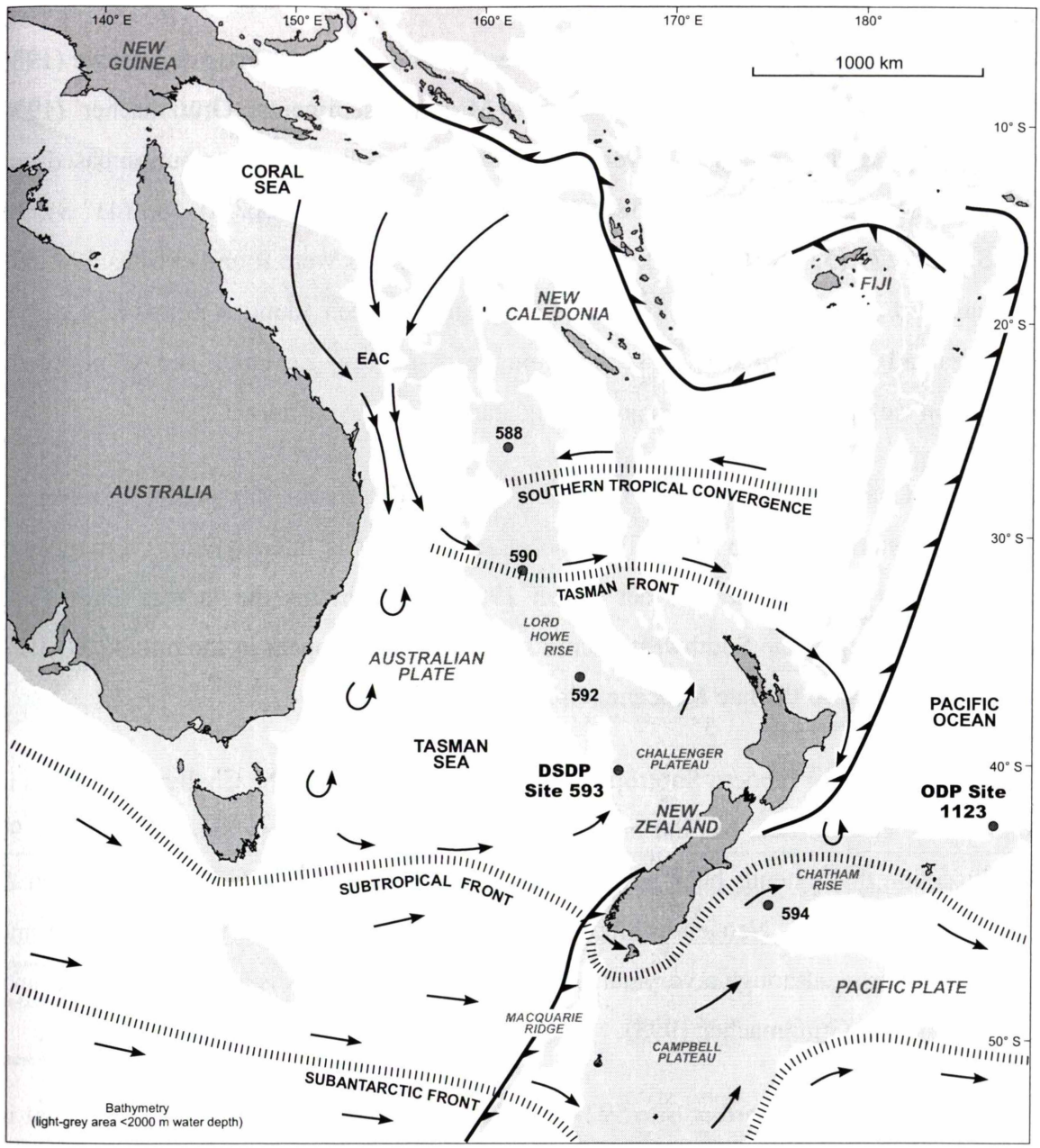
The potential biostratigraphic resolution offered by bolboforms is better than planktic foraminifers and calcareous nannofossils in the middle and late Miocene and it is far superior to both fossil groups in deep-water sequences affected by calcite dissolution. The future, however, for greater biostratigraphic refinement lies in the integration of bolboforms with other fossil groups.

Keywords: Bolboform biostratigraphy; late Miocene; DSDP Site 593; Tasman Sea; Southwest Pacific; New Zealand stage correlation; *Bolboforma gruetzmacheri* n. sp.

INTRODUCTION

The genus *Bolboforma* was introduced by Daniels & Spiegler (1974) for an enigmatic group of calcareous marine microfossils that were first described in the benthic foraminiferal genus *Lagena* (Clodius 1922). Although the bulbous lagenoid-shaped tests resemble simple unilocular benthic foraminifera, the wall is fundamentally different in that it is made of imperforate monocrystalline calcite and lacks the complex internal structure of foraminifers (Daniels & Spiegler 1974; Rögl & Hochuli 1976). Bolboforms also differ in the irregularity and variability of their ornament. Test sizes range from 70 to 240 µm, although most are less than 150 µm. They are comprised of a single hollow chamber or two embracing chambers, and have a conical or tubular neck with a simple terminal aperture. Surface morphology ranges from smooth to highly ornamented, with spines, flanges, knobs, ridges, and reticulations. Bolboforms have generally been interpreted as phytoplanktic organisms (Rögl & Hochuli 1976; Tappan 1980; Poag & Karowe 1986; Spiegler & Daniels 1991), although their tests are thought to have calcified in mid to lower levels of the water column (Poag & Karowe 1986; Spiegler & Erlenkeuser 2001). There is a lack of consensus, however, as to whether bolboforms are resting cysts (Tappan 1980; Murray 1984; Spiegler & Erlenkeuser 2001), reproductive bodies (Müller et al. 1985), or encystments at all (Spiegler 1987; Kennett & Kennett 1990; Mackensen & Spiegler 1992).

In the Southern Ocean region, the distribution of bolboforms extends from the early Eocene (c. 53 Ma) on Campbell Plateau (Grützmacher 1993; Berggren et al. 1995) and the middle Eocene (c. 45 Ma) on Maud Rise (Kennett & Kennett 1990; Spiegler & Daniels 1991) to the early Pliocene on Kerguelen Plateau (Mackensen & Spiegler 1992). The youngest occurrences to date, of late Pliocene age (2.84 Ma), have been noted in the North Atlantic from the Hatton-Rockall Basin (Spiegler 1999). The greatest diversity and number of species occur during two time intervals, namely the late Eocene to early Oligocene, and the middle to late Miocene (Spiegler 1991). Their distribution is broadly bipolar and they occur most commonly in sediments interpreted to have originated in temperate waters at mid to high latitudes (Poag & Karowe 1986; Kennett & Kennett 1990; Spiegler 1991). Their wide geographic distribution, combined with their distinctive morphology, their short ranges, and their resistance to dissolution, make them potentially useful biostratigraphic, paleobiogeographic, and paleoceanographic markers (Rögl & Hochuli 1976; Murray 1979; Müller et al. 1985; Poag & Karowe 1986).



Modern oceanic fronts and surface water masses from Cooke (2002)	Abbreviation	Neogene biogeography Kennett & Srinivasan (1983)		Late Miocene biogeography (THIS STUDY)	Example
		Subtropical		Subtropical	Site 588
SOUTHERN TROPICAL CONVERGENCE	– **STC** –	– **STC** –		– **STC** –	– **STC** –
Warm Subtropical Water	WSTW	Transitional	Cool subtropical assemblage		Site 590
TASMAN FRONT	– **TF** –	– **TF** –		Temperate	– **TF** –
Cool Subtropical Water	CSTW	Temperate			Sites 592, 593, 1123
SUBTROPICAL FRONT	– **STF** –	– **STF** –		– **STF** –	– **STF** –
Subantarctic Surface Water	SASW				Site 594
SUBANTARCTIC FRONT	– **SAF** –	Subantarctic		Subantarctic	– **SAF** –
Circumpolar Surface Water	CSW				Site 278 (56°33.7'S; 160°04.5'E)

Figure 3.1 – Modern bathymetry, locations of DSDP and ODP Sites, oceanic fronts and general circulation of surface water in the Tasman Sea region, after Heath (1985). EAC = East Australian Current. The relationships between modern oceanic fronts and surface water masses, and biogeography are given in the table beneath the location map.

Regional occurrence of bolboforms

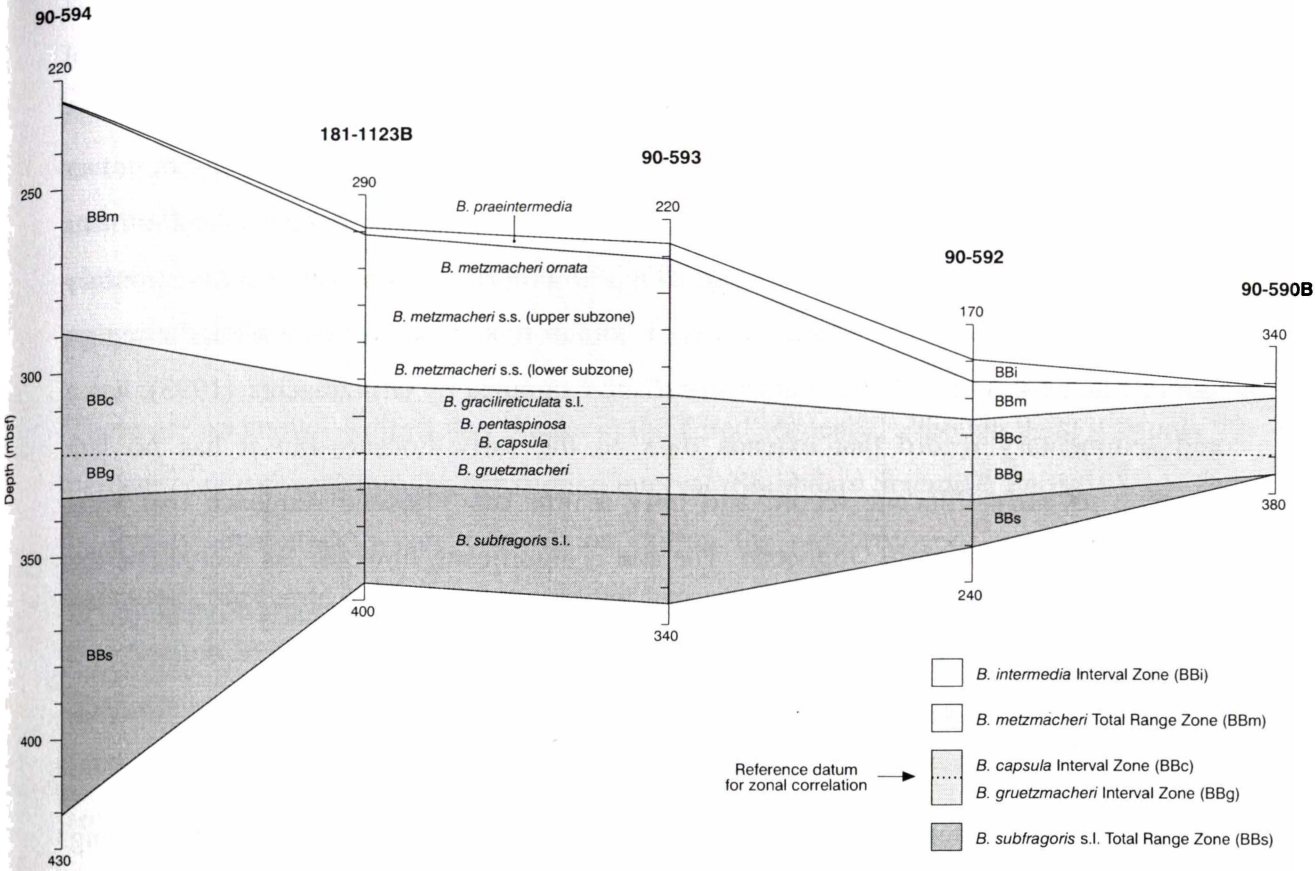
Bolboforms were first recorded in the Southwest Pacific region by Poag & Karowe (1986) at DSDP Site 592, in late Eocene to late Miocene sediments. Grützmacher (1993) subsequently provided a regional overview of Cenozoic bolboform distribution based on a latitudinal transect of DSDP Sites 588 (26° S), 590 (31° S), 592 (36° S), 593 (41° S), 594 (46° S), and 277 (52° S) (Figure 3.1). Neogene occurrences were found at Sites 594, 593, 592, and 590 (Figure 3.2), and they have subsequently been found at Site 1123, east of New Zealand (Study 5) and at sections on land in New Zealand, and at petroleum exploration wells in at least five major sedimentary basins (Appendix 3.2).

Site 594 on Chatham Rise, south of the modern Subtropical Front, has a cored sedimentary record that extends back to the early Miocene, although it is interrupted by a number of unconformities (Kennett & von der Borch 1986b). It contains the largest numbers of bolboforms of any of the Southwest Pacific sites. They first appear in the middle Miocene and they disappear in the late Miocene (Grützmacher 1993).

Site 593, between the modern Subtropical and Tasman Fronts, on the Challenger Plateau in the southern Tasman Sea, has the most complete cored sedimentary record of all Leg 90 sites, a section that extends back virtually uninterrupted to the middle Eocene (Kennett & von der Borch 1986b). Neogene bolboforms are largely confined to the late middle and early late Miocene, although a very narrow interval of bolboforms is also noted in the early middle Miocene (Grützmacher 1993).

The core sedimentary record at Site 592 extends back to the middle Eocene, although it is interrupted by a major unconformity and the middle Oligocene to early Miocene is missing. The site contains a similar Neogene record of bolboforms to that at Site 593, with occurrences in the late middle and early late Miocene (Poag & Karowe 1986; Grützmacher 1993).

Site 590B, near the modern Tasman Front and the northern limit of cool subtropical (temperate) assemblages, has a cored sedimentary record that extends back to the early Miocene (Kennett & von der Borch 1986b). Bolboform occurrences at the site are confined to the early late Miocene, although they occur in very small numbers compared with other sites (Grützmacher 1993).



DSDP/ODP Site:	90-594		181-1123B		90-593		90-592		90-590B	
Location:	SW Chatham Rise		NE Chatham Rise		Challenger Plateau		Lord Howe Rise		Lord Howe Rise	
Latitude:	46°S		42°S		41°S		36°S		31°S	
Water depth:	1214 m		3290 m		1068 m		1088 m		1299 m	
B. *intermedia* Interval Zone (BBi)										
B. praeintermedia	224.13	224.13	299.04	300.14	236.52	240.32	179.32	185.32		
B. *metzmacheri* Total Range Zone (BBm)										
B. metzmacheri ornata	252.42	258.99	301.64	307.64	240.92	246.06	185.32	185.32		
B. metzmacheri s.s.	228.31	234.32	321.34	340.44	254.27	277.55	189.45	195.46		
B. *capsula* Interval Zone (BBc)										
B. gracilireticulata s.s.	290.42	290.42					199.00	199.41	355.51	355.51
B. gracilireticulata s.l.			343.94	347.94	278.72	284.55				
B. pentaspinosa	232.35	313.05	355.44	355.94	287.32	290.33	202.47	203.91		
B. capsula	316.58	319.62	357.14	358.54	289.73	289.73	203.91	205.00		
B. *gruetzmacheri* Interval Zone (BBg)										
B. gruetzmacheri	324.71	334.91	362.04	366.04	295.33	298.93	206.61	211.17	369.61	369.61
B. *subfragoris* s.l. Total Range Zone (BBs)										
B. subfragoris s.l.	334.91	420.74	367.64	395.56	304.66	334.43	213.21	230.33	374.76	374.76
Maximum abundance: specimens per gram (>63 μm)	200000		>8200		12000		5000		400	
Average abundance: specimens per gram (>63 μm)	14000		>500		2200		820		74	
Diversity: number of species (n)	12		>8		10		11		4	

Figure 3.2 – Distribution and relative abundance of late Miocene bolboforms in the Tasman Sea and Southwest Pacific regions. Data from Sites 594, 592, and 590B are based on specimens in the >63 μm sediment size fraction (Grützmacher 1993) and those from Sites 593 and 1123 are based on specimens in the >150 μm sediment size fraction (This Study and Study 5). Grützmacher (1993) examined Site 588 (26° S) but recorded no bolboforms, and he also examined Site 277 (52° S) but found no Neogene bolboforms – the site has no late Oligocene to middle Pliocene section.

The correlation of bolboform zones is based on sub-seafloor depths (mbsf) at Sites 594, 593, 592, and 590B, and revised (mcd) depths at Site 1123B. All zones are hung relative to the base of the *B. capsula* Interval Zone. The most diverse bolboform sequences are recorded at Sites 593 and 1123B, although the other sites have not been studied in the same detail.

No bolboforms were found at Site 588, the northernmost site examined by Grützmacher (1993). This is consistent with the northwards decrease in the number and diversity of Miocene bolboforms noted at other sites in the Southwest Pacific (Figure 3.2) and it suggests the biostratigraphic utility of bolboforms may not extend to regions of lower latitude. This is a feature of the middle to high latitude bipolar distribution of bolboforms (Spiegler & Daniels 1991). The extent to which bolboforms extend southwards is poorly constrained. There are no Neogene records of bolboforms in the Southwest Pacific region south of Site 594. Site 277, the southernmost site examined by Grützmacher (1993), has a cored sedimentary record that extends back to the early Eocene, but it has no late Oligocene to early Pliocene record and only a thin late Pliocene sequence that rests unconformably on the early Oligocene. The site is significant, however, as it contains the oldest known occurrences of bolboforms, which are reported from the early Eocene (c. 53 Ma) (Grützmacher 1993).

Aim of this study

The primary aim of this study is to ascertain the potential of bolboforms for improving biostratigraphic subdivision within the late Miocene of the Southwest Pacific region. Previous studies (e.g. Poag & Karowe 1986; Grützmacher 1993) have established a regional bolboform zonation integrated with calcareous nannofossil zones, although it was not correlated with New Zealand stages. This study builds on the recent discovery of bolboforms in a high-resolution study of late Miocene planktic foraminifers at Site 593 (Crundwell et al. 1997) and it documents in detail the distribution of bolboforms in relation to important planktic foraminiferal events that are correlated with New Zealand stages. It also forms part of a wider study that aims to develop a robust regional late Miocene biostratigraphic framework and geological time scale.

Aspects of size-related morphological variation in bolboforms that are important for the interpretation of species are discussed in Study 4. A chronology for late Miocene bolboforms and planktic foraminifers is developed in Study 5, based on the exceptionally complete Neogene paleomagnetic record at Site 1123, and an integrated biostratigraphic framework for bolboforms and planktic foraminifers is used in Study 7 to reassess Tongaporutuan (early late Miocene) stage correlations in onland New Zealand. The paleoceanographic significance of bolboforms is examined separately by Cooke et al. (2002).

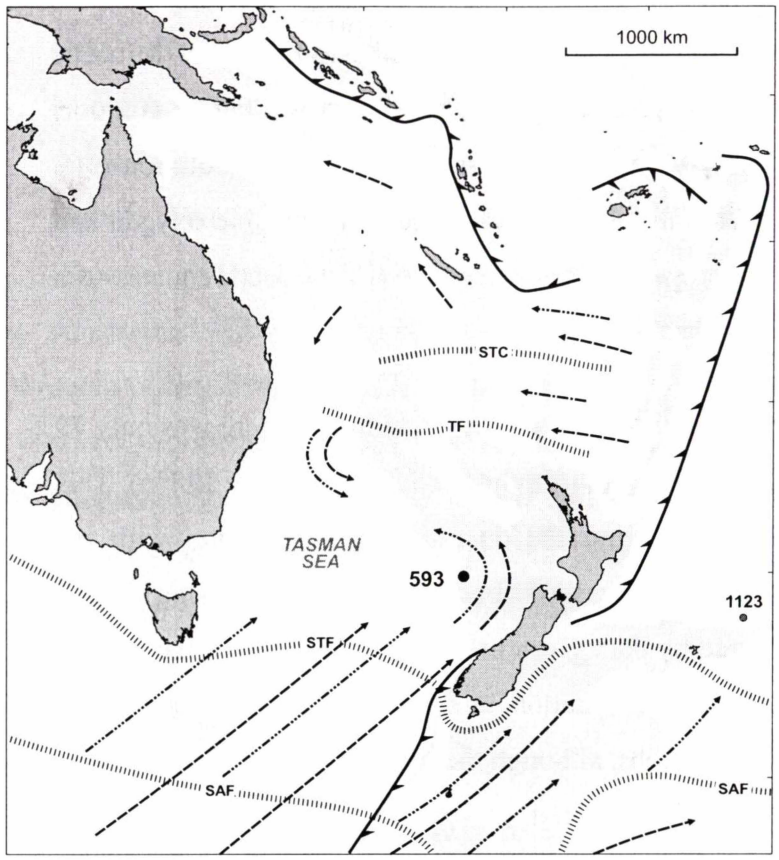
Material and methods

This study examines a suite of 396 samples from the late middle to early late Miocene interval of Site 593, from the base of core 593-36X (336.80 mbsf – metres below seafloor) to the top of core 593-25X (225.91 mbsf). The samples are part of a high-resolution suite used to study late Miocene planktic foraminifers (Studies 1 and 2) and stable oxygen and carbon isotopes (Cooke 2002). The average sample spacing of about 25 cm equates to a temporal resolution of approximately 9 k.y.

There are no known sedimentary breaks in the cored sequence, although there was only 79 percent core recovery through the studied interval (Shipboard Scientific Party 1986a). This is largely attributed to core compaction during the core recovery operation with the extended core-barrel system and it does not necessarily imply that there is missing section (see Section 2) – a view that is supported by data given in Section 6. Modern ocean coring operations routinely apply corrections for compaction in the construction of composite sections (e.g. Shipboard Scientific Party 1999b), although the necessary down-hole logging technology was not available when Site 593 was cored.

Bolboform distribution and abundance data were initially compiled as part of a foraminiferal census study of material contained in the >150 μm sediment fraction (Study 1). These data were then supplemented with picks from the >150 μm sediment fractions of census samples and infill samples that were not examined during the census. The frequency of specimens was determined from the number of individuals in randomly chosen squares, on a sample tray with 45-squares, each covering 1 cm^2. The 63-150 μm sediment size fractions of samples in the vicinity of bolboform occurrences, particularly small species, were also checked to refine species ranges. Because this did not include all samples, it is possible some isolated occurrences of small bolboforms may have been missed.

Species identifications were made under a binocular microscope and confirmed by scanning electron microscopy of selected specimens. Digitally captured SEM images of selected specimens were checked by Dr Dorothee Spiegler from the GEOMAR Research Centre for Marine Geosciences, in Germany. The bolboform taxonomy adopted in this study is based on Spiegler & Daniels (1991); Grützmacher (1993); and Spiegler 1999).



INTERMEDIATE WATER CIRCULATION

Subantarctic Mode Water (SAMW)

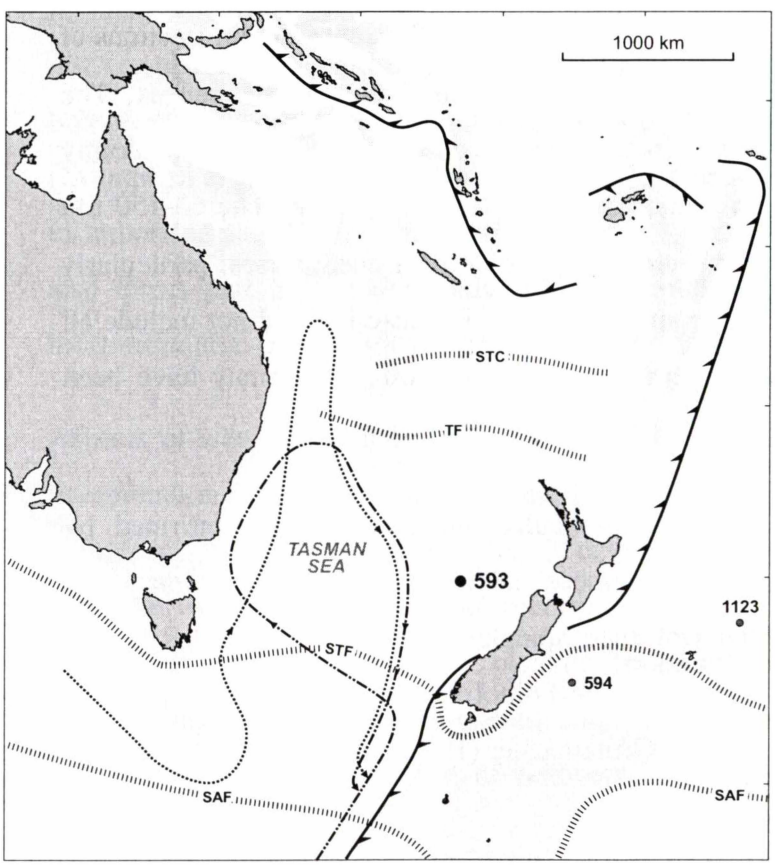
Antarctic Intermediate Water (AAIW)

STC = Subtropical Convergence
TF = Tasman Front
STF = Subtropical Front
SAF = Subantarctic Front

Water Mass	Abbrev.	Depth (m)
Circumpolar Surface Water	CSIW	0-400
Subantarctic Mode Water	SAMW	400-600
Antarctic Intermediate Water	AAIW	600-1450
Circumpolar Deep Water (upper)	u-CPDW	1450-2550
Circumpolar Deep Water (middle)	m-CPDW	2550-2900
Circumpolar Deep Water (lower)	l-CPDW	>3800
Antarctic Bottom Water	AABW	

after Shipboard Scientific Party (1999a)

Figure 3.3 – General circulation of Subantarctic Mode Water and Antarctic Intermediate Water in the Tasman Sea region, after Wyrtki (1961, 1973), Bingham & Lukas (1994), Fine et al. (1994), Tomczak and Godfrey (1994), and Hautala (1996). See Figure 3.1 for explanation of bathymetry and oceanic fronts.



DEEP WATER CIRCULATION

Cicumpolar Deep Water (CPDW)

Antarctic Bottom Water (AABW)

STC = Subtropical Convergence
TF = Tasman Front
STF = Subtropical Front
SAF = Subantarctic Front

Water Mass	Abbrev.	Depth (m)
Circumpolar Surface Water	CSIW	0-400
Subantarctic Mode Water	SAMW	400-600
Antarctic Intermediate Water	AAIW	600-1450
Circumpolar Deep Water (upper)	u-CPDW	1450-2550
Circumpolar Deep Water (middle)	m-CPDW	2550-2900
Circumpolar Deep Water (lower)	l-CPDW	>3800
Antarctic Bottom Water	AABW	

after Shipboard Scientific Party (1999a)

Figure 3.4 – General circulation of Circumpolar Deep Water and Antarctic Bottom Water in the Tasman Sea region, for an explanation of bathymetry and oceanic fronts see Figure 3.1, and for source references see Figure 3.3.

Physical and oceanographic setting

DSDP Site 593 was drilled on the Challenger Plateau, in 1068 m of water. The site is located at 40° 30.47'S and 167° 40.47'E on a relatively shallow-water continental platform in the southern Tasman Sea, 470 km west of central New Zealand. This setting allowed the accumulation of a thick sequence of Neogene oozes with virtually no terrigenous sedimentary influences or interruptions in the sedimentary succession (Kennett & von der Borch 1986a). Calcareous microfossil assemblages are extremely well preserved and have been studied in detail (Jenkins & Srinivasan 1986; Hoskins 1990; Scott 1992; Grützmacher 1993; Scott et al. 1995), including here in Studies 1 and 2. This work, in combination with earlier work on Site 284 (Jenkins 1975; Kennett & Vella 1975; Hornibrook 1982), a rotary drilled site adjacent to Site 593, forms the basis of New Zealand deep water Neogene microfossil zonations and underpins the correlation of the New Zealand stage classification system.

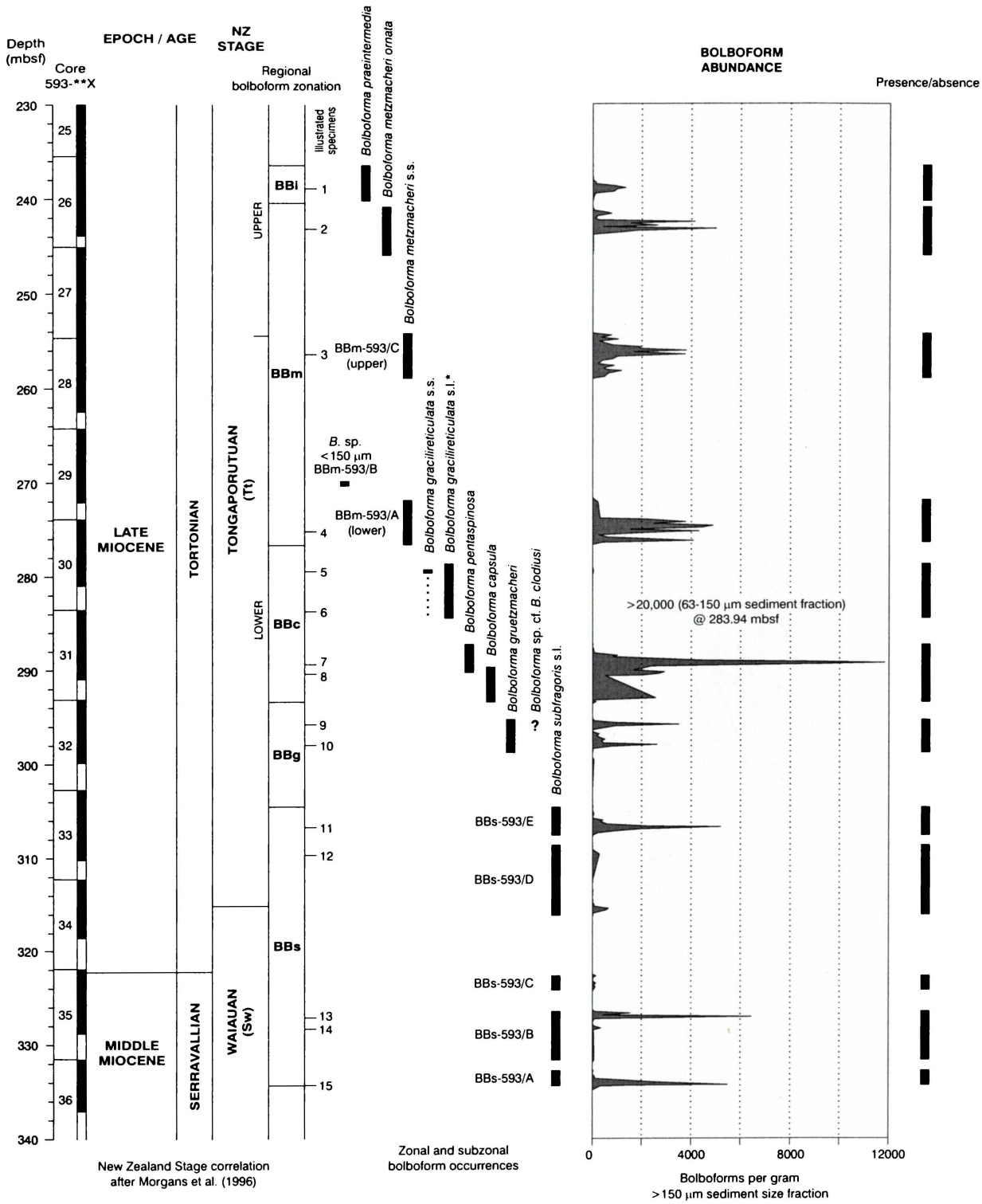
Site 593 is presently located about 500 km north of the Subtropical Front and almost twice that distance south of the Tasman Front (Figure 3.1). Due to its elevated position on the Challenger Plateau, the seafloor at the site is bathed by the core of Antarctic Intermediate Water (AAIW), close to the southern-edge of the zone of mixing between northward and south-westward directed flows of AAIW (Wyrtki 1962) (Figure 3.3). Deep-water (Antarctic Bottom Water and Circumpolar Deep water) is restricted by seafloor topography to the deeper part of the Tasman Sea basin, west of Site 593 (Figure 3.4). AAIW is overlain by Subantarctic Mode Water (SAMW) – a seasonal northwards flowing highly oxygenated water mass, 400-600 m deep, which forms by winter cooling of surface waters between the Subantarctic Front and Subtropical Front (McCartney 1982). Surface water overlying the site is from a residual counter-clockwise flow of cool subtropical water in the southern Tasman Sea that is derived from the East Australian Current (Heath 1985).

The present pattern of circulation has remained substantially unchanged since the beginning of the late Miocene (Edwards 1975; Nelson & Cooke 2001), even though seafloor spreading between Australia and Antarctic has shifted the western side of the New Zealand subcontinent and landmass (including Site 593) northwards by as much as 5° (Weissel et al. 1977; Sutherland 1995). Changes in the intensity of circulation, however, are noted in textural records at Site 593, on the scale of Milankovich perturbations (Cooke 2002).

BIOSTRATIGRAPHIC RECORD OF BOLBOFORMS AT SITE 593

Neogene bolboform occurrences at Site 593 are largely confined to the upper Waiauan to lowermost upper Tongaporutuan (late middle to early late Miocene) between cores 593-36X and 593-26X (334.43-236.52 mbsf) (Figure 3.5). They have also been found in a narrow interval near the Waiauan-Lillburnian Stage boundary, core 593-40X (376.92-376.65 mbsf) (Grützmacher 1993; Elkington 2000). To date no bolboforms have been found in the upper Tongaporutuan to Opoitian (late Miocene to early Pliocene) section above core 593-26X, despite the suitable facies and the abundance of well preserved calcareous microfossils. This points to a premature truncation of the bolboform record with respect to the southern Indian Ocean (Mackensen 1992) and North Atlantic (Spiegler 1999) where bolboforms disappear in the early and late Pliocene, respectively. Bolboform records appear to be similarly truncated on the Pacific Ocean side of New Zealand at DSDP Site 594 (Grützmacher 1993) and ODP Site 1123 (Chapter 5), in what appears to be a synchronous regional extinction (see later discussion).

Bolboforms occur in 206 (52 percent) of the 396 samples examined in this study. Despite the relatively high frequency of occurrence, specimen numbers are often very low and only 12 percent of samples contain large assemblages with a 1000 or more bolboforms per gram of sediment from the >150 μm size fraction. Most occurrences are confined to narrow zones and subzones that range from 1.6 to 5.8 m thick (c. 50 to 330 k.y. duration – Study 5). The discontinuous distribution of bolboforms in combination with their small size (70-240 μm) may explain why the genus has been overlooked for so many years in the New Zealand fossil record and why it was not documented *per se* in the initial reports on DSDP Leg 90. Despite bolboform numbers often being low, most zones and subzones have a high persistence (continuity of occurrence) in excess of 80 percent. Bioturbation may have contributed to the persistence of bolboforms within some zones, although trace fossil abundances are uniformly low throughout the late Miocene and deep-burrowing *Planolites-Chondrites-Zoophycus* assemblages that would contribute to the mixing of microfossil assemblages are only noted in the late Eocene chalk at the bottom of the core (Nelson 1986).



Species	Age(Ma)	Maximum abundance	Species	Age (Ma)	Maximum abundance
Bolboforma praeintermedia	236.52 - 240.32	1333	*Bolboform capsula*	289.73 - 293.51	2879
Bolboforma metzmacheri ornata	240.92 - 246.06	5000	*Bolboforma gruetzmacheri*	295.33 - 298.93	3068
Bolboforma metzmacheri s.s.			*Bolboforma subfragoris* s.l.		
- upper subzone	254.27 - 259.07	3793	BBs-593/E	304.66 - 307.70	5214
- lower subzone	271.94 - 277.55	4884	BBS-593/D	308.99 - 316.27	645
Bolboforma gracilireticulata s.l.	278.72 - 284.55	*>20000	BBs-593/C	322.72 - 324.30	136
Bolboforma gracilireticulata s.s.	279.33 - 279.75	28	BBs-593/B	326.50 - 331.69	6452
Bolboforma pentaspinosa	287.32 - 290.33	11840	BBs-593/A	332.80 - 334.43	5489

Figure 3.5 – Bolboform distribution, abundance, zonation, and stage correlation at Site 593. Maximum abundances normalized as specimens per gram of sediment (>150 µm sediment size fraction). **Bolboforma gracilireticulata* s.l. is a small species and is poorly represented in the >150 µm sediment size fraction, but reaches a maximum abundance of >20000 in the 125-150 µm sediment size fraction. Numbered stratigraphic horizons relate to specimens illustrated in Figure 3.6.

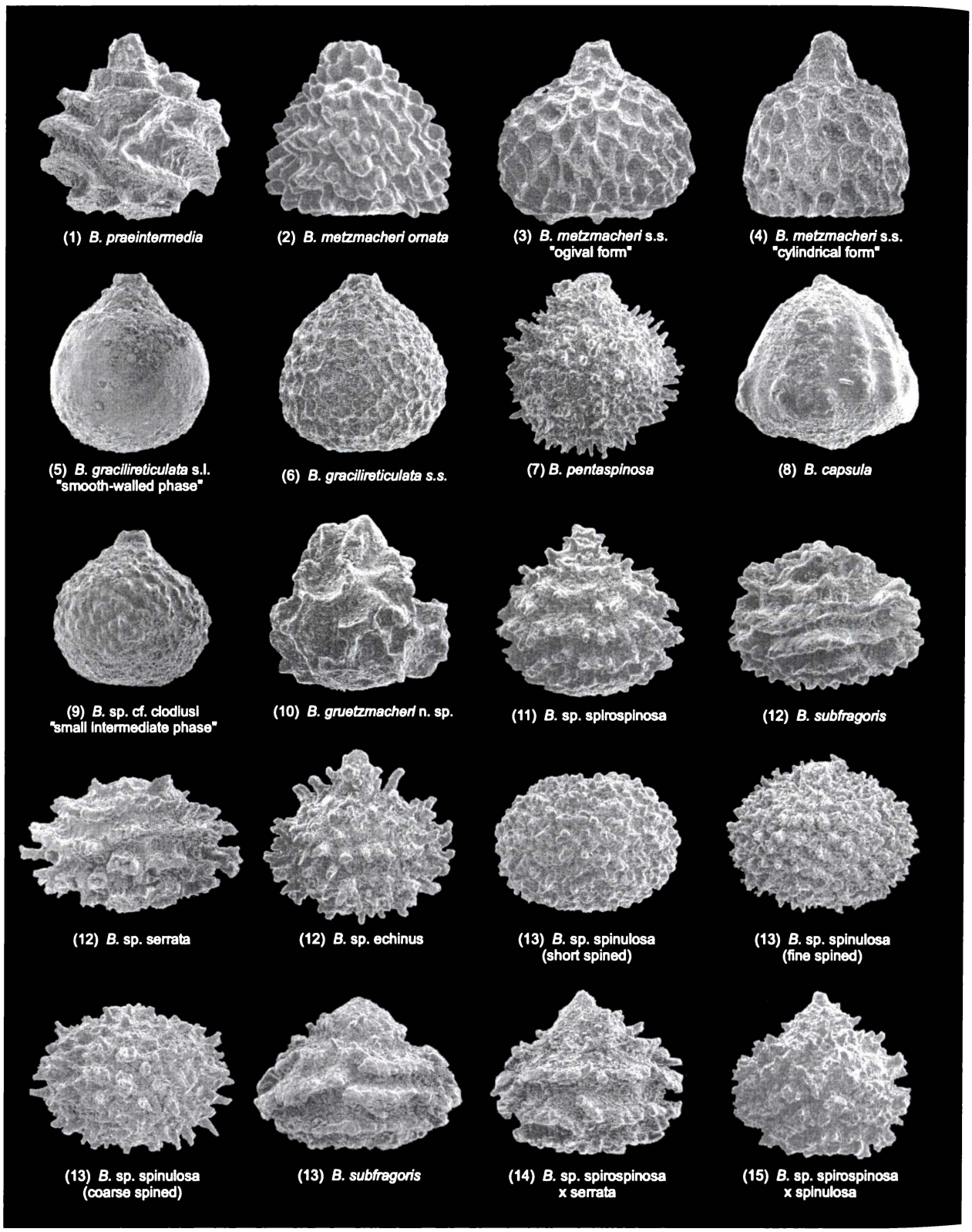


Figure 3.6 – Bolboform species and morphotypes identified at Site 593. All specimens have been illustrated in axial orientation and unless otherwise stated images represent large ornate phases – images not shown to scale. Numbers relate to stratigraphic horizons in Figure 3.5. Distinctive morphotypes included in *Bolboforma subfragoris* s.l. are described in open nomenclature.

Bolboform species and common morphotypes

Bolboform species and common morphotypic variants found in the late middle and early late Miocene section at Site 593 (Figure 3.6) are described below in ascending stratigraphic order. A glossary of terminology used in the following descriptions of bolboform species and morphotypes is given in Table 3.1.

Table 3.1 – Glossary: guide to adopted terminology

Descriptive terminology

- Aboral: posterior end of test diametrically opposed to the neck and apertural opening.
- Neck: hollow tube or cone-like extrusion of the oral (anterior) surface.
- Bicamerate: two chambers either embracing or totally encapsulated.
- Bipolar: pertaining to both oral and aboral surfaces.
- Cylindrical: axially elongated lagenoid test – as seen in some morphotypes of *B. metzmacheri* s.s.
- Collar: low ring-like neck.
- Intermediate phases: morphological stages in the development of bolboform tests between small smooth-walled and large ornate phases.
- Lagenoid: subspherical or bulbous tests with an extruded neck.
- Meridional section: equatorial section of test wall.
- Oblate: test with equal oral and aboral compression.
- Obsolete neck: poorly developed or obscured by ornament.
- Ogival: inflated squat lagenoid test.
- Oral: anterior portion of test associated with the aperture – diametrically opposed to the aboral (posterior surface).
- Ornate phases: large fully developed morphological stages in the development of bolboform tests – usually with well-developed ornaments.
- Smooth-walled phases: early morphological stages in the development of bolboform tests – usually small and lacking ornament.
- Subquadrate: box-shaped test – as in seen some morphotypes of *B. gruetzmacheri*.
- Subspheroidal: evenly rounded tests with poorly developed necks.
- Subtriangular: subconical to pyramid-shaped test – as in seen some morphotypes of *B. gruetzmacheri*.

Ornament

- Blade: prominent sharp-edged ridge.
- Cancellate: reticulate-ridged ornament consisting of 5- to 6-sided polygonal cells.
- Corrugate: axially aligned low fold-like ridges – as seen in *B. capsula*.
- Furcate-tipped: complex spines that divaricate or fork.
- Furrowed: spines with grooves set in the elongate direction.
- Nodular: poorly developed proto-spines.
- Polygonal-spinose: geometrical arrangement of spines.
- Proto-flange: morphologically incomplete – formed from partially fused spines or nodules.
- Rudimentary ornament: very weak ornament with no discernible pattern – usually associated with small intermediate phases.
- Serrate-flange: broken or tooth-like spiral flange.
- Spinose-flange: irregular spiralled flange consisting of partially fused spines.
- Spiral flange: continuous or near continuous axially spiralled ridge.

- Spirospinose: spirally arranged spinose ornament.
- Subradial: spines projecting outwards from the surface of the test wall but non-necessarily at a high-angle.
- Radial: spines projecting at a high-angle to the surface of the test wall.
- Tubercles: blunt very heavily thickened nodules.

Bolboforma sp. spirospinosa – Plates 3.1/1-3; 3.2/13-15; and 3.3/10-15

Bolboforma clodiusi, Echols, 1985, pl. 2/3-4.

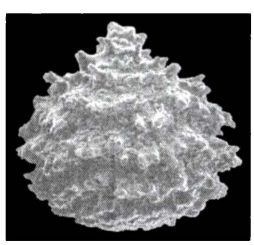
Bolboforma sp., Poag and Karowe, 1986, fig. 2/K.

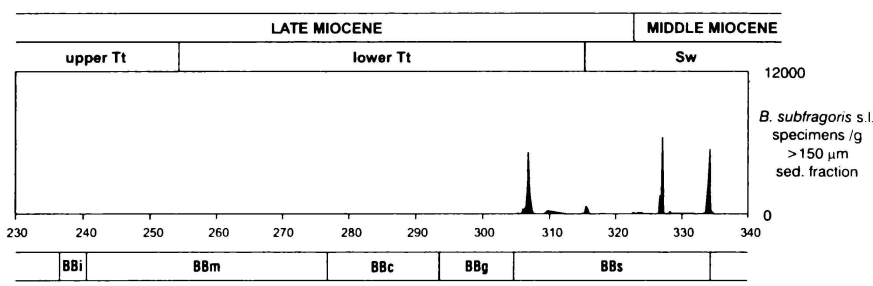
Bolboforma aculeata, Spiegler and Rögl, 1992, pl. 2/4-6.

Bolboforma subfragori, Mackensen and Spiegler, 1992, pl. 1/5.

Bolboforma subfragoris, Grützmacher, 1993, pl. III/10-12.

Bolboforma sp. K, Grützmacher, 1993, pl. IV/7.





Description: Ornate phases up to 200 µm in diameter. Spiro-spinose, subspherical lagenoid to squat lagenoid test, with a gently convex to rounded aboral surface. Short conical neck with small terminal aperture. Test surface ornamented with closely spaced subradial spines, arranged in a poorly defined spiral pattern with groups of spines often partially fused. The spirospinose ornament of large ornate phases is strongly developed in meridional section and tends to become weaker towards the polar extremities. Large intermediate phases have a subspheroidal lagenoid test with short spines (Plates 3.1/3, 3.2/14, 3.3/11) that become more nodular in small intermediate phases. Small phases with rudimentary ornament are generally subspherical and have relatively smooth aboral surfaces and nodular oral surfaces (Plate 3.3/13).

Remarks: Three primary variants are distinguished on the basis of spine length and the degree to which spines are fused: a spinose-flanged form with partially fused spines (Plate 3.1/1-3); a nodular form (Plate 3.2/13-15) equivalent to *Bolboforma* sp. K of Grützmacher (1993); and a spinose form (Plate 3.3/10-15). Although some assemblages are dominated by one morphotype, others contain all three morphotypes. The spinose-flanged morphotype is generally most common.

Discrimination: The poorly defined spiral pattern of the spinose ornament distinguishes *B.* sp. spirospinosa from most other spinose bolboforms. Similar spiral ornamented species include the middle Miocene to early Pliocene species *B. acuelata* that has a broader conical neck and widely spaced furcate-tipped spines; and the middle to late Miocene species *B. fragori* and *B. subfragoris* that are bipolarly compressed and have a well developed spiral-flanged ornament and poorly developed apertural necks.

Distribution: *B.* sp. spirospinosa is confined to the upper part of subzone BBs-593/E (Figure 3.5), in the interval between 593-33X-3, 105-107 cm and 593-33X-2, 82-84 cm (306.54-304.66 mbsf). Variants of *B.* sp. spinulosa x spirospinosa also occur in subzone BBs-593/A and the lower part of subzone BBs-593/B, between 593-36X-2, 143 cm and 593-35X-5, 57-59 cm (334.43-328.47 mbsf). Variants of *B.* sp. spirospinosa x serrata also occur in subzone BBs-593/D and the lower part of subzone BBs-593/E, between 593-34X-3, 97-99 cm and 593-33X-2-135-137 cm (316.27-305.55 mbsf). As a group, the three variants of *B.* sp. spirospinosa are confined to the upper Waiauan and lower Tongaporutuan (late middle to earliest late Miocene).

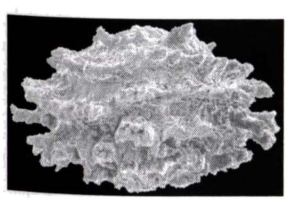
Associated planktic foraminiferal events include the Kaiti Coiling Zone (*Gc*-593/A), the last common occurrence of *Neogloboquadrina mayeri* s.l., the base of the Glomar Coiling Zone (*Nq*-593/A1), and the *Menardella panda* acme zone. They all occur within the upper part of the *B. subfragoris* s.l. Range Zone in the interval spanned by subzones BBs-593/D and BBs-595/E.

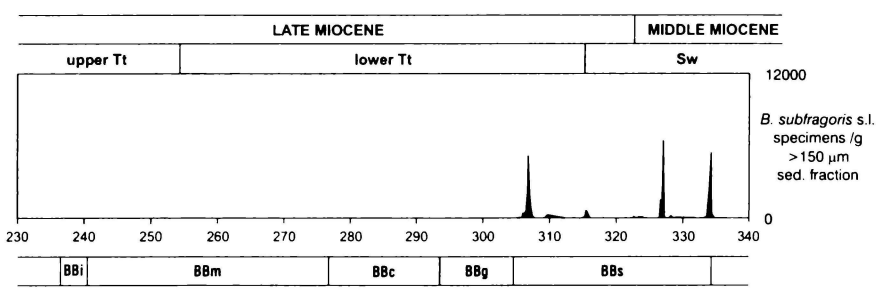
Bolboforma sp. serrata – Plate 3.1/4-12

Bolboforma spiralis, Müller, Spiegler and Pastouret, 1985, pl. 2/4-7, 13-16, 3/1-2.

Bolboforma sp., Poag and Karowe, 1986, fig. 2/J.

Bolboforma subfragori, Mackensen and Spiegler, 1992, pl. 1/5.





Description: Ornate phases up to 220 µm in diameter. Spiral-flanged to fused spinose-flanged, subspheroidal lagenoid to squat lagenoid test, with a gently convex to rounded

aboral surface. Broad conical neck with a very small, terminal aperture. Test surface ornamented with serrated teeth-like spiral ornament, usually 3 to 5 revolutions. Morphotypic variation extends to continuous-flanged and spinose-flanged end members. The compression of large ornate phases is exaggerated by the strong development of meridional test ornament and weak polar ornament. Intermediate phases have a subspherical lagenoid test with rounded aboral surface and a broad apertural neck developed as a conical extrusion of the oral surface. Test ornament is less well developed than in large ornate phases and comprises a series of low spirally arranged nodules or low asymmetrical ridges. Smaller phases are generally smooth-walled, although some show vestiges of rudimentary ornament.

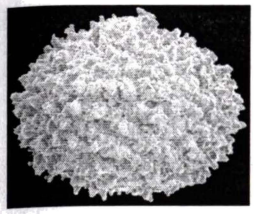
Remarks: The range of morphotypic variation displayed by *B.* sp. serrata – from continuous-flanged to spinose-flanged – is similar to the range of variation attributed to *B. aculeata* (Spiegler & Daniels 1991), even though it appears to be inconsistent with a single taxonomic entity.

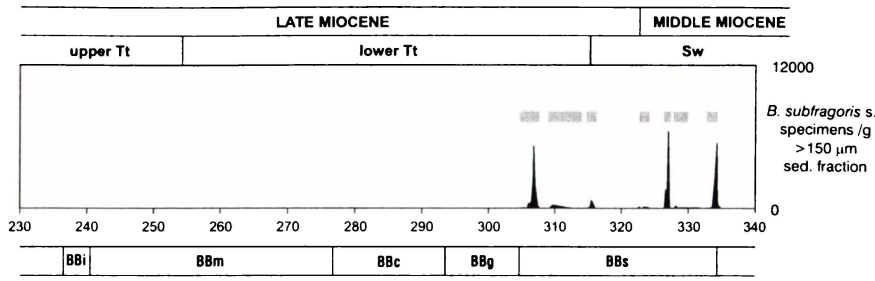
Discrimination: The squat lagenoid test, robust conical apertural neck, and tooth-like spiral ornament distinguish *B.* sp. serrata from most Miocene spiral-flanged taxa. The late Oligocene to middle Miocene species *B. spiralis* has a more elongated subconical test; the late middle to early late Miocene species *B. fragori* and *B. subfragoris* are bipolarly compressed and have reduced or obsolete apertural necks; and the middle Miocene to early Pliocene species *B. aculeata* is more sparsely ornamented with widely spaced furcate-tipped spines. The broad conical neck also distinguishes *B.* sp. serrata from most other spiro-spinose bolboforms. The middle Miocene species *B. furcata* has well formed, widely spaced, furcate-tipped spines; and the earliest late Miocene forms *B.* sp. spirospinosa and *B.* sp. echinus have narrower apertural necks and the spiral ornament is less flange-like.

Distribution: *Bolboforma* sp. serrata occurs in subzones BBs-593/E, D, and A (Figure 3.5), in the interval between 593-35X-5, 82-84 cm and 593-35X-5, 82-84 cm (328.72-328.72 mbsf). It only occurs below the Kaiti Coiling Zone (*Gc*-593/A) and the highest common occurrence of *Neogloboquadrina mayeri* s.l. and is correlated with the upper Waiauan (earliest late Miocene).

Bolboforma sp. spinulosa – Plates 3.1/13-15; and 3.2/1-6

Bolboforma compressispinosa Mackensen and Spiegler, 1992, pl. 1/6.





Description: Ornate phases up to 200 µm in diameter. Highly spinose, bipolarly compressed, oblate test, with a poorly developed or obsolete apertural neck. Test surface ornamented with closely packed subradial spines. Three morphotypic variants have been recognized – short blunt spined (Plate 3.1/13-15), fine spined (Plate 3.2/1-3), and coarse spined (Plate 3.2/4-6). While coarse spined morphotypes have strong meridional ornaments that exaggerate test compression, fine and short spined morphotypes are more evenly spinose and tend to be less compressed. A small circular aperture occurs at the centre of the oral surface. It is associated with a very short neck in fine and coarse spined morphotypes. A smaller secondary opening also occurs at the centre of the aboral surface in some short and fine spined morphotypes, but has not been seen in coarse spined morphotypes. There is strong overlap in the range of test sizes associated with each of the three morphotypes and there is no obvious connection between test size and the development of the spinose ornament. No smooth-walled phases or small intermediate phases with rudimentary ornament have been observed.

Remarks: The three morphotypic variants that have been recognized in assemblages of *B.* sp. spinulosa appear to be linked in a continuum of morphological variation and do not warrant taxonomic separation. Given the range of intraspecific variation involving test shape and test ornament, it is speculated that test development is associated with a transformation from short- to fine-spined and then coarse-spined forms.

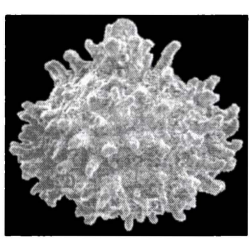
Discrimination: The oblate, highly spinose test and very poorly developed apertural neck distinguish *B.* sp. spinulosa from *B. compressispinosa* – with its strongly oblate test, widely spaced furcate-tipped spines, and well formed narrow apertural neck. Such features also distinguish *B.* sp. spinulosa from most other spinose Neogene bolboforms. The late Oligocene to early Miocene species *B. spinosa* has a subspherical lagenoid test and short blunt spines; and the middle to late Miocene species *B. badenensis* and *B. compressibadenensis* have a regular polygonal-spinose ornament; *B. clodiusi* has an

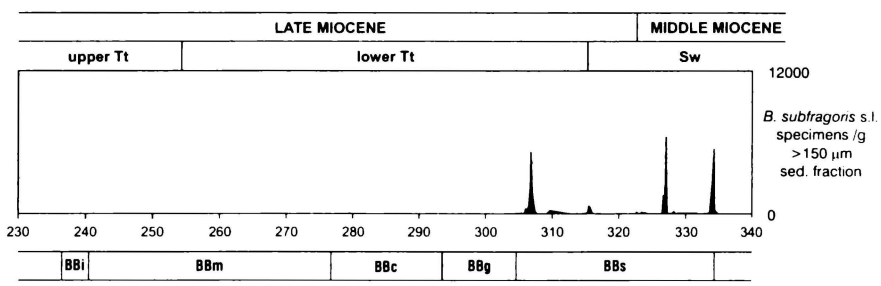
aborally flattened test and short blunt spines; and morphotypes of *B. pentaspinosa* from Site 593 have a subspherical test with a low collar-like apertural neck and large aperture.

Distribution: The range of *B.* sp. spinulosa is poorly defined, but variants with affinities to *B.* sp. spirospinosa occur in subzone BBs-593/A, and more typical assemblages occur in subzone BBs-593/B (Figure 3.5). It is generally represented in the interval between 593-36X-1, 19-21 cm and 593-35X-4, 10-12 cm (331.69-326.50 mbsf). Questionable specimens also occur in the middle of subzone BBs-593/D. Morphotypes of *B.* sp. spinulosa largely occur below the Kaiti Coiling Zone and the last common occurrence of *Neogloboquadrina mayeri* s.l. in an interval correlated with the upper Waiauan (earliest late Miocene).

Bolboforma sp. echinus – Plate 3.2/7-12

Bolboforma sp. I, Grützmacher, 1993, pl. IV/1-3.





Description: Ornate phases up to 200 µm in diameter. Highly spinose, subspherical lagenoid to squat lagenoid test, with a rounded to gently convex aboral surface. Short conical or tubular neck with a small terminal aperture. Test surface ornamented with very prominent subradial spines interspersed with short blunt spines and furcate-tipped spines. In large ornate phases, the spinose ornament is most strongly developed in meridional section and tends weaker towards the polar extremities. Intermediate phases have a subspherical lagenoid test and less prominent spinose ornament, arranged in an ill-defined spiral pattern. Small intermediate phases with rudimentary ornament and smooth-walled phases have not been observed.

Remarks: The range of morphotypic variation associated with *B.* sp. echinus overlaps with highly spinose variants of *B.* sp. spirospinosa. This suggests they may be morphotypic variants of just one taxon.

Discrimination: *B.* sp. echinus is distinguished from *B.* sp. spirospinosa by the prominent development of its spinose ornament. The highly spinose ornament and squat lagenoid test also distinguish *B.* sp. echinus from most other Miocene bolboforms. The middle to late Miocene species *B. pentaspinosa* has a subspherical test and very fine spined ornament; the middle Miocene to early Pliocene species *B. aculeata* has a broad conical neck and widely spaced, furcate-tipped spines; and the late middle to early middle Miocene species *B. fragori* and *B. subfragoris* have moderately oblate tests, spiral-flanged ornaments, and poorly developed apertural necks.

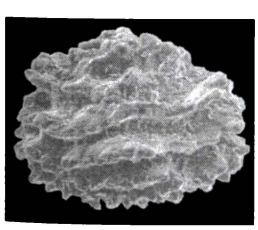
Distribution: Monomorphotypic assemblages of *B.* sp. echinus are confined to subzone BBs-593/C (Figure 3.5) and are typical of the interval between 593-35X-2, 90-92 cm and 593-35X-1, 82-84 cm (324.30-322.72 mbsf). Rare variants may also occur in sample 593-33X-5, 104-106 cm (309.54 mbsf) in an assemblage dominated by *B.* sp. serrata. Most specimens occur below the Kaiti Coiling Zone and the last common occurrence of *Neogloboquadrina mayeri* s.l. in an interval correlated with the uppermost Waiauan (earliest late Miocene).

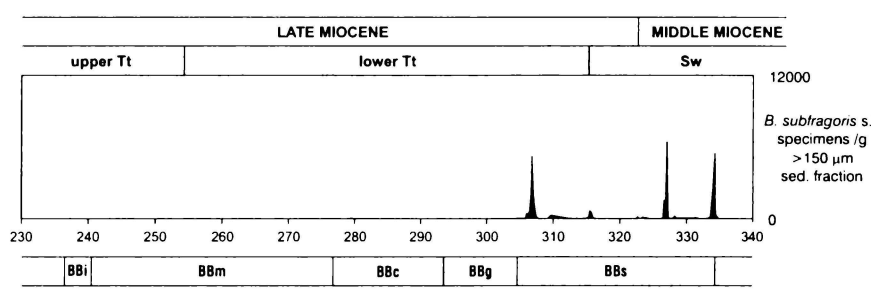
Bolboforma subfragoris Spiegler and Daniels – Plate 3.4/6-10

Bolboforma spiralis, King 1983, pl. 1/14-15.

Bolboforma sp., Poag and Karowe, 1987, pl. 1/11-12.

Bolboforma subfragoris, Spiegler and Daniels, 1991, pl. 11/3-6.





Description: Ornate phases up to 240 µm in diameter. Ovate, spirally-flanged test, with a reduced or obsolete neck and small terminal aperture. Test surface ornamented with 3 to 5 well formed spiral flanges, developed from laterally fused spines. Bipolar compression in large ornate phases is falsely exaggerated by the strong development of meridional ornament. Intermediate phases have a subspherical test covered with closely spaced, spirally arranged, nodular spines that fuse to form a proto-flange in larger intermediate phases (Plate 3.3/4).

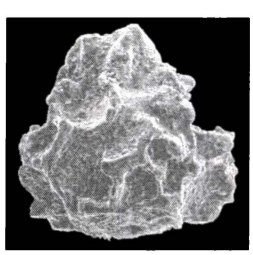
Remarks: Some specimens from Site 593 are very similar to the holotype of *B. subfragoris* in terms of their moderately ovate test, spiral-flanged ornament, and poorly developed apertural neck, but the spiral-flanged ornament tends to be more serrated or spinose.

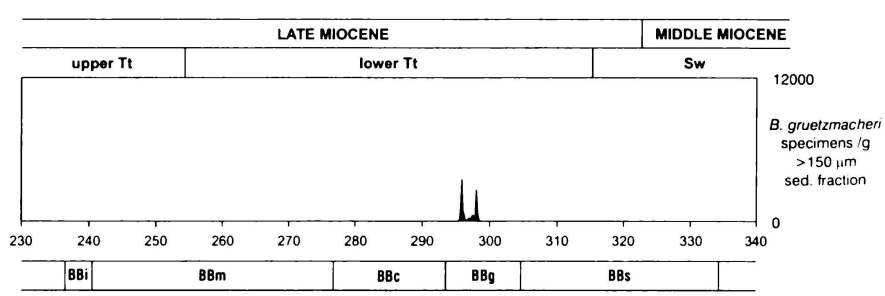
Discrimination: The moderately ovate test and serrate spiral-flanged ornament distinguish *B. subfragoris* from most spiral-flanged Miocene bolboforms, although it intergrades with continuous-flanged variants of *B.* sp. serrata. The late Oligocene to middle Miocene species *B. spiralis* has an elongated subconical test; the middle Miocene to early Pliocene species *B. acuelata* has a well developed broad conical neck and widely spaced furcate-tipped spines; the latest middle to earliest late Miocene species *B. fragori* has a more strongly compressed ovate test; and *B.* sp. spirospinosa has a squat lagenoid test and spirospinose ornament.

Distribution: Rare variants of *B. subfragoris* occur in subzones BBs-593/C, D, and E (Figure 3.5), in the interval between 593-36X-1, 19-21 cm and 593-33X-3, 23-25 cm (331.69-305.93 mbsf). Planktic foraminiferal events associated with *B. subfragoris* include the Kaiti Coiling Zone (*Gc*-593/A), the last common occurrence of *Neogloboquadrina mayeri* s.l., the base of the Glomar Coiling Zone (*Nq*-593/A1), and the *Hirsutella panda* acme zone. It is correlated with the uppermost Waiauan and lowermost Tongaporutuan (earliest late Miocene).

Bolboforma gruetzmacheri n. sp. Crundwell – Plate 3.4/1-6

Bolboforma sp. H, Grützmacher, 1993, pl. 3/7-9.





Description: Ornate phases up to 240 µm in diameter. Irregularly ridged and bladed species with subtriangular to subquadrate axial profiles, superimposed on a lagenoid to squat lagenoid test with a rounded to gently convex aboral surface. Short conical or tubular neck with a small terminal aperture. Test surface ornamented with robust, blind and interconnected, widely spaced, unevenly thickened blades and ridges. In large ornate

phases, the test ornament fuses with the base of the smooth-walled phase to form a relatively flat aboral surface. Intermediate phases have a subspherical lagenoid test with a well developed conical apertural neck and irregular poorly developed ridges (Plate 3.4/4). Small smooth-walled phases are generally subspherical, although some have vestiges of a rudimentary irregular-ridged ornament.

Remarks: Test ornament is highly variable, although pseudoreticulate ornaments, formed where interconnecting ridges meet at high-angles, are typical of specimens with subquadrate profiles, and ornaments with oblique high-angle blade-like ridges and fewer equatorial connections are more common in specimens with subtriangular profiles.

Discrimination: The irregular, strongly developed, bladed and ridged ornament distinguish *B. gruetzmacheri* from most other bolboforms. The late Oligocene species *B. irregularis* has an irregularly spinose-ridged ornament; the late Miocene species *B. praeintermedia* has a more closely spaced irregular spiro-concentric ornament; *B. mutabilis* is axially elongate and has an irregular, serrate spiral-flanged ornament; and the late Miocene to Pliocene species *B. intermedia* has a less prominent, irregularly ridged ornament.

Types: Holotype (TF 1664/1), 5 figured paratypes (TF1663/2-6), and 200 paratypes (TF 1663/7-206) lodged in the New Zealand national micropaleontological collections, maintained by Geological and Nuclear Sciences, Lower Hutt.

Type locality: DSDP Site 593, Challenger Plateau, 470 km west of central New Zealand (longitude 40° 30.47' S; latitude 167° 40.47' E), water depth 1068 m.

Type horizon: 593-32-4, 48-50 cm (298.08 mbsf), early late Miocene.

Derivation of name: Named after Jürgen Grützmacher, who first described the species under open nomenclature (Grützmacher 1993).

Distribution: Occurrences, at least those that are known to be *in situ*, are confined to a well defined subzone in the lower part of the BBg-Partial Zone (Figure 3.5), in the interval extending from 593-32X, 68-70 cm to 593-32X-2, 113-115 cm (298.28-295.73 mbsf). This occurs between the Kaiti and Tukemokihi Coiling Zones and is correlated with the lower Tongaporutuan (early late Miocene). Several specimens of *B. gruetzmacheri* also occur with *B. capsula* at 593-32CC, 2-4 cm (299.67 mbsf), where there is evidence of

sedimentary disturbance from the drilling and core recovery operation. Both species are thought to be contaminants, but reworking can not be ruled out.

Bolboforma capsula Spiegler – Plate 3.4/7-12

Bolboforma sp. Poag and Karowe, 1986, fig. 2/E-F.

Bolboforma sp. Poag and Karowe, 1987, pl. 2/10-12.

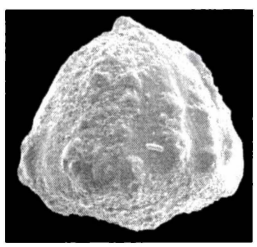
Bolboforma capsula Spiegler, 1987, pl. 2/4-6, 3/1-4.

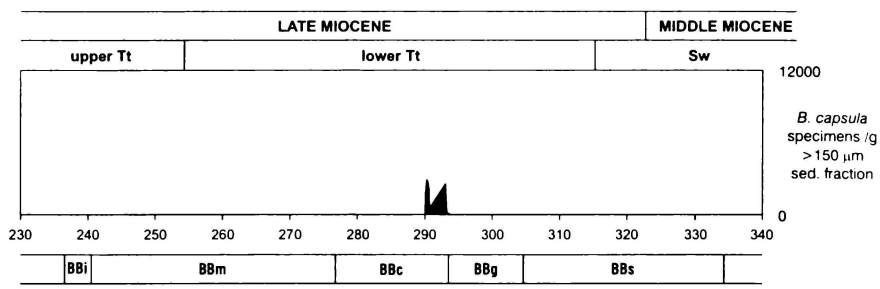
Bolboforma capsula Spiegler and Daniels, 1991, pl. 8/1-7.

Bolboforma capsula Mackensen and Spiegler, 1992, pl. 1/4.

Bolboforma capsula Grützmacher, 1993, pl. 3/4-6.

Bolboforma capsula Spiegler, 1999, pl. 2/17.





Description: Large tuberculate phases up to 220 µm in meridional section. Moderately smooth, axially corrugate and tuberculate, inflated lagenoid test with a smaller, encapsulated, subspherical, thin-walled chamber. Test widest at the junction of the high domed oral and gently rounded aboral surfaces. Very short conical neck with a small terminal aperture – not present in all specimens. Test surface ornamented with 8-12 widely spaced, axially aligned corrugate ridges, with tubercles. Tubercles are more common and strongly developed on larger specimens, especially near the base of the axial surface. Subcircular equatorial profile with radial symmetry, related to the regular spacing of corrugations and tubercles. Aboral surface smooth and lacking ornament. Intermediate phases have poorly developed tubercles and a rounded aboral surface, formed from the protruding base of the encapsulated chamber.

Remarks: Ornament varies on an intra-assemblage basis, from relatively smooth-walled specimens to those with well developed corrugate ridges and tubercles. The tests of large specimens are sometimes broken and show the encapsulated chamber fused to the base of the enclosing chamber wall.

Discrimination: The inflated, high-domed, moderately smooth corrugate-ridged and tuberculate test distinguish *B. capsula* from almost all other smooth-walled Miocene bolboforms. The large smooth walled middle to late Miocene species *B. robusta* lacks axial ridges and tubercles, although a slightly nodular species, *B.* cf. *robusta,* occurs near the middle-late Miocene boundary (Spiegler & Daniels 1991). The Miocene to early Pliocene species *B. laevis* has a much smaller, smooth-walled, lagenoid shaped test.

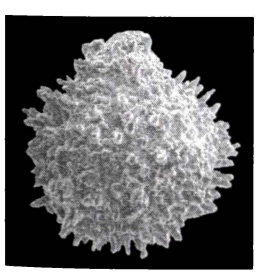
Distribution: *Bolboforma capsula* is confined to a well defined interval at the base of the BBc-Partial Range Zone (Figure 3.5), between 593-31X-5, 23-25 cm and 593-32X-1, 41-43 cm (289.73-293.51 mbsf). It occurs between the Kaiti and Tukemokihi Coiling Zones and it is correlated with the lower Tongaporutuan (early late Miocene). Assemblages of *B. capsula* are generally monospecific, expect for a narrow overlap with *B. pentaspinosa* s.l. in the lower part of core 593-31X. The rapid decrease in the relative proportion of *B. capsula* up through the overlap suggests they have sequential or closely sequential ranges and the overlap is due to bioturbation. A similar overlap between the ranges of *B. capsula* and *B. pentaspinosa* is also noted at Site 1123 (Chapter 5).

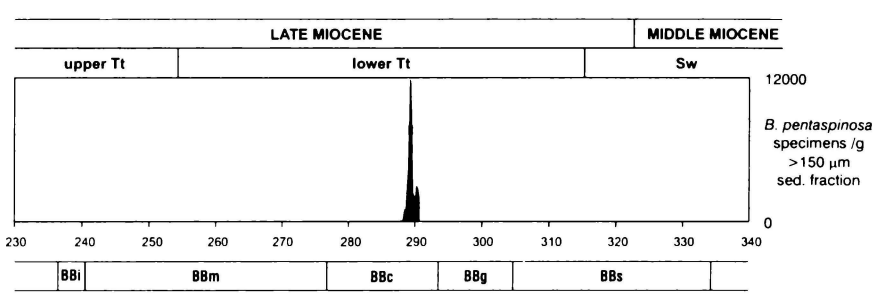
Bolboforma pentaspinosa Spiegler – Plate 3.4/13-15; and 3.5/1-3

Bolboforma pentaspinosa, Spiegler and Daniels, 1991, pl. 6/5-7.

Bolboforma pentaspinosa, Grützmacher, 1993, pl. II/10.

Bolboforma pentaspinosa, Spiegler, in press, pl. 3/6.





Description: Ornate phases up to 190 µm in meridional section. Highly spinose, subspheroidal test, with a low collar-like neck and large circular terminal aperture that can be up to one third the size of the test. In some specimens a much smaller opening also occurs at the centre of the aboral surface. Ornament comprised of closely packed, fine radial spines that are sometimes furcate-tipped. Spinose ornament similarly developed over most of the test, except for the apertural neck where spines are less prominent. Intermediate phases are very similar to large phases in having a subspheroidal test and low

collar-like aperture, but the fine spinose ornament is less prominent. No small smooth-walled phases have been observed.

Remarks: Morphotypes from Site 593 differ from the holotype and figured paratypes of *B. pentaspinosa* in several ways – the aperture is generally much larger and surrounded by a low collar-like neck, and the spines are more closely packed and show no evidence of a regular pentagonal arrangement. In describing *B. pentaspinosa*, Spiegler & Daniels (1991) did not discuss interspecific variation, but the figured types show a similar range of spine development to morphotypes from Site 593.

Discrimination: The highly spinose subspherical test with its low collar-like neck and large aperture distinguish Site 593 morphotypes of *B. pentaspinosa* from most other spinose Miocene bolboforms. The late Oligocene to early Miocene species *B. spinosa* has shorter spines; the middle to late Miocene species *B. clodiusi* is aborally flattened and has short blunt spines; the middle Miocene species *B. compressispinosa* is bipolarly compressed and has widely spaced furcate-tipped spines; and *B. "spinulosa"* has a moderately ovate test and poorly developed apertural neck.

Distribution: Generally confined to a monospecific interval in the lower part of the BBc-Partial Range Zone (Figure 3.5), between 593-31X-5, 23-25 cm and 593-31X-3, 82-84 cm (289.73-287.32 mbsf). This occurs between the Kaiti and Tukemokihi Coiling Zones and is correlated with the lower Tongaporutuan (late Miocene).

Bolboforma gracilireticulata s.l. Spiegler – Plate 3.5/4-12

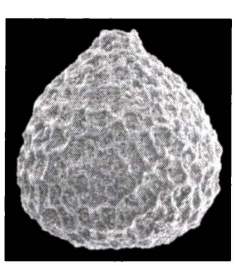
Bolboforma metzmacheri, Müller, Spiegler and Pastouret, 1985, pl. 1/1-3.

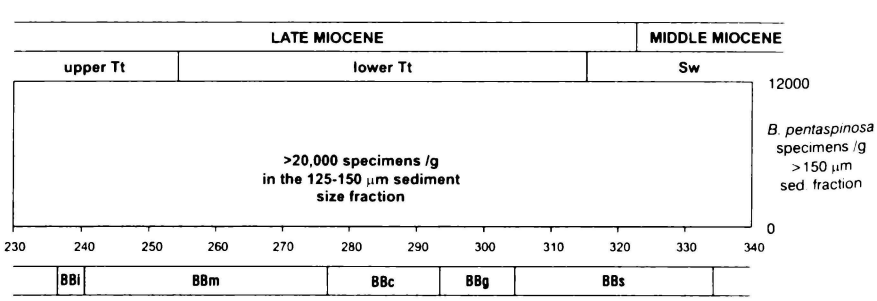
Bolboforma metzmacheri, Pallant and Kaminski, 1989, pl. 1/1.

Bolboforma metzmacheri, Daniels and Spiegler, 1991, pl. 4/3.

Bolboforma sp. G, Grützmacher, 1993, pl. III/1-3.

Bolboforma gracilireticulata, Spiegler, 1999, pl. 2/14.





Description: Ornate phases up to 160 μm in meridional section, but most commonly less than 150 μm. Delicately ornamented, cancellate, subspheroidal lagenoid test, with a rounded to gently convex aboral surface. Short conical neck with a small terminal aperture. Test surface ornamented with fine cancellate-ridged network of five- to six-sided polygonal-shaped cells that are often distorted by close packing – 30 or more cells in meridional section. Ornament equally developed over most of test, but tends to be weaker towards the polar extremities of the oral and aboral surfaces. Intermediate phases are similar in shape to large ornate phases but have weaker ornament and intergrade with smooth-walled phases without ornament (Plate 3.5/4-6).

Remarks: In the past, smooth-walled phases that are considered here to part of the range of intraspecific morphotypic variation of *B. gracilireticulata* s.l. have been assigned to *B. laevis*. They differ however, from the holotype of *B. laevis*, refigured by Spiegler & Daniels (1991). The holotype has a much squatter, almost ovate, lagenoid test, with vestiges of rudimentary ornament. This suggests it is not a smooth-walled phase of *B. gracilireticulata*, but is related to an unspecified large ornate phase. Until this species has been identified and there is clarification of its taxonomic status, use of the name *B. laevis* should be avoided.

Discrimination: The fine cancellate-ridged ornament and small subspheroidal lagenoid test distinguish *B. gracilireticulata* s.l. from most polygonal-ridged Miocene bolboforms. The early to middle Miocene species *B. reticulata*, has a much wider-spaced ornament with only 10-20 polygonal cells in meridional section; and the late Miocene species *B. metzmacheri* s.s. and *B. metzmacheri ornata* are larger, aborally flattened, and have more strongly developed ornaments with 20-30 polygonal cells in meridional section.

Distribution: Ornate and smooth-walled phases of *B. gracilireticulata* s.l. are relatively rare in the >150 μm sediment size fraction, but smooth-walled phases are often common in the 125-150 μm size fraction and form a continuous zone extending from 593-31X-1, 105-107 cm to 593-30X-4, 32-34 cm (284.55-278.72 mbsf). The maximum abundance of specimens in this size fraction peaks in sample 593-30X-4, 32-34 cm (278.72 mbsf) at more than 20,000 specimens per gram of sediment. The species is confined to the upper part of the BBc-Partial Range Zone (Figure 3.5), between the Kaiti and Tukemokihi Coiling Zones, in an interval correlated with the lower Tongaporutuan (early late Miocene).

Bolboforma sp. indet. (smooth-walled phase) – Plate 3.6/4-6

Description: Maximum size about 150 µm in meridional section, but most specimens are less than 125 µm. Small, smooth-walled, subspheroidal lagenoid, sac-like test, with a rounded to gently convex aboral surface. Short conical neck with a small terminal aperture. Test shape highly variable. Most specimens lack ornament, but occasionally some have vestiges of rudimentary ornament.

Remarks: The identification of small smooth-walled phases has been a source of considerable taxonomic confusion, as alluded to by Spiegler & Daniels (1991) when they specifically noted difficulty distinguishing *B. laevis* and small cyst-like phases of other bolboform species. It has also been common practise to assign such nondescript morphotypes to *B. laevis*, even when there is a direct or obvious link to larger ornate phases (e.g. Poag & Karowe 1986). Such improper use has recently been highlighted by the documentation of a morphological transformation from small smooth-walled phases to large ornate phases, in monospecific assemblages of at least three late Miocene species (Study 4). Furthermore, it is recommended that small smooth-walled phases and those with rudimentary ornaments that have no obvious connection to larger ornate phases, should be identified as species of uncertain affinity and they should not be assigned to *B. laevis*.

Figured specimens: Deposited in the New Zealand national micropaleontological collections maintained by Geological and Nuclear Sciences, Lower Hutt: FP4969-4971.

Distribution: Small smooth-walled phases occur at a number of stratigraphic horizons, but most are closely associated with larger ornate phases and have been assigned accordingly. However, a few smooth-walled phases of uncertain affinity occur in subzone BBs-593/D, the uppermost part of the BBc-Partial Range Zone, and just above subzone BBm-593/A (Appendix 3.1). The majority of these specimens occur in the <150 µm sediment size fraction.

Bolboforma metzmacheri (Clodius 1922) – Plate 3.5/1-3; 3.6/1-3, 7-12; and 3.7/11, 13, 15

Lagena metzmacheri, Clodius, 1922, pl. 1/2.

Bolboforma metzmacheri, Daniels and Spiegler, 1974, pl. 7/1-3.

Bolboforma metzmacheri, Willems, 1976, fig. 3-5, pl. 1/a-d.

Bolboforma metzmacheri, King, 1983, pl. 1/12-13.

Bolboforma metzmacheri, Murray, 1984, pl. 1/9-10.

Bolboforma metzmacheri, Poag and Karowe, 1986, fig. 3/P-Q.

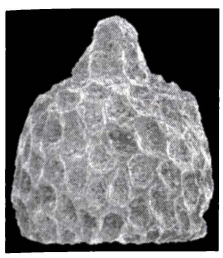
Bolboforma metzmacheri, Qvale and Spiegler, 1989, pl. 1/5.

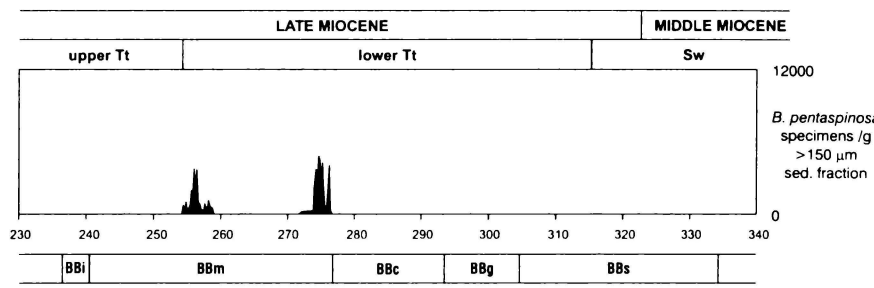
Bolboforma metzmacheri, Daniels and Spiegler, 1991, pl. 4/1-2.

Bolboforma metzmacheri, Mackensen and Spiegler, 1992, pl. 1/2.

Bolboforma metzmacheri, Grützmacher, 1993, pl. 2/7-9.

Bolboforma metzmacheri metzmacheri, Spiegler, in press, pl. 2/11.





Description: Ornate phases up to 190 µm in meridional section. Cancellate, cylindrical, or squat ogival lagenoid test, with a relatively flat, strongly differentiated aboral surface. Short conical neck with a small terminal aperture. Test surface ornamented with a strongly developed reticulate-ridged network of small, 5- to 6-sided, closely packed, polygonal cells – 20 to 30 cells in meridional section. Ornament extends onto the outer margin of the aboral surface and fuses with the base of the early-formed smooth-walled phase. The cancellate ornament also extends onto the neck, but becomes weaker and does not reach the terminal aperture. Intermediate phases differ from large ornate phases in having a subspheroidal lagenoid test with a rounded aboral surface. The polygonal-ridged ornament is less well developed in larger intermediate phases, especially on the upper oral surface. In smaller intermediate phases a rudimentary polygonal-ridged ornament is usually confined to the lower aboral surface – such specimens grade into even smaller smooth-walled phases.

Remarks: Two distinct forms of *B. metzmacheri* s.s. have been identified – elongated cylindrical morphotypes (Plate 3.5/13-15) and inflated squat ogival morphotypes (Plate 3.6/7-8). They occupy separate, but not entirely exclusive, ranges.

Discrimination: The cancellate ornament, aborally flattened test, and well developed apertural neck distinguish *B. metzmacheri* s.s. from most other Miocene bolboforms. The late Miocene subspecies *B. metzmacheri ornata* is distinguished by its spinose-cancellate ornament. Other cancellate species are aborally rounded – the early to middle Miocene species *B. reticulata*, has a more widely-packed ornament with 10-20 polygonal cells in

meridional section; and the late Miocene species *B. gracilireticulata* has a very fine ornament with 30 or more polygonal cells in meridional section.

Distribution: Specimens of *B. metzmacheri* s.s. are largely confined to two well defined subzones. Subzone BBm-593/A (Figure 3.5) that extends from 593-30X-2, 133-135 cm to 593-29X-6, 14-16 cm (276.73-271.94 mbsf) is dominated by cylindrical morphotypes of *B. metzmacheri s.s.* It occurs just below the Tukemokihi Coiling Zone and is correlated with the lower Tongaporutuan (early late Miocene). Subzone BBm-593/C (Figure 3.5) extends from 593-28X-3, 137-139 cm to 593-27X-7, 17-19 cm (258.88-254.27 mbsf) and includes a few cylindrical morphotypes in its lower part, but is generally dominated by squat ogival morphotypes. It includes the highest occurrence of *Globoquadrina dehiscens* in its uppermost part and is correlated with the uppermost lower to lowermost upper Tongaporutuan (middle late Miocene).

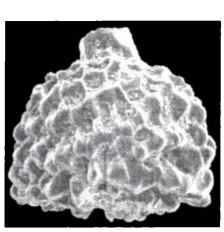
Another narrow subzone, BBm-593/B (Figure 3.5) comprising small smooth-walled phases (<150 μm) of uncertain affinity, occurs between subzones BBm-593/A and C. It occurs within the Tukemokihi Coiling Zone, and extends from 593-29X-5, 15-17 cm to 593-29X-4, 107-109 cm (270.45-269.87 mbsf).

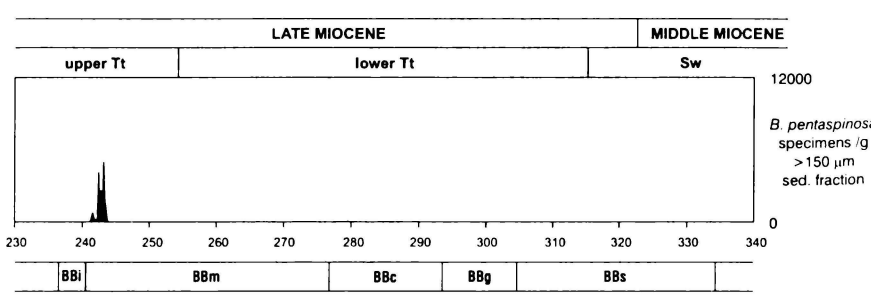
Bolboforma metzmacheri ornata Spiegler – Plate 3.6/13-15; and 3.7/1-3

Bolboforma cf. *metzmacheri*, Spiegler and Daniels, 1991, pl. 4/5.

Bolboforma cf. *metzmacheri*, Grützmacher, 1993, pl. 2/4-6.

Bolboforma metzmacheri ornata, Spiegler, in press, pl. 2/10.





Description: Ornate phases up to 190 μm in meridional section. Spinose-cancellate lagenoid test, with a relatively flat, strongly differentiated aboral surface. Conical neck with a small terminal aperture. Robust closely packed ornament, comprised of short, blunt, subradial spines, superimposed on a cancellate-ridged network of 5- to 6-sided polygonal cells. Spines are strongly developed on the meridional section of the test wall and become weaker towards the neck. The cancellate ornament also extends onto the outer margin of

the aboral surface, and fuses with the base of the early-formed smooth-walled phase. Intermediate phases also have cancellate ornaments, but they differ from large ornate phases in having subspheroidal tests with rounded aboral surfaces. They intergrade with smaller intermediate phases with rudimentary nodular ornaments and smooth-walled phases with no discernible ornament.

Discrimination: The relatively flat, strongly differentiated aboral surface and spinose-cancellate ornament, distinguish *B. metzmacheri ornata* from most Miocene bolboforms – *B. metzmacheri* s.s. has a similar test shape, but lacks spines. Other taxa with polygonally arranged spines tend to be aborally rounded – the late Oligocene to late Miocene species *B. pseudohysterix* has furrowed spines; the middle to late Miocene species *B. badenensis* is subspherical; the middle Miocene species *B. voeringensis* has spines with shallow furrows; *B. bella* has strongly furrowed furcate-tipped spines; and *B. compressibadenensis* is bipolarly compressed.

Distribution: Confined to monospecific assemblages in the uppermost part of the BBm-Range Zone (Figure 3.5), in the interval between 593-26X-6, 63-65 cm and 593-26X-4, 92-94 cm (243.63-240.92 mbsf). It occurs above the highest occurrence of *Globoquadrina dehiscens* and below the lowest occurrence of *Globoconella conomiozea s.s.*, and is correlated with the lower upper Tongaporutuan (middle late Miocene).

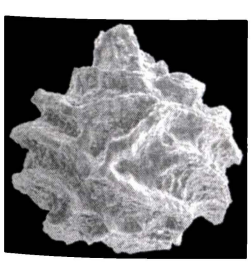
Bolboforma praeintermedia Spiegler – Plate 3.7/4-9

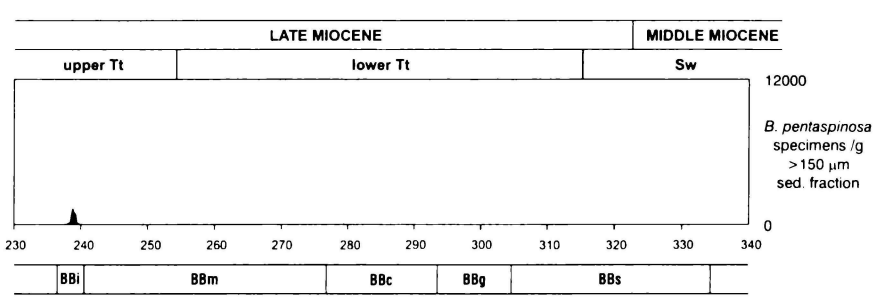
Bolboforma intermedia, Murray, 1984, pl. 1/5-6.

Bolboforma sp. A, Pallant and Kaminski, 1989, pl. 1/2.

Bolboforma cf. *intermedia*, Grützmacher, 1993, pl. 2/1-3.

Bolboforma praeintermedia, Spiegler, in press, pl. 2/4.





Description: Ornate phases up to 190 µm in meridional section. Irregularly spiro-concentric ridged, subspherical lagenoid test, with a rounded aboral surface. Short conical neck with a small terminal aperture. Test surface ornamented with a well-developed

irregular network of unevenly thickened spiro-concentric flanges and ridges. In large ornate phases the test ornament is strongly developed in meridional section and is weaker towards the neck and centre of the aboral surface. Larger intermediate phases have a more sac-like lagenoid test with a rounded aboral surface and an extruded apertural neck, and the test is ornamented with a poorly developed irregular network of nodular ridges (Plate 3.4/4). Smaller intermediate phases have a rudimentary surface ornament of widely spaced, irregular interconnected ridges.

Remarks: Test ornament is highly variable, and ranges from undulating, closely spaced, almost continuous, nodular spiro-concentric flanges with few interconnections (Plate 3.7/5), to more widely spaced, oblique, discontinuous flanges with numerous high-angle interconnections (Plate 3.7/4).

Discrimination: The squat lagenoid test shape and irregular interconnecting network of spiro-concentric flanges and ridges distinguish *B. praeintermedia* from most other irregular ridged bolboforms. The late Oligocene species *B. irregularis* has a very irregular spinose-ridged ornament; the late Oligocene to early Miocene species *B. spiralis* has a spiral-flanged ornament; the middle to late Miocene species *B. subfragoris* and *B. fragori* have bipolarly compressed spiral-flanged tests; and the late Miocene species *B. gruetzmacheri* has a more strongly developed, widely spaced, bladed and irregular ridged ornament.

Distribution: Confined to monospecific assemblages in the BBi-Partial Range Zone (Figure 3.5), in an interval extending from 593-26X-4, 32-34 cm to 593-26X-2, 112-114 cm (240.32-238.12 mbsf). This occurs between the highest occurrence of *Globoquadrina dehiscens* and the lowest occurrence of *Globoconella conomiozea* s.s., in an interval correlated with the lower upper Tongaporutuan (middle late Miocene). The highest occurrence of *B. praeintermedia* marks the last known occurrence of bolboforms at Site 593 and the greater New Zealand region (see earlier discussion).

BOLBOFORM ZONATION

The bolboform zonation adopted in this study is based on the Southwest Pacific zonal scheme introduced by Grützmacher (1993) and it includes many of the zonal species used in the North Atlantic and southern Indian Ocean zonations (Figure 3.7). An integrated scheme of bolboform and planktic foraminiferal events identified at Site 593 is given in Table 3.2.

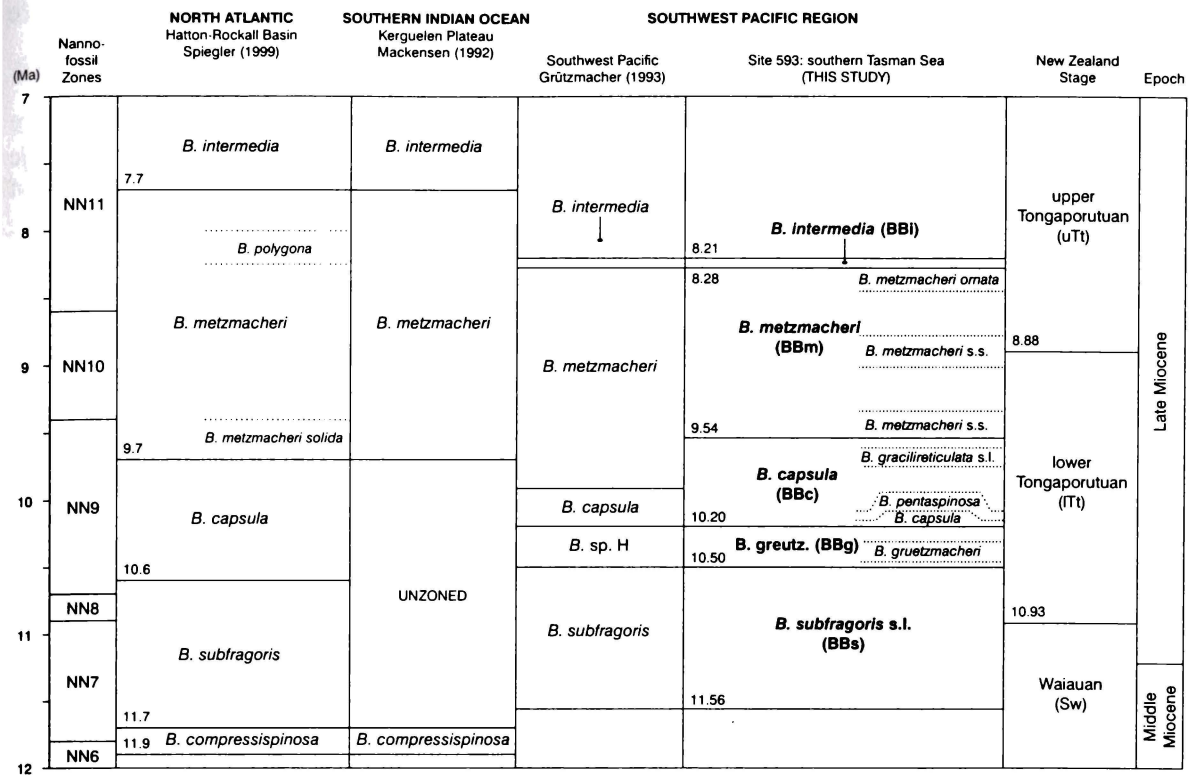


Figure 3.7 – Correlation of bolboform zonations from the North Atlantic, southern Indian Ocean, and Southwest Pacific region associated with the New Zealand subcontinent. Geological ages are reported in terms of Berggren et al. (1995) and the calcareous nannofossil zonation is from Martini (1971). Site 593 ages are from the magnetostratigraphically constrained chronology at Site 1123 (Study 5).

The lower part of the bolboform sequence, inclusive of cores 593-36X and 593-33X, has five bolboform subzones BBs-593/A–E that are populated with at least four overlapping morphotypic assemblages of spirospinose bolboforms that have an affinity to *Bolboforma subfragoris* (Figure 3.5). Because these morphotypes have only been recognized at Site 593 and discrimination is often difficult, they have been described under open nomenclature: *B.* sp. spirospinosa, *B.* sp. serrata, *B.* sp. echinus, and *B.* sp. spinulosa. It is anticipated that some of these morphotypes may eventually be separated as new species or subspecies. Collectively they are included here in the *B. subfragoris* s.l. Range Zone that extends from the base of subzone BBs-593/A to the top of subzone BBs-593/E (Figure 3.5). While most BBs-subzones are heterogeneous and include several morphotypes, samples are often dominated by a single morphotypes and some samples appear to be monomorphotypic. The upper part of subzone BBs-593/B and subzone BBs-593/C also appear to be monomorphotypic. The complex pattern of morphotypic variation within the *B. subfragoris* s.l. Range Zone, and the problem of distinguishing some morphotypic variants, reduce the reliability of subzonal correlations, but there is the potential to refine

biostratigraphic correlations with more detailed study. Peaks in bolboform abundance are also potentially useful for refining correlations at a subzonal level.

Table 3.2 – Integrated middle and late Miocene (Waiauan to Tongaporutuan) bolboform and planktic foraminiferal events, Site 593. BB = bolboform, PF = planktic foraminifer – see Study 2 for an explanation of planktic foraminiferal events.

Fossil group	Bolboform and planktic foraminiferal events	Depth (mbsf)	NZ Stage	Bolboform zonation	Age/Epoch	
PF	LO *Globoconella conomiozea* **Tk/Tt proxy**	167.06	Kapitean		MESSIN.	UPPER MIOCENE
PF	Top middle *Truncorotalia juanai* acme	185.07	upper Tongaporutuan (uTt)			
PF	Base middle *Truncorotalia juanai* acme*	193.50				
BB	HO *Bolboforma praeintermedia*	236.52		B. intermedia (BBi)	TORTONIAN	
PF	LO *Hirsutella* aff. *ichinosekiensis* (non-carinate)	240.07				
BB	LO *Bolboforma praeintermedia*	240.32				
BB	HO *Bolboforma metzmacheri ornata*	240.92		B. metzmacheri (BBm)		
BB	LO *Bolboforma metzmacheri ornata*	246.06				
BB	HO *Bolboforma metzmacheri s.s.* BBm-593/B	254.27				
PF	LO *Globoquadrina dehiscens* **upper-lower Tt proxy**	254.49	lower Tongaporutuan (lTt)			
PF	LO *Hirsutella* aff. *ichinosekiensis* (weakly carinate)	255.28				
BB	LO *Bolboforma metzmacheri s.s.* BBm-593/B	259.07				
PF	Top Tukemokihi Coiling Zone (Gm-593/2)*	269.28				
PF	Base Tukemokihi Coiling Zone (Gm-593/2)*	270.72				
BB	HO *Bolboforma metzmacheri* s.s. BBm-593/A	271.94				
BB	*Bolboforma metzmacheri* s.s. BBm-593/A (abundance spike)	274.72				
BB	LO *Bolboforma metzmacheri* s.s. BBm-593/A	276.73				
BB	HO *Bolboforma gracilireticulata* s.l.	278.72		B. capsula (BBc)		
BB	LO *Bolboforma gracilireticulata* s.l.	284.55				
BB	HO *Bolboforma pentaspinosa*	287.32				
BB	HO *Bolboforma capsula*	289.73				
BB	LO *Bolboforma pentaspinosa*	290.33				
BB	LO *Bolboforma capsula*	293.51				
PF	Top Glomar Coiling zone (Nq-593/1A)	294.51		B. gruetzmacheri (BBg)		
BB	HO *Bolboforma gruetzmacheri*	295.12				
PF	HO *Hirsutella panda* (strongly keeled morphotypes)	298.08				
BB	LO *Bolboforma gruetzmacheri*	298.93				
PF	LO *Neogloboquadrina pachyderma* (Nq-593/1A)	299.67				
PF	HO *Neogloboquadrina mayeri* s.l. (Nq-593/1)	302.71				
PF	Top lower *Truncorotalia juanai* acme	303.29				
BB	HO *Bolboforma subfragoris* s.l. (top BBs-593/E)	304.66		B. subfragoris (BBs)		
PF	Top *Hirsutella panda* acme (>10% abundance)	305.55				
PF	Top Mapiri Coiling Zone (Gm-593/1A)	306.11				
PF	Base Mapiri Coiling Zone (Gm-593/1A)	306.54				
BB	*Bolboforma subfragoris* s.l. abundance spike (BBs-593/E)	306.86				
BB	*Bolboforma subfragoris* s.l. (base BBs-593/E)	307.70				
PF	LO *Truncorotalia juanai* (base lower *T. juanai* acme)	308.99				
PF	Base Glomar Coiling zone (Nq-593/1)	308.99				
BB	*Bolboforma subfragoris* s.l. (top BBs-593/D)	308.99				
PF	Base *Hirsutella panda acme* (>10% abundance)	309.11				
PF	Top Kaiti Coiling Zone (Gm-593/1)	309.11				
PF	HCO *Neogloboquadrina mayeri* s.l. (>5% abundance)	313.17				
PF	Base Kaiti Coiling Zone (Gm-593/1) **Tt/Sw proxy**	315.19				
BB	*Bolboforma subfragoris* s.l. (base BBs-593/D)	316.27	Waiauan (Sw)		SERRAVALLIAN	MIDDLE MIOCENE
BB	*Bolboforma subfragoris* s.l. (top BBs-593/C)	322.72				
BB	*Bolboforma subfragoris* s.l. (base BBs-593/C)	324.30				
BB	*Bolboforma subfragoris* s.l. (top BBs-593/B)	326.50				
BB	*Bolboforma subfragoris* s.l. (base BBs-593/B)	331.69				
BB	*Bolboforma subfragoris* s.l. (top BBs-593/A)	332.68				
BB	LO *Bolboforma subfragoris* s.l. (base BBs-593/A)	334.43				
PF	HO *Fohsella peripheroronda* **Sw/Sl proxy**	372.16	Lillburnian (Sl)			

The upper part of the bolboform sequence, from the base of core 593-32X to the top of 593-26X, includes a well defined succession of distinct bolboform species that are confined to eight subzones, largely punctuated by intervals without bolboforms (Figure 3.5). In ascending species order, the succession includes: *Bolboforma gruetzmacheri* within the *B. gruetzmacheri* Partial Range Zone (BBg); *B. capsula, B. pentaspinosa,* and *B. gracilireticulata* s.l. within the *B. capsula* Partial Range Zone (BBc); *B. metzmacheri* s.s. (BBm-593/A and BBm-593C) and *B. metzmacheri ornata* within the *B. metzmacheri* Range Zone (BBm); and *B. praeintermedia* within the *B. intermedia* Partial Range Zone (BBi). Subzonal occurrences from the upper part of the bolboform succession are largely monospecific. Joint species occurrences have been noted in at least four samples (Appendix 3.1), although they are attributed to bioturbation and sample contamination.

***Bolboforma subfragoris* s.l. Range Zone**

The BBs-Zone extends from 593-36X-2, 143 cm to 593-33-2, 46-48 cm (334.43-304.66 mbsf). Rare spiral-flanged specimens of *B. subfragoris* s.s., from which the zone derives its name, occur as morphotypic end members of the variation field associated with the relatively common *B.* sp. serrata morphotype. Bolboform occurrences within the BBs-Zone are confined to five short-lived subzones (BBs-593/A to E) that are punctuated by intervals without bolboforms (Figure 3.5). Most subzonal assemblages are morphotypically heterogeneous and include several spirospinose morphotypes: *B.* sp. spirospinosa, *B.* sp. serrata, *B.* sp. echinus, and *B.* sp. spinulosa, except for subzones BBs-593/A and the upper part of BBs-593/B, which appear to be monomorphotypic.

Subzone BBs-593/A: Extends from 593-36X-2, 143 cm to 593-36X-1, 130 cm (334.43-332.80 mbsf). The subzone is dominated by spinose morphotypes of *B.* sp. spirospinosa with fused or partially fused spines that form an irregular axially spiralled pattern (Figure 3.6/15). The subzone also includes some specimens of *B.* sp. spinulosa x spirospinosa with partially fused spines. A prominent peak in abundance occurs in the lower part of the subzone where there are up to 5500 specimens per gram of sediment, in the >150 µm size fraction.

Subzone BBs-593/B: Extends from 593-36X-1, 19-21 cm to 593-35X-4, 10-12 cm (331.69-326.50 mbsf). The lower part of the subzone is only sparsely populated with bolboforms and assemblages include morphotypes of *B. subfragoris* s.s. and *B.* sp. serrata.

Assemblages also include rare *B.* sp. spinulosa morphotypes that are somewhat atypical and have a partially fused, spiralled, spinulose ornament. The upper part of the subzone includes monomorphotypic assemblages of *B.* sp. spinulosa with short-spined, fine-spined, and coarse-spined forms (Figure 3.6/13). A prominent peak in abundance occurs in the upper part of the subzone where there are up to 6500 specimens per gram of sediment, in the >150 μm size fraction.

Subzone BBs-593/C: Extends from 593-35X-2, 90-92 cm to 593-35X-1, 82-84 cm (324.30-322.72 mbsf). The subzone is only sparsely populated with bolboforms and morphotypic variation is confined to *B.* sp. echinus (Figure 3.6/12).

Subzone BBs-593/D: Extends from 593-34X-3, 97-99 cm to 593-33X-5, 29-31 cm (316.27-308.99 mbsf). Morphologic variation in the lower part of the subzone is confined to serrate-flanged spirospinose morphotypes that have affinities to *B.* sp. spirospinosa and B. sp. serrata. Assemblages from the upper part of the subzone include morphotypes of *B. subfragoris* s.s. and *B.* sp. serrata. They also include a few spinose morphotypes of *B.* sp. spirospinosa that appear to be end members of the variation field associated with *B.* sp. serrata. Bolboforms are moderately sparse throughout the subzone and abundances peak at only 645 specimens per gram of sediment, in the >150 μm size fraction.

Subzone A: Extends from 593-33X-4, 50-52 cm to 593-33X-2, 46-48 cm (307.70-304.66 mbsf). The lower part of the subzone is well populated and assemblages include *B.* sp. spirospinosa and B. sp. serrata morphotypes. Rare spiral flanged morphotypes of *B. subfragoris* s.s. are also present.

The BBs-Zone includes at least three prominent peaks in bolboform abundance, where specimen numbers are two to three orders of magnitude above background numbers: subzone BBs-593/A, 593-36X-2, 130 cm (334.30 mbsf); subzone BBs-5993/B, 593-35-4, 69-71 cm (327.09 mbsf); and subzone BBs-593/E, 593-33X-3, 116-118 cm (306.86 mbsf). Although the abundance peaks are not unique, they are very conspicuous and potentially useful as biostratigraphic markers, at least for intraregional correlation. For example, a reliable correlation has been established between abundance peaks in subzones BBs-593/A and BBs-1123/A, and BBs-593/E and BBs-1123/D from Sites 593 and 1123 (Study 5).

Planktic foraminiferal events associated with the BBs-Zone include the Kaiti Coiling Zone (*Gc*-593/A), the last common occurrence of *Neogloboquadrina mayeri* s.l., the *Hirsutella panda* acme zone, and the base of the Glomar Coiling Zone (subzone *Nq*-593/A1) (Table 3.2). They all occur within the upper part of the BBs-Zone in the interval between subzones BBs-593/D and E. The BBs-Zone is correlated with the upper Waiauan and lowermost Tongaporutuan (latest middle to earliest late Miocene).

In the North Atlantic, Mediterranean, and southern Indian Ocean regions, the base of the BBs-Zone is marked by the last common occurrence of the oblate species *B. compressispinosa* (Spiegler & Daniels 1991) (Figure 3.7). Oblate morphotypes of *B.* sp. spinulosa are noted in the lower part of core 593-35X and upper part of 593-36X, although the very fine spinulose ornament sets them apart from *B. compressispinosa,* which has a widely spaced furcate-tipped ornament. These oblate specimens are also underlain by spirospinose morphotypes of *B. subfragoris* s.l. and not *B. badenensis* as in the North Atlantic (Spiegler 1999). This suggests the lowermost part of the BBs-Zone may not be represented at Site 593.

***Bolboforma gruetzmacheri* Partial Range Zone (BBg)**

The BBg-Zone is equivalent to the *Bolboforma* sp. H zone of Grützmacher (1993). It extends from immediately above the highest occurrence of *B. subfragoris* s.l. to just below the lowest occurrence of *B. capsula,* and is represented by the interval between 593-33X-2, 27-29 cm and 593-32X-1, 61-63 cm (304.47-293.93 mbsf). The zone takes its name from the new species *B. gruetzmacheri* (*B.* sp. H of Grützmacher 1993). *Bolboforma gruetzmacheri* is confined to the middle to upper part of the BBg-Zone between 593-32X-133-135 cm and 593-32X-2, 73-75 cm (298.93-295.33 mbsf). There are no bolboforms in the lower and uppermost parts of the BBg-Zone, although specimens of a small species with rudimentary nodular ornament (Figure 3.6/9) occur in very large assemblages of *B. gruetzmacheri* at 593-32X-2, 133-135 cm (295.93 mbsf). The two species appear to have coexisted, although the nodular forms are similar to small intermediate phases of spirospinose morphotypes from the underlying BBs-Zone and there is the possibility that they have been reworked. The small nodular forms also bear a superficial resemblance to the long ranging Miocene species *B. clodiusi* Daniels and Spiegler.

The BBg-Zone includes two prominent peaks in abundance where specimen numbers are up to two orders or magnitude above background values. The peaks occur in samples 593-

32X-4, 48-50 cm and 593-32X-2, 133-135 cm (298.08-295.93 mbsf). Associated planktic foraminiferal events include the lowest occurrence of *Neogloboquadrina pachyderma* at the base of the BBg-Zone, the highest occurrence of strongly keeled *Hirsutella panda* within the *B. gruetzmacheri* subzone, and the top of the Glomar Coiling Zone (subzone *Nq*-593/1A) in the uppermost part of the BBg-Zone (Table 3.2). The BBg-Zone is correlated with the lower Tongaporutuan (early late Miocene).

A similar zone has not been recognized in the North Atlantic, South Atlantic, and southern Indian Ocean. In these regions the *B. capsula* Zone immediately overlies the *B. subfragoris* s.l. Zone (Spiegler & Daniels 1991; Spiegler 1999) (Figure 3.7).

***Bolboforma capsula* Partial Range Zone**

The BBc-Zone extends from the lowest occurrence of *B. capsula* up to immediately below the lowest occurrence of *B. metzmacheri* s.s. and is represented by the interval between 593-32X-1, 41-43 cm and 593-30X-2, 133-135 cm (293.51-276.73 mbsf). The lower part of the BBc-Zone includes the overlapping *B. capsula* and *B. pentaspinosa* subzones, and the upper part includes the *B. gracilireticulata* s.l. subzone. The inclusion of the latter taxon in the BBc-Zone is concomitant with its description as a new species by Spiegler (in press). Previously it was interpreted as a morphotypic variant of *B. metzmacheri* (e.g. Müller et al. 1985; Pallant & Kaminski 1989; Spiegler & Daniels 1991) and included in the BBm-Zone.

The BBc-Zone is located between the Glomar (*Nq*-593/A1) and Tukemokihi (*Gc*-593/C) Coiling Zones (Table 3.2), and is correlated with the lower Tongaporutuan (early late Miocene).

In the North Atlantic and southern Indian Ocean, the BBc-Zone extends down to immediately above the *B. subfragoris* s.l. Zone (Spiegler & Daniels 1991) (Figure 3.7).

***Bolboforma metzmacheri* Range Zone**

The BBm-Zone extends from the lowest occurrence of *B. metzmacheri* s.s. up to the highest occurrence of *B. metzmacheri ornata* and is represented by the interval between 593-30X-2, 112-114 cm to 593-26X-4, 92-94 cm (276.52-240.92 mbsf). It includes three well defined bolboform subzones that are punctuated by intervals without bolboforms. The lower subzone is dominated by elongate bottle-shaped morphotypes of *B. metzmacheri* s.s.

(BBm-593/A); the middle subzone is dominated by squat ogival morphotypes of *B. metzmacheri* s.s. (BBm-593/C); and the upper subzone consists entirely of *B. metzmacheri ornata*. Very rare small smooth-walled bolboforms of uncertain taxonomic affinity (*B.* sp. indet.) also occur in a narrow interval just above subzone BBm-593/A, between 593-29X-5, 15-17 cm to 593-29X-4, 107-109 cm (270.45-269.87 mbsf) – they are associated with the Tukemokihi Coiling Zone (*Gc*-593/C). The highest occurrence of *Globoquadrina dehiscens,* which marks the top of lower Tongaporutuan, occurs just below the top of subzone BBm-593/C (Table 3.2). The BBm-Zone is correlated with the upper lower to lowermost upper Tongaporutuan (middle late Miocene).

The BBm-Zone has been recorded in the North Sea Basin, Mediterranean, North Atlantic, Gulf of Mexico, South Atlantic, and southern Indian Ocean (Spiegler & Daniels 1991; Spiegler 1999), and in the Southwest Pacific (Grützmacher 1993).

Bolboforma intermedia Partial Range Zone

The BBi-Zone extends upwards from immediately above the highest occurrence of *B. metzmacheri ornata* and is represented by the interval between 593-26X-4, 32-34 cm and 593-26X-2, 112-114 cm (240.32-238.12 mbsf). Compared to bolboform successions in the North Atlantic and southern Indian Ocean, the BBi-Zone is prematurely truncated at Site 593 and includes only *B. praeintermedia* – a species that is restricted to the base of the BBi-Zone (Spiegler 1999). No other bolboforms have been found in the upper Tongaporutuan to lower Opoitian (late Miocene to early Pliocene) section above core 593-26X (see earlier).

The only significant planktic foraminiferal event associated with the truncated BBi-Zone is the highest occurrence of non-carinate *Hirsutella* aff. *ichinosekiensis,* close to the base of the zone (Table 3.2). The truncated BBi-zone at Site 593 is correlated with the lowermost upper Tongaporutuan (middle late Miocene).

DISCUSSION – INTERPRETATION OF BOLBOFORM RECORD

The stratigraphic record of bolboforms at Site 593, particularly the upper part of the succession prior to the regional disappearance of bolboforms (c. 8 Ma), shows several distinctive features that are not seen in the distribution patterns of planktic foraminifers at the same site: 1) bolboform occurrences are confined to narrow intervals ranging from 1.6 to 5.8 m thick, approximately 50 to 330 k.y. duration; 2) occurrences are often punctuated

by intervals without bolboforms; 3) occurrences are often comprised of single species assemblages; and 4) distinctive abundance spikes occur within most zones and subzones (Figure 3.5). These features appear to be unique to the ecology of bolboforms and they provide important insights into the potential biostratigraphic and paleoceanographic utility of this enigmatic microfossil group. A detailed discussion of bolboform ecology is beyond the scope of the present study, although some aspects of the bolboform distribution at Site 593 are discussed below. The paleoceanographic significance of bolboforms is addressed separately by Cooke et al. (2002).

Punctuated bolboform record

The middle to late Miocene record of bolboforms at Site 593 is characterized by at least 14 very narrow subzones, which include the total range zones of some species (Figure 3.5). The subzones are punctuated by intervals without bolboforms and most are comprised of distinctive morphotypic variants or single species assemblages. A limited range of size-related morphotypic variation is apparent within all assemblages and subzones (Study 4), although there are no intermediate forms linking morphologically distinct subzonal assemblages. This suggests bolboforms did not evolve at the site where they were deposited and that their origin is extra-regional. Bolboforms are largely temperate organisms (Kennett & Kennett 1990; Cooke et al. 2002) and anomalous subtropical records in the Southwest Pacific region (including Site 593) are considered by Cooke et al. (2002) to be due to entrainment in the northward subsurface flow of Southern Component Intermediate Water (SCIW) – the Cenozoic precursor of modern Antarctic Intermediate Water (Wright & Miller 1993; Cooke 2002). In this respect, the punctuated record of bolboform influxes at Site 593 may represent periods of invigorated subsurface flow at intermediate water depths.

The suggestion that bolboforms were entrained and transported to Site 593 in a subsurface flow of intermediate water, is supported by the lack an obvious relationship between the stratigraphic distribution patterns of bolboforms and planktic foraminifers at the same site. The only possible link is noted in the upper part of core 593-26X, where the extinction of bolboforms occurs at about the same stratigraphic level as the withdrawal of warm subtropical planktic foraminifers from the same site (Figure 3.8). There is no evidence, however, to suggest these events are related to a common causal mechanism. More significantly, there is a major change in benthic foraminiferal assemblages at the same

stratigraphic level where common infaunal taxa such as *Cassidulina neocarinata*, *Globocassidulina subglobosa*, and *Ehrenbergina* disappear, and there is a marked increase in shallow infaunal forms such as *Astrononion*, *Euuvigerina*, *Siphouvigerina*, and *Sphaeroidina bulloides* (Figure 3.8). The former taxa occur in a part of the late Miocene section at Site 593 where Cooke (2002) has suggested there were invigorated flows of highly-oxygenated Southern Component Intermediate Water (SCIW) and strong sediment winnowing. The later taxa have a greater tolerance for oxygen deficient environments and are commonly associated with poorly oxygenated bottom waters (Dulk 2000). This suggests there may have been a significant reduction in the flow of Southern Component Intermediate Water over the seafloor at Site 593, coincident with the disappearance of bolboforms. The synchronous disappearance of bolboforms from Sites 594 and 1123 suggests there may also have been a reduced northwards flow of Southern Component Intermediate Water, at the same time, along the Pacific Ocean side of New Zealand. The causal mechanism for the reorganization of intermediate water circulation is not understood, although the extinction of bolboforms is clearly a regional feature and is likely to be linked to some local tectonic control such as subsidence of the Norfolk Ridge (Herzer et al. 1997) or restriction of the Indonesian Seaway (Kennett et al. 1985; Gasperi & Kennett 1993).

The appearance of bolboforms in the upper Waiauan (late middle Miocene) occurs just prior to the highest common occurrence of *Neogloboquadrina mayeri* s.l. – a well defined biostratigraphic event in the Southwest Pacific region that marks the transition from relatively warm middle Miocene planktic foraminiferal assemblages to cool subtropical (temperate) assemblages dominated by *Zeaglobigerina*, *Globoconella*, and *Globigerina* (Study 2). Prior to this, the only Miocene bolboform occurrences are confined to a very narrow interval near the base of the Lillburnian (middle Miocene), where there is a positive baseline shift in the oxygen isotope values of benthic foraminifers (i.e. cooler bottom waters), interpreted as the base of Mi4 (Elkington 2000). These data appear to link bolboform occurrences at the site with major paleoclimatic events. Regional appearances and disappearances of bolboforms in the South Atlantic and southern Indian Ocean have been similarly linked to major climatic and paleoceanographic events (Kennett & Kennett 1990; Cooke et al. 2002). This suggests there may be a causal link between climatic perturbations in paleoceanographic circulation and the punctuated record of short-lived bolboform appearances and disappearances. The short durations of bolboform influxes (50

to 330 k.y.) are on a scale comparable to astronomically-forced Milankovich cycles in obliquity and precession, although there is no obvious relationship between the distribution patterns of bolboforms and planktic foraminifers at the same site, at least none that are indicative of a simple climatically controlled model for the bolboform influxes.

Monospecific assemblages and abundance spikes

Bolboform assemblages at Site 593 are largely monospecific or monomorphotypic, and most subzonal assemblages are also comprised of a single species or a morphotypic variant. This is most notable in the upper part of the bolboform succession above the BBs-Zone where most subzones represent the range zones of distinctive species. Single species assemblages are also reported from the North Atlantic (Poag & Karowe 1986). This lack of species diversity with large numbers of specimens is characteristic of plankton blooms (Echols 1985; Kennett & Kennett 1990). Fluctuations in bolboform abundances have also been attributed to the frequency of blooms, with high bolboform flux rates associated with prolonged seasonal blooms, and low flux rates associated with intermittent blooms (Kennett & Kennett 1990). Although a single species may reproduce prolifically under suitable conditions and become highly dominant with respect to other species from the same group, assemblages formed under such circumstances are unlikely to be entirely monospecific. In this respect, the single species assemblages in the upper part of the bolboform succession at Site 593 are anomalous. Single species assemblages may also form under highly stressed environments, as in the case of some high-latitude planktic foraminiferal assemblages that are comprised entirely of *Neogloboquadrina pachyderma* (e.g. Kennett 1969).

Large bolboform numbers have also been found in sediments affected by carbonate dissolution (Rögl & Hochuli 1976; Echols 1985; Müller et al. 1985) and in drift deposits associated with contourites (Murray 1984). Carbonate dissolution and drift deposits may play an important role in the concentration of bolboforms at some oceanic sites, although the excellent preservation of planktic foraminifers and the lack of evidence for faunal reworking at Site 593 suggest they have not contributed to the sites bolboform record.

At present, no substantive explanation can be offered for the change from heterogeneous morphotypic assemblages of *Bolboforma* within the BBs-Zone, to monospecific assemblages above the BBs-Zone. It may be significant, however, that abundance and coiling changes in the planktic foraminiferal clade *Neogloboquadrina*, which constitute

part of a staged regional withdrawal of warm-water forms in the late Miocene (Study 2), occur immediately above the BBs-Zone. These faunal changes point to a major biogeographic displacement of planktic assemblages in the Tasman Sea region coinciding with the change in bolboform assemblages. The position of the site relative to evolving bolboform stocks may also have been important. It is speculated that heterogeneous assemblages were proximal to evolving bolboform stocks, and monospecific assemblages that appear subsequently were more distal.

Ecology

Bolboforms have generally been interpreted as phytoplanktic organisms (Rögl & Hochuli 1976; Tappan 1980; Spiegler & Daniels 1991), although comparative oxygen isotope data from the analysis of bolboform shells (Poag & Karowe 1986; Spiegler & Erlenkeuser 2001) suggest they spent at least part of their lifecycle below the photic zone, in mid to lower levels of the water column. In this respect, calcareous bolboform tests that accumulate on the seafloor may represent a submarine phase of the bolboform lifecycle and they may not necessarily be indicative of shallow surface-dwelling phases of the lifecycle where it is speculated non-testate bolboform phases may have evolved with no apparent trace in the fossil record. Submarine shell-forming phases may represent only a small part of the bolboform lifecycle, but the robust nature of bolboform shells (Echols 1985; Müller et al. 1985) has ensured that they are well represented in the fossil record. The potential for such bias should at least be taken into consideration when reviewing the ecology of bolboforms.

The similarity of the early late Miocene bolboform records in the Southwest Pacific, southern Indian Ocean, and North Atlantic poses somewhat of an enigma as to how bipolar mid- to high latitude bolboform stocks were maintained. Although the records are not identical, there are sufficient similarities between Southern and Northern Hemisphere records (Spiegler & Daniels 1991) to necessitate at least some genetic exchange across regions of low latitude. Darling et al. (2000) have recently demonstrated that upwelling systems and subsurface boundary currents are important factors in maintaining the bipolar distribution of cool-water genotypes in some modern planktic foraminifers. It is possible that a similar scenario could apply to bolboforms and that the entrainment of bolboforms in the subsurface flow of intermediate water was part of the organisms strategy for reproduction and dispersal. It is significant that the distribution of bolboforms mirrors that

of Antarctic Intermediate Water, the modern equivalent of Southern Component Intermediate Water, which has been linked to the entrainment of bolboforms in the temperate Southwest Pacific (Cooke et al. 2002). It is further speculated that a southwards flowing Cenozoic counterpart of modern North Atlantic Deep Water may have contributed to a reciprocal genetic transfer and completed the bipolar cycle of genetic exchange.

CONCLUSIONS

This study of bolboforms at Site 593 provides the most detailed and complete late Miocene record to date of bolboforms in the Southwest Pacific region. Features of the bolboform distribution, including narrow monospecific subzones, distinctive peaks in abundance, and a well defined succession of morphologically distinct species are generally not seen in the distribution patterns of planktic foraminifers at the same site and appear to be unique to the ecology of bolboforms. Although these features are poorly understood, they offer considerable potential for biostratigraphic subdivision within the early late Miocene, where at least eight zones and subzones are recognized: *Bolboforma gruetzmacheri, B. capsula, B. pentaspinosa, B. gracilireticulata* s.l., *B. metzmacheri* s.s. (subzones BBm-593/A and C), *B. metzmacheri ornata,* and *B. praeintermedia.* There are also several distinctive abundance spikes that offer the potential for refining subzonal correlations. The late middle Miocene also includes at least five subzones which are populated with morphotypic variants of *B. subfragoris* s.l. (subzones BBs-A to E). The punctuated nature of this record offers some scope for biostratigraphic refinement, although more detailed taxonomic studies are needed to improve the reliability of correlations.

Stratigraphic resolution in the late middle and early late Miocene is at least comparable to planktic foraminifers and calcareous nannofossils and is potentially superior to both fossil groups in deep-water sequences affected by calcite dissolution. Bolboforms also serve as important monitors of subsurface (intermediate depth) waters and they have the potential to be used in conjunction with planktic and benthic foraminifers to map major paleoceanographic changes in regions of mid to high latitudes. Although this study is based on a single oceanic site in the southern Tasman Sea, it highlights the potential biostratigraphic and paleoenvironmental utility of bolboforms for regional and interregional studies.

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Plates 3.1–3.7
Scanning electron microscope (SEM) images

Late middle and early late Miocene bolboform species and common morphotypes from Site 593 showing the range of morphologic variability. Images are all shown to scale. The ornament is included in the maximum dimensions of figured specimens: axial view (maximum equatorial diameter x axial height), oral or aboral view (maximum diameter). Figured specimens with FP curation-numbers are deposited in the New Zealand national micropaleontological collections at Geological and Nuclear, Lower Hutt.

Plate 3.1

Bolboforms from core 593-36X to 593-35X (334.36-327.09 mbsf)

***Bolboforma* sp. spirospinosa x serrata** 593-36X-2, 100-102 cm (334.00 mbsf)

1) Axial view (200 x 164 µm), FP4891.
2) Axial view (167 x 152 µm), FP4892.
3) Large intermediate phase – axial view (124 x 134 µm), FP4893.

***Bolboforma subfragoris* Spiegler** 593-35X-5, 37-39 cm (328.27 mbsf)

4) Axial view (235 x 171 µm), FP4894.
5) Oral view (diameter 206 µm), FP4895.
6) Aboral view (diameter 203 µm), FP4896.

***Bolboforma* sp. serrata** 593-35X-5, 37-39 cm (328.27 mbsf)

7) Axial view (208 x 176 µm), FP4897.
8) Oral view (diameter 208 µm), FP4898.
9) Aboral view (diameter 204 µm), FP4899.
10) Axial view (194 x 173 µm), FP4900.
11) Oral view (diameter 186 µm), FP4901.
12) Aboral view (diameter 189 µm), FP4902.

***Bolboforma* sp. spinulosa** (short-spined form), 593-35X-4, 69-71 cm (327.09 mbsf)

13) Axial view (157 x 118 µm), FP4903.
14) Oral view (diameter 176 µm), FP4904.
15) Aboral view (diameter 192 µm), FP4905.

Plate 3.1

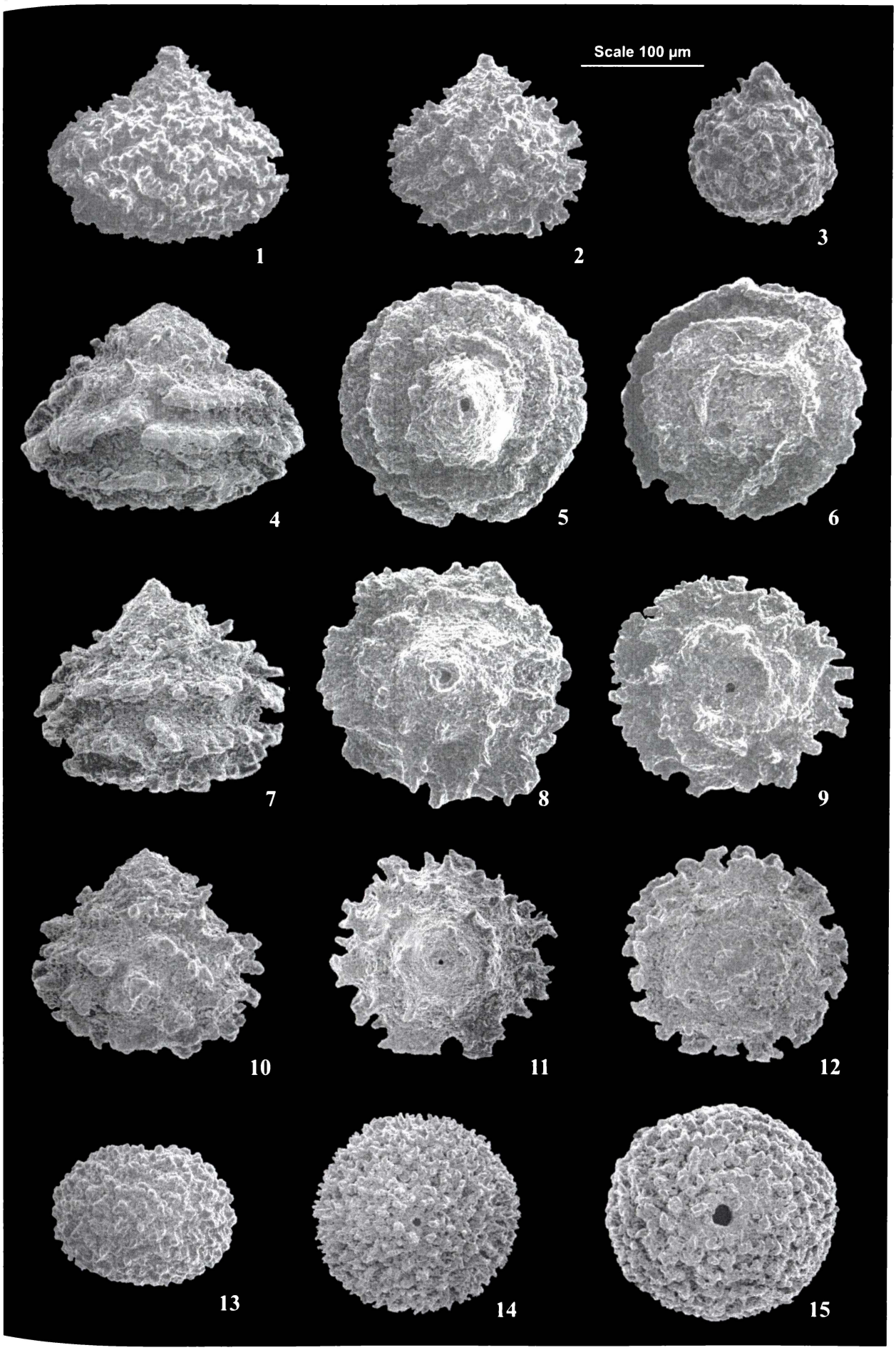


Plate 3.2

Bolboforms from core 593-35X to 593-34X (327.09-315.52 mbsf)

***Bolboforma* sp. spinulosa** (fine-spined form), 593-35-4, 69-71 cm (327.09 mbsf)

1) Axial view (193 x 143 µm), FP4906.
2) Oral view (diameter 184 µm), FP4907
3) Aboral view (diameter 180 µm), FP4908.

***Bolboforma* sp. spinulosa** (coarse-spined form), 593-35X-4, 69-71 cm (327.09 mbsf)

4) Axial view (171 x 121 µm), FP4909.
5) Oral view (diameter 177 µm), FP4910.
6) Aboral view (diameter 180 µm), FP4911.

***Bolboforma* sp. echinus** 35/2/32-34 cm (323.72 mbsf)

7) Axial view (189 x 171 µm), FP4912.

***Bolboforma* sp. echinus** 593-35X-1, 82-84 cm (322.72 mbsf)

8) Axial view (186 x 160 µm), FP4913.
9) Axial view (157 x 150 µm), FP4914.
10) Large intermediate phase – axial view (143 x 150 µm), FP4915.
11) Oral view (diameter 163 µm), FP4916.
12) Aboral view (diameter 170 µm), FP4917.

***Bolboforma* sp. spirospinosa** 593-34X-3, 22-24 cm (315.52 mbsf)

13) Axial view (180 x 163 µm), FP4918.
14) Large intermediate phase – axial view (157 x 157 µm), FP4919.
15) Oral view (diameter 160 µm), FP4920.

Plate 3.2

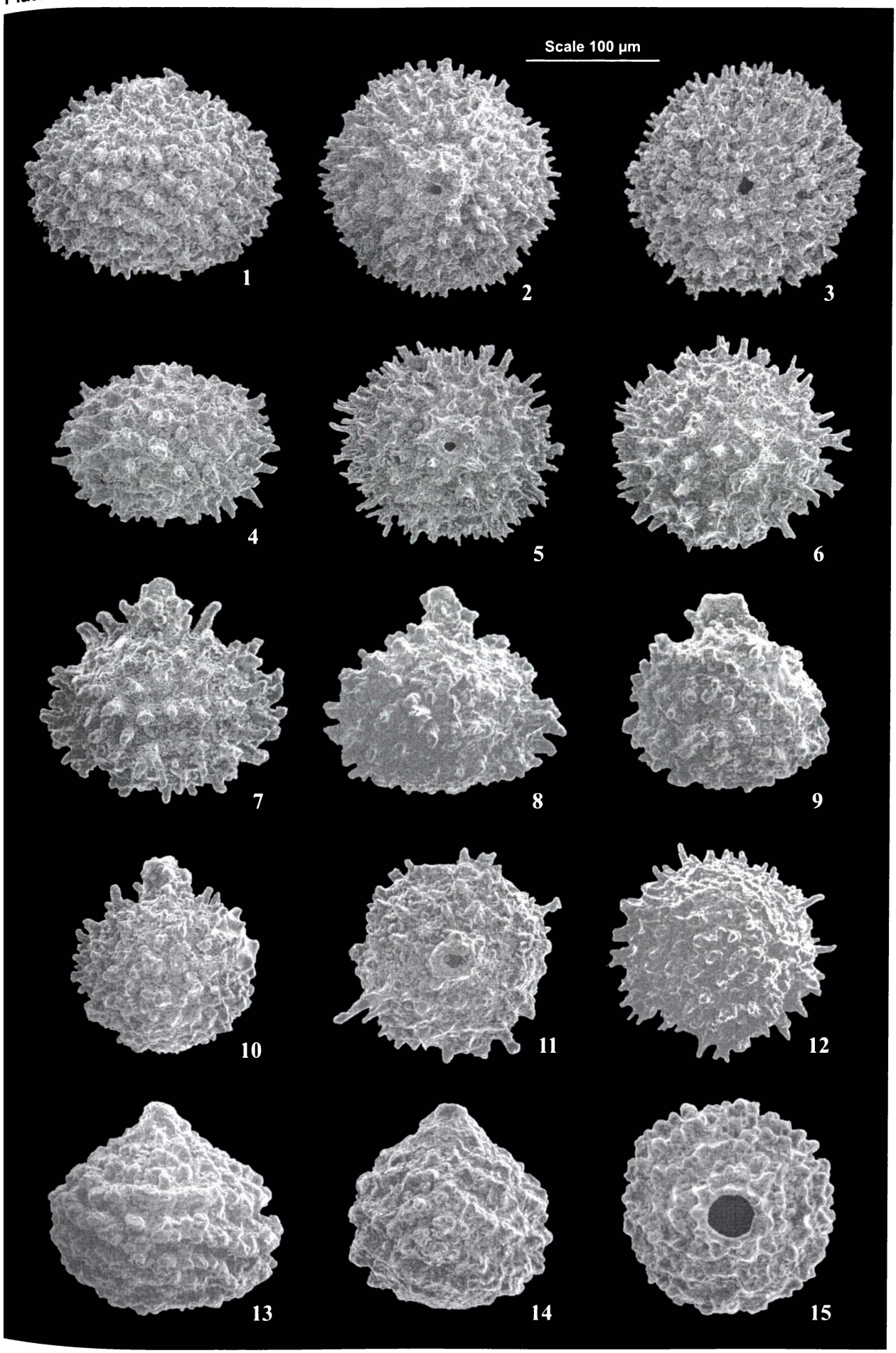


Plate 3.3

Bolboforms from core 593-33X (309.74-306.11 mbsf)

***Bolboforma subfragoris* Spiegler** 593-33X-5, 104-106 cm (309.74 mbsf)

1) Axial view (190 x 147 µm), FP4921.
2) Axial view (187 x 143 µm), FP4922.
3) Axial view (165 x 133 µm), FP4923.
4) Small intermediate phase – axial view (130 x 113 µm), FP4924.
5) Oral view (diameter 141 µm), FP4925.
6) Aboral view (diameter 173 µm), FP4926.

***Bolboforma* sp. serrata** 593-33-5, 84-86 cm (309.54 mbsf)

7) Axial view (216 x 130 µm), FP4927.
8) Oral view (diameter 176 µm), FP4928.
9) Aboral view (diameter 147 µm), FP4929.

***Bolboforma* sp. spirospinosa** 593-33-3, 41-43 cm (306.11 mbsf)

10) Axial view (172 x157 µm), FP4930.
11) Axial view (165 x152 µm), FP4931.
12) Large intermediate phase – axial view (134 x 135 µm), FP4932.
13) Small intermediate phase – axial view (96 x 102 µm), FP4933.
14) Oral view (diameter 140 µm), FP4934.
15) Aboral view (diameter 158 µm), FP4935.

Plate 3.3

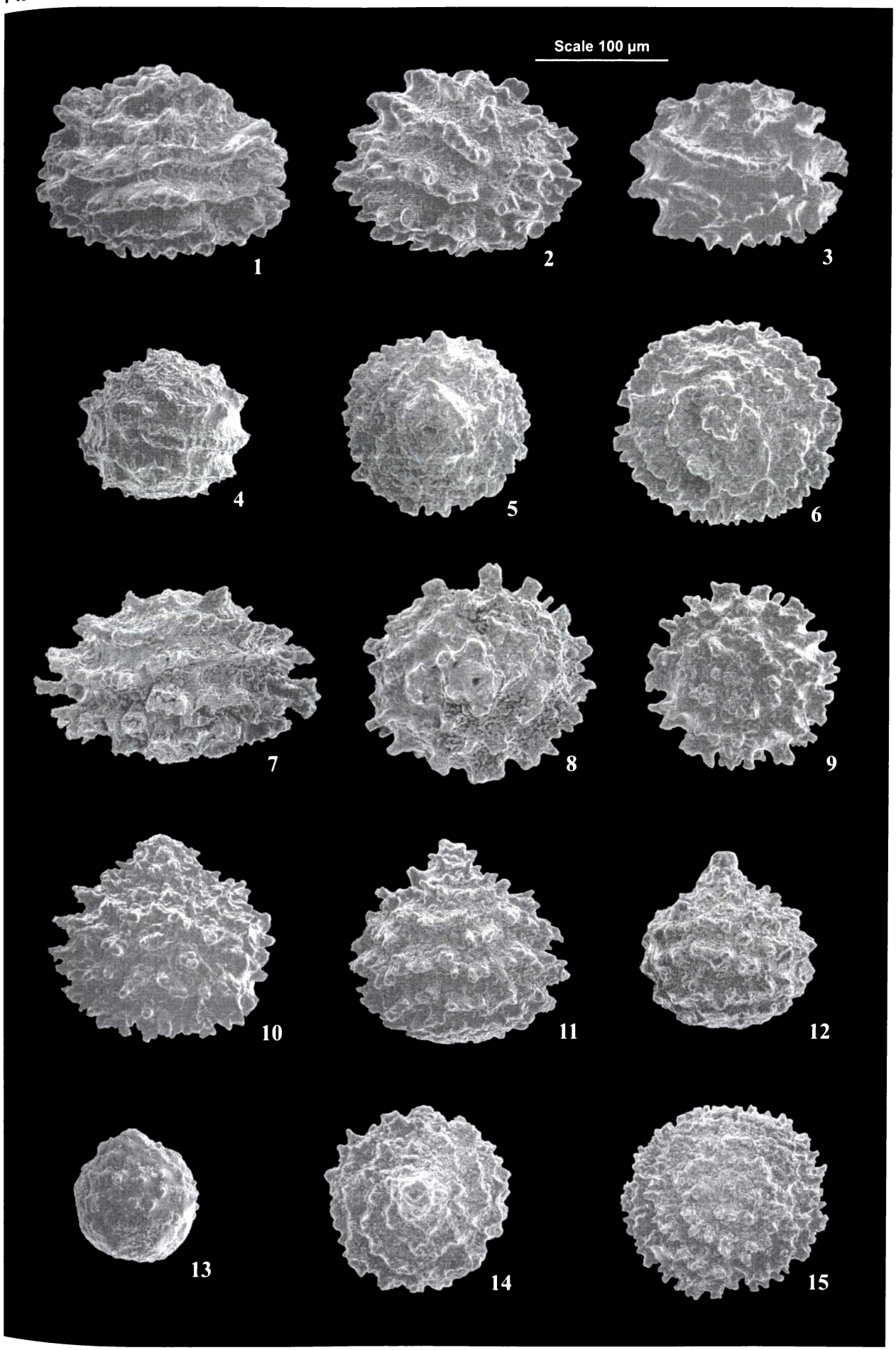


Plate 3.4

Bolboforms from core 593-32X to 593-31X (298.08-289.34 mbsf)

***Bolboforma gruetzmacheri* n.sp.** 593-32X-4, 48-50 cm (298.08 mbsf)

1) Holotype, subtriangular form – axial view (182 x 177 µm), FP4936.
2) Axial view (175 x 158 µm), FP4937.
3) Subquadrate form – axial view (170 x 181 µm), FP4938.
4) Small intermediate phase – axial view (138 x 155 µm), FP4939.
5) Oral view (diameter 181 µm), FP4940.
6) Aboral view (diameter 174 µm), FP4941.

***Bolboforma capsula* Spiegler** 593-31X-5, 101-103 cm (290.51 mbsf)

7) Axial view (203 x 188 µm), FP4942.
8) Axial view (185 x 177 µm), FP4943.
9) Axial view (153 µm x 162 µm), FP4944.
10) Oral view (diameter 172 µm), FP4945.
11) Aboral view (diameter 184 µm), FP4946.
12) Small intermediate phase – axial view (132 x 113 µm), FP4947.

***Bolboforma pentaspinosa* Spiegler** 593-31X-4, 134-136 cm (289.34 mbsf)

13) Axial view (168 x 169 µm), FP4948.
14) Axial view (168 x 171 µm), FP4949.
15) Small specimen – axial view (127 x 138 µm), FP4950.

Plate 3.4

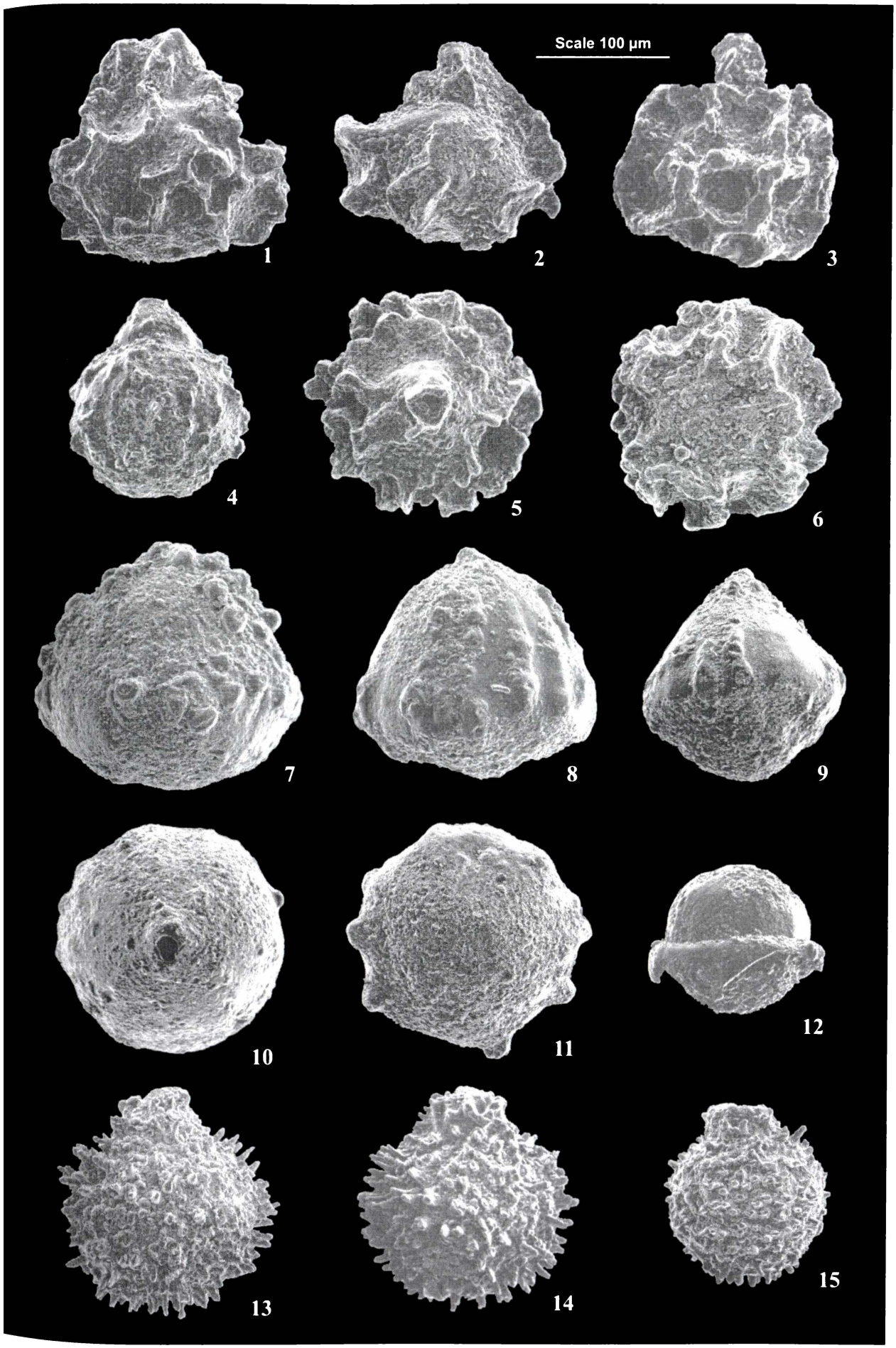


Plate 3.5

Bolboforms from core 593-31X to 593-30X (298.34-274.72 mbsf)

***Bolboforma pentaspinosa* Spiegler** 593-31X-4, 134-136 cm (289.34 mbsf)

1) Oral view (diameter 172 µm), FP4951.
2) Aboral view (diameter 180 µm), FP4952.
3) Small intermediate phase – axial view (131 x 129 µm), FP4953.

***Bolboforma gracilireticulata* s.l.** (smooth walled phase), 593-31X-1, 44-46 cm (283.94 mbsf)

4) Axial view (135 x 135 µm), FP4954.
5) Axial view (128 x 143 µm), FP4955.
6) Oral view (diameter 132 µm), FP4956.

***Bolboforma gracilireticulata* Spiegler** 593-30X-4, 135-137 cm (279.75 mbsf)

7) Axial view (143 x 153 µm), FP4957.
8) Axial view (143 x 151 µm), FP4958.
9) Axial view (130 x 168 µm), FP4959.
10) Small specimen – axial view (91 x 135 µm), FP4960.
11) Oral view (diameter 147 µm), FP4961.
12) Aboral view (diameter 143 µm), FP4962.

***Bolboforma metzmacheri* (Clodius)** cylindrical form, 593-30X-1, 82-84 cm (274.72 mbsf)

13) Axial view (154 x 171 µm), FP4963.
14) Axial view (172 x 180 µm), FP4964.
15) Axial view (164 x 184 µm), FP4965.

Plate 3.5

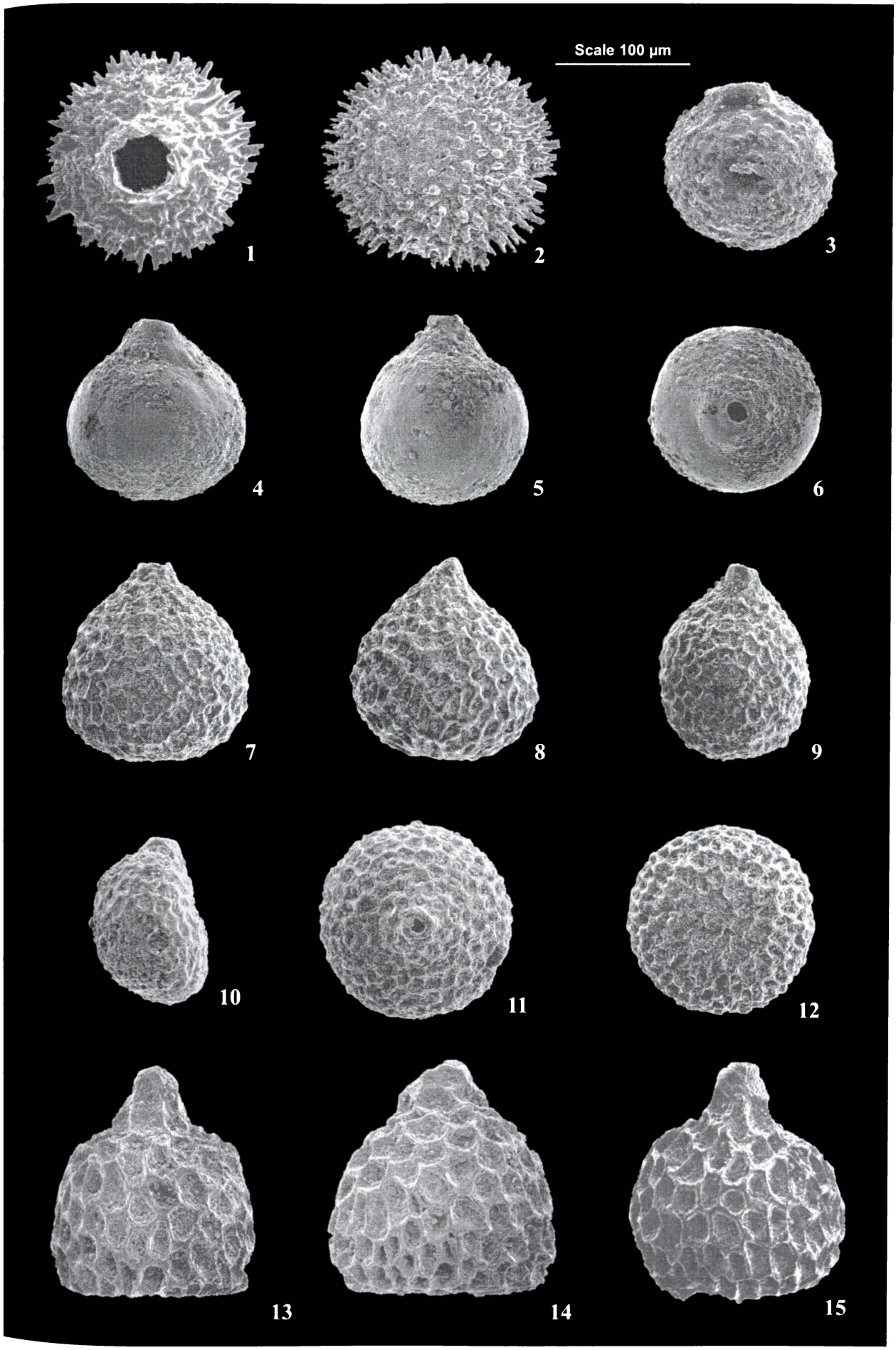


Plate 3.6

Bolboforms, Site 593 (274.72 to 242.52 mbsf)

***Bolboforma metzmacheri* (Clodius)** cylindrical form, 593-30X-1, 82-84 cm (274.72 mbsf)

1) Large intermediate phase – axial view (136 x 140 µm), FP4966.
2) Oral view (diameter 152 µm), FP4967.
3) Aboral view (diameter 156 µm), FP4968.

***Bolboforma* sp. indet.** (smooth-walled phase), 593-29X-4, 107-109 cm (269.87 mbsf)

4) Axial view (137 x 146 µm), FP4969.
5) Axial view (143 x 163 µm), FP4970.
6) Oral view (diameter 140 µm), FP4971.

***Bolboforma metzmacheri* (Clodius)** ogival form, 593-30X-1, 82-84 cm (274.72 mbsf)

7) Axial view (177 x 142 µm), FP4972.
8) Axial view (176 x 164 µm), FP4973.
9) Large intermediate phase – axial view (147 x 145 µm), FP4974.
10) Oral view (diameter 170 µm), FP4975.
11) Aboral view (diameter 176 µm), FP4976.
12) Small intermediate phase – axial view (134 x 134 µm), FP4977.

***Bolboforma metzmacheri ornata* Spiegler** 593-26X-5, 102-104 cm (242.52 mbsf)

13) Axial view (165 x 157 µm), FP4978.
14) Axial view (155 x 146 µm), FP4979.
15) Axial view (151 x 143 µm), FP4980.

Plate 3.6

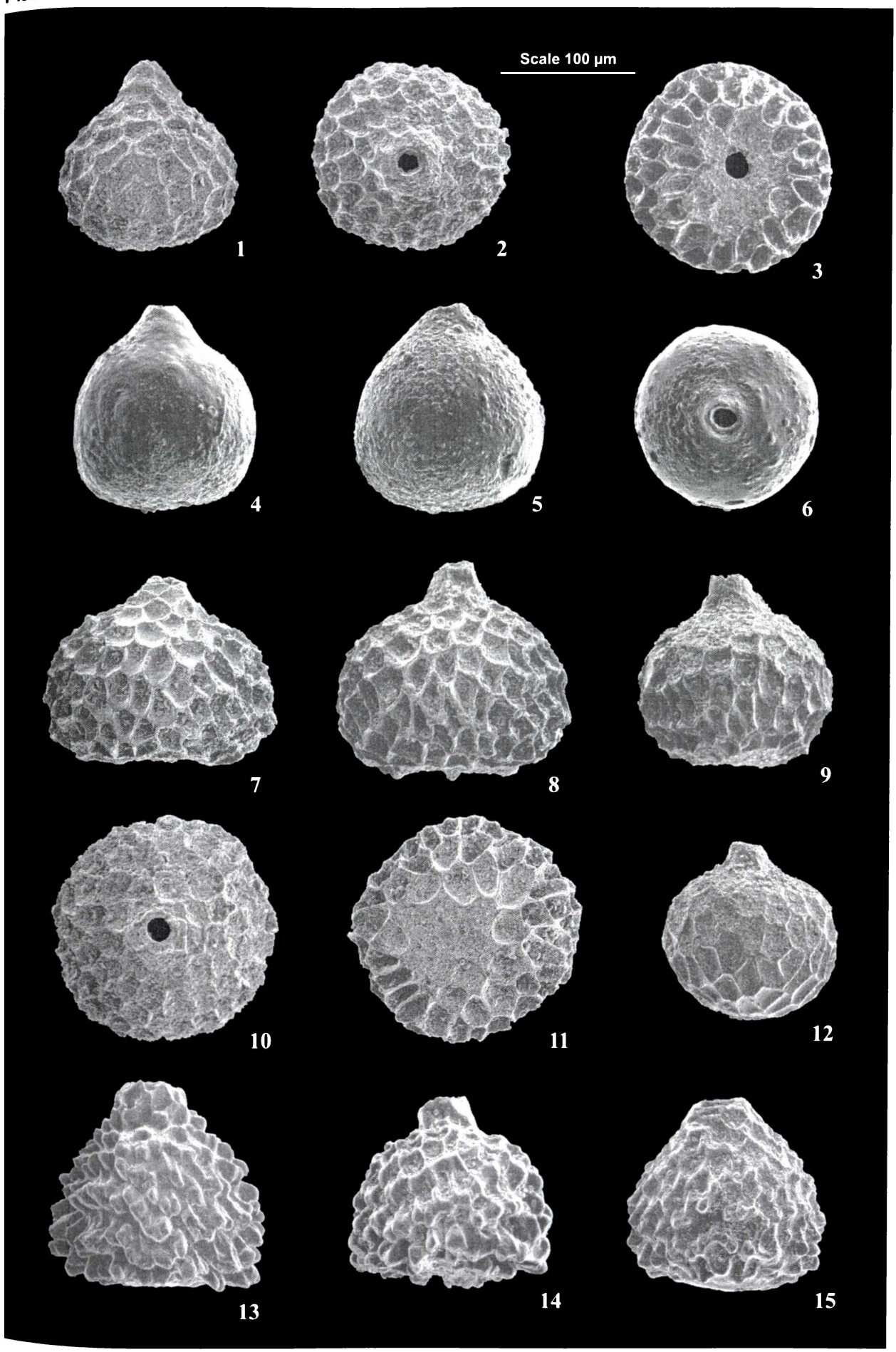


Plate 3.7

3.7/1-9: Bolboforms, Site 593 (242.52-238.93 mbsf)

Bolboforma metzmacheri ornata **Spiegler** 593-26X-5, 102-104 cm (242.52 mbsf)

1) Oral view (diameter 170 µm), FP4981.
2) Aboral view (diameter 168 µm), FP4982.
3) Small intermediate phase – axial view (123 x 126 µm), FP4983.

Bolboforma praeintermedia **Spiegler** 593-26X-3, 43-45 cm (238.93 mbsf)

4) Axial view (172 x 172 µm), FP4984.
5) Axial view (153 x 153 µm), FP4985.
6) Intermediate phase, axial view (138 x 157 µm), FP4986.
7) Small intermediate phase – axial view (99 x 120 µm), FP4987.
8) Oral view (diameter 162 µm), FP4988.
9) Aboral view (diameter 170 µm), FP4989.

3.7/10-15: Bolboforms from New Zealand onland sections

Tukemokihi Stream, Wairoa

10) *Bolboforma subfragoris* s.l. – axial view (188 x 170 µm), FP4990. MC97/6/03, immediately below Kaiti coiling zone

11) *Bolboforma metzmacheri* s.s. (Clodius) – axial view (176 x 172 µm), FP4991. MC97/3/12, middle Tukemokihi Coiling Zone.

Auroa Point - Table Cape, Mahia

12) *Bolboforma subfragoris* s.l. – axial view 161 x 139 µm), FP4992. MC97/6/03, just below Kaiti Coiling Zone.

13) *Bolboforma metzmacheri* (Clodius) – axial view (168 x 145 µm), FP4993. MC97/6/42, lower Tukemokihi Coiling Zone.

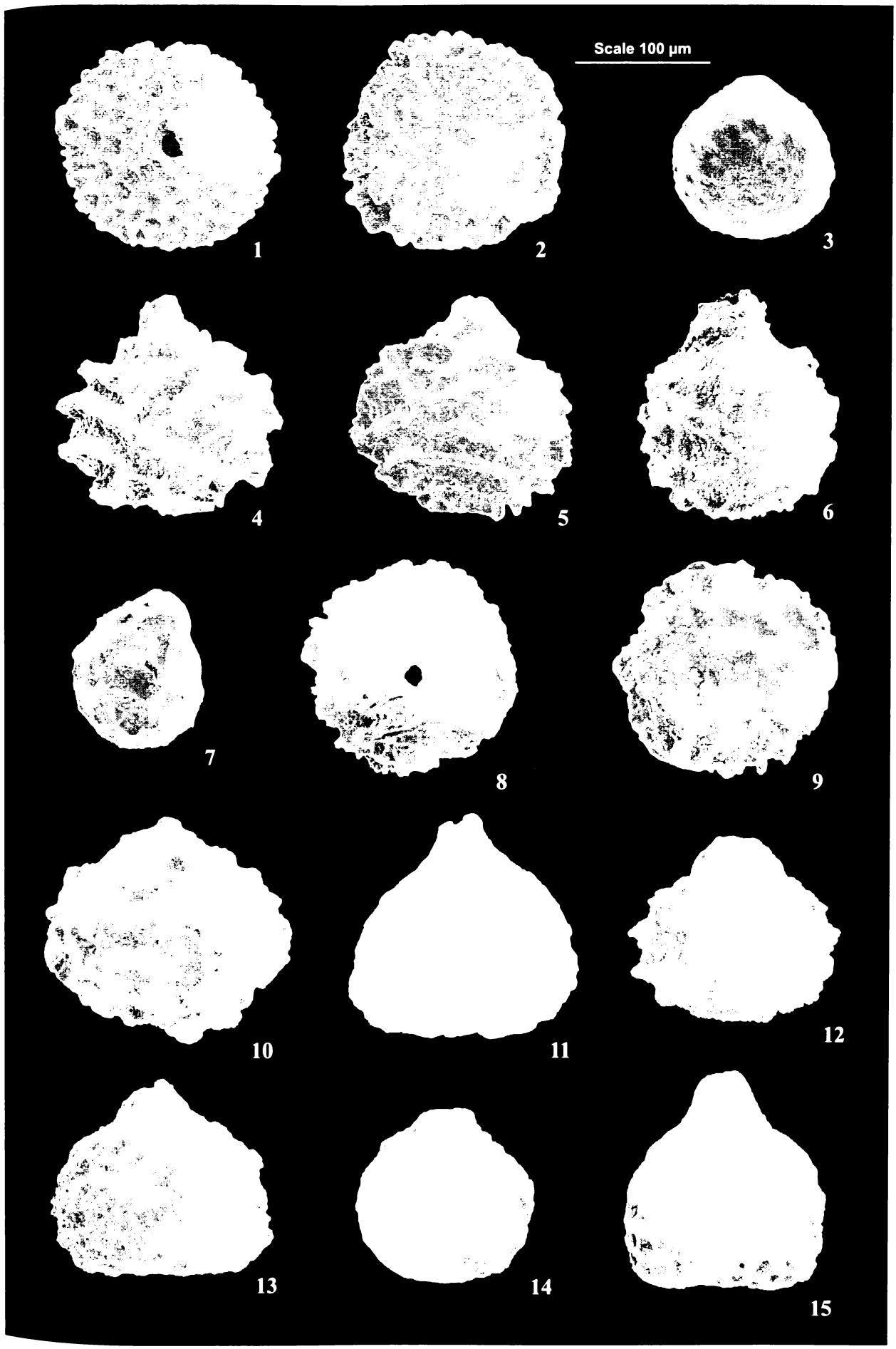
Kaiti Beach, Gisborne

14) *Bolboforma subfragoris* s.l. (small intermediate phase) – axial view (135 x 132 µm), FP4994. Y18/f509, (F29210) middle Kaiti Coiling Zone.

North Taranaki Coast, Tongaporutuan stratotype

15) *Bolboforma metzmacheri* s.s. (Clodius) cylindrical form – axial view (151 x 165 µm), FP4995. Q18/f174, (F30708) lower Tukemokihi Coiling Zone.

Plate 3.7



Appendices

Appendix 3.1 – Bolboform distribution and abundance data: (1 of 6)

DSDP Site 593 Core-Section Depth (cm)	Depth (mbsf)	*B. praeintermedia*	*B. metzmacheri ornata*	*B. metzmacheri* s.s. (ogival)	*B. metzmacheri* s.s. (cylindrical)	*B. gracilireticulata* s.s.	*B. gracilireticulata* s.l.	*B. pentaspinosa*	*B. capsula*	*B. gruetzmacheri* n. sp.	*B.* sp. spirospinosa	*B.* sp. spirospinosa x serrata	*B.* sp. serrata	*B. subfragoris* s.s.	*B.* sp. echinus	*B.* sp. spinulosa	*B.* sp. spinulosax spirospinosa	*B.* sp. indet. (smooth-walled)	Bolboform count (n)	Normalized abundance	Picked or scanned (g)	Southwest Pacific zonation	New Zealand Stage	Epoch
26X 1 1-3	235.51																		0	0	0.1349			
26X 1 23-25	235.73																		0	0	0.1344			
26X 1 41-43	235.91																		0	0	0.1907			
26X 1 58-60	236.08																		0	0	0.1240			
26X 1 82-84	236.32																		0	0	0.2296			
26X 1 102-104	236.52	R																	1	4	0.2459			
26X 1 117-119	236.67	R																	1	3	0.3032			
26X 1 142-144	236.92																		0	0	0.2842			
26X 2 13-15	237.13																		0	0	0.2452			
26X 2 32-34	237.32	R																	1	5	0.2186			
26X 2 56-58	237.56																		0	0	0.1917			
26X 2 93-95	237.93	R																	3	17	0.1775			
26X 2 112-114	238.12	R																	6	20	0.3020			
26X 2 133-135	238.33	C																	3	135	0.0223			
26X 3 1-3	238.51	C																	4	137	0.0291			
26X 3 22-24	238.72	C																	32	941	0.0340	BBi		
26X 3 43-45	238.93	A																	4	1333	0.0030			
26X 3 56-58	239.06	C																	29	986	0.0294			
26X 3 82-84	239.32	C																	26	858	0.0303			
26X 3 102-104	239.52	C																	68	107	0.4498			
26X 3 117-119	239.67	R																	31	86	0.3612			
26X 3 133-135	239.83	R																	16	48	0.3347			
26X 4 7-9	240.07	R																	12	32	0.3700			
26X 4 32-34	240.32	R																	2	6	0.3481			
26X 4 52-54	240.52																		0	0	0.1568			
26X 4 72-74	240.72																		0	0	0.2443			
26X 4 92-94	240.92		R																1	2	0.5282			
26X 4 112-114	241.12		R																6	14	0.4224			
26X 4 132-134	241.32		R																15	66	0.2267			
26X 5 0-2	241.50		C																8	530	0.0151			
26X 5 15-17	241.65		C																3	769	0.0039			
26X 5 42-44	241.92		C																4	192	0.0208			
26X 5 63-65	242.13		C																3	119	0.0253			
26X 5 82-84	242.32		C																4	213	0.0188			
26X 5 102-104	242.52		A																22	4151	0.0053			
26X 5 117-119	242.67		A																25	1534	0.0163			
26X 5 142-144	242.92		A																13	2653	0.0049			
26X 6 7-9	243.07		C					R											148	430	0.3440			
26X 6 26-28	243.26		A																19	5000	0.0038			
26X 6 47-49	243.47		A																45	1779	0.0253			
26X 6 63-65	243.63		A																3	1200	0.0025			
26X CC 13-15	243.86		R																6	12	0.4836			
27X 1 1-3	245.11		R																6	21	0.2842			
27X 1 25-27	245.35		R																2	7	0.2817			
27X 1 43-45	245.53		R																5	22	0.2314			
27X 1 65-67	245.75		R																1	5	0.2056	BBm		
27X 1 81-83	245.91		R																1	6	0.1763			
27X 1 96-98	246.06		R																<1	0	0.1880			
27X 1 117-119	246.27																		0	0	0.0036			
27X 1 142-144	246.52																		0	0	0.0052			
27X 2 5-7	246.65																		0	0	0.1927			
27X 2 27-29	246.87																		0	0	0.0037			
27X 2 53-55	247.13																		0	0	0.4416			
27X 2 73-76	247.33																		0	0	0.0027			
27X 2 93-95	247.53																		0	0	0.7602			
27X 2 107-109	247.67																		0	0	0.0034			
27X 2 132-134	247.92																		0	0	0.3336			
27X 3 1-3	248.11																		0	0	0.0023			
27X 3 16-18	248.26																		0	0	0.6032			
27X 3 37-39	248.47																		0	0	0.0041			
27X 3 56-58	248.66																		0	0	0.4071			
27X 3 83-85	248.93																		0	0	0.0023			
27X 3 104-106	249.14																		0	0	0.4910			
27X 3 117-119	249.27																		0	0	0.0036			
27X 3 142-144	249.52																		0	0	0.5387			
27X 4 7-9	249.67																		0	0	0.0039			

Appendix 3.1 – Bolboform distribution and abundance data: (2 of 6)

DSDP Site 593 Core-Section	Depth (cm)	Depth (mbsf)	*B. praeintermedia*	*B. metzmacheri ornata*	*B. metzmacheri* s.s. (ogival)	*B. metzmacheri* s.s. (cylindrical)	*B. gracilireticulata* s.s.	*B. gracilireticulata* s.l.	*B. pentaspinosa*	*B. capsula*	*B. gruetzmacheri* n. sp.	*B.* sp. spirospinosa	*B.* sp. spirospinosa x serrata	*B.* sp. serrata	*B. subfragoris* s.s.	*B.* sp. echinus	*B.* sp. spinulosa	*B.* sp. spinulosax spirospinosa	*B.* sp. indet. (smooth-walled)	Bolboform count (n)	Normalized abundance	Picked or scanned (g)	Southwest Pacific zonation	New Zealand Stage	Epoch
27X 4	32-34	249.92																		0	0	0.2150			
27X 4	52-54	250.12																		0	0	0.0045			
27X 4	67-69	250.27																		0	0	0.3426			
27X 4	86-88	250.46																		0	0	0.0032			
27X 4	112-114	250.72																		0	0	0.2300			
27X 4	132-134	250.92																		0	0	0.0044			
27X 5	0-2	251.10																		0	0	0.2878			
27X 5	23-25	251.33																		0	0	0.0041			
27X 5	38-40	251.48																		0	0	0.4875			
27X 5	57-59	251.67																		0	0	0.0029			
27X 5	83-85	251.93																		0	0	0.3166			
27X 5	103-105	252.13																		0	0	0.0041			
27X 5	118-120	252.28																		0	0	0.3358			
27X 5	143-145	252.53																		0	0	0.0033			
27X 6	7-9	252.67																		0	0	0.4437			
27X 6	32-34	252.92																		0	0	0.0039			
27X 6	53-55	253.13																		0	0	0.2558			
27X 6	73-75	253.33																		0	0	0.0024			
27X 6	87-89	253.47																		0	0	0.4501			
27X 6	107-109	253.67																		0	0	0.0046			
27X 6	132-134	253.92																		0	0	0.2304			
27X 7	0-2	254.10																		0	0	0.2580			
27X 7	17-19	254.27			R															3	9	0.3261			
27X CC	10-12	254.49			C															3	769	0.0039			
28X 1	4-6	254.74			C															10	353	0.0283			
28X 1	23-25	254.93			A	R														4	1053	0.0038			
28X 1	42-44	255.12			C															7	295	0.0237			
28X 1	58-60	255.28			C															2	444	0.0045			
28X 1	83-85	255.53			C															17	817	0.0208			
28X 1	103-105	255.73			A															8	1951	0.0041			
28X 1	121-123	255.91			A	R														399	1916	0.2082			
28X 1	141-143	256.11			A															11	3793	0.0029			
28X 2	7-9	256.27			A															31	1676	0.0185			
28X 2	33-35	256.53			A															12	3750	0.0032	BBm		
28X 2	54-56	256.74			C															21	995	0.0211			
28X 2	83-85	257.03			C															3	811	0.0037			
28X 2	98-100	257.18			C															10	379	0.0264			
28X 2	113-115	257.33			C															1	323	0.0031			
28X 2	133-135	257.53			C															5	230	0.0217			
28X 3	1-3	257.71			C															3	882	0.0034			
28X 3	25-27	257.95			C	R														10	442	0.0226			
28X 3	42-44	258.12			C	R														2	556	0.0036			
28X 3	55-57	258.25			C	R														21	1173	0.0179			
28X 3	84-86	258.54			C	R														2	625	0.0032			
28X 3	118-120	258.88			C	R														10	483	0.0207			
28X 3	137-139	259.07			R															1	6	0.1606			
28X 4	6-8	259.26																		0	0	0.2459			
28X 4	33-35	259.53																		0	0	0.2430			
28X 4	47-49	259.67																		0	0	0.0140			
28X 4	66-68	259.86																		0	0	0.0043			
28X 4	93-95	260.13																		0	0	0.3286			
28X 4	108-110	260.28																		0	0	0.0037			
28X 4	134-136	260.54																		0	0	0.0037			
28X 5	1-3	260.71																		0	0	0.1851			
28X 5	16-18	260.86																		0	0	0.0026			
28X 5	42-44	261.12																		0	0	0.1608			
28X 5	61-63	261.31																		0	0	0.0037			
28X 5	85-87	261.55																		0	0	0.3936			
28X 5	102-104	261.72																		0	0	0.0044			
28X 5	121-123	261.91																		0	0	0.2813			
28X 5	141-143	262.11																		0	0	0.0030			
28X 6	8-10	262.28																		0	0	0.2697			
28X CC	8-10	262.45																		0	0	0.0053			
29X 1	0-2	264.30																		0	0	0.0025			
29X 1	34-36	264.64																		0	0	0.0044			
29X 1	58-60	264.88																		0	0	0.0041			

Appendix 3.1 – Bolboform distribution and abundance data: (3 of 6)

DSDP Site 593 Core-Section Depth (cm)	Depth (mbsf)	*B. praeintermedia*	*B. metzmacheri ornata*	*B. metzmacheri* s.s. (ogival)	*B. metzmacheri* s.s. (cylindrical)	*B. gracilireticulata* s.s.	*B. gracilireticulata* s.l.	*B. pentaspinosa*	*B. capsula*	*B. gruetzmacheri* n. sp.	*B.* sp. spirospinosa	*B.* sp. spirospinosa x serrata	*B.* sp. serrata	*B. subfragoris* s.s.	*B.* sp. echinus	*B.* sp. spinulosa	*B.* sp. spinulosax spirospinosa	*B.* sp. indet. (smooth-walled)	Bolboform count (n)	Normalized abundance	Picked or scanned (g)	Southwest Pacific zonation	New Zealand Stage	Epoch
29X 1 80-82	265.10																		0	0	0.5252			
29X 1 96-98	265.26																		0	0	0.0034			
29X 1 117-119	265.47																		0	0	0.5204			
29X 1 142-144	265.72																		0	0	0.0044			
29X 2 12-14	265.92																		0	0	0.5021			
29X 2 32-34	266.12																		0	0	0.0044			
29X 2 46-48	266.26																		0	0	0.1675			
29X 2 64-66	266.44																		0	0	0.0030			
29X 2 85-87	266.65																		0	0	0.1915			
29X 2 107-109	266.87																		0	0	0.0031			
29X 2 133-135	267.13																		0	0	0.1337			
29X 3 1-3	267.31																		0	0	0.0037			
29X 3 23-25	267.53																		0	0	0.0039			
29X 3 42-44	267.72																		0	0	0.0045			
29X 3 57-59	267.87																		0	0	0.0035			
29X 3 84-86	268.14																		0	0	0.0029			
29X 3 104-106	268.34																		0	0	0.0043			
29X 3 117-119	268.47																		0	0	0.0055			
29X 3 138-140	268.68																		0	0	0.0024			
29X 4 6-8	268.86																		0	0	0.0024			
29X 4 48-50	269.28																		0	0	0.0023			
29X 4 72-74	269.52																		0	0	0.0024			
29X 4 95-97	269.75																		0	0	0.2296			
29X 4 107-109	269.87																	x	<1	0	0.2171			
29X 4 135-137	270.15																	x	<1	0	0.2156	BBm		
29X 5 1-3	270.31																	x	<1	0	0.2251			
29X 5 15-17	270.45																	x	<1	0	0.3916			
29X 5 42-44	270.72																		0	0	0.1812			
29X 5 61-63	270.91																		0	0	0.0039			
29X 5 85-87	271.15																		0	0	0.0041			
29X 5 104-106	271.34																		0	0	0.0041			
29X 5 118-120	271.48																		0	0	0.0037			
29X 5 142-144	271.72																		0	0	0.0023			
29X 6 14-16	271.94				R														2	76	0.0263			
29X CC 17-19	272.19				C														47	215	0.2183			
30X 1 1-3	273.91				C														1	303	0.0033			
30X 1 14-16	274.04				A														6	2222	0.0027			
30X 1 42-44	274.32				A														14	3784	0.0037			
30X 1 58-60	274.48				A														8	2500	0.0032			
30X 1 82-84	274.72				A														21	4884	0.0043			
30X 1 103-105	274.93				A														534	4435	0.1204			
30X 1 122-124	275.12				A														6	1538	0.0039			
30X 1 141-143	275.31				A														16	4324	0.0037			
30X 2 5-7	275.45				A														7	2414	0.0029			
30X 2 32-34	275.72				C														4	242	0.0165			
30X 2 53-55	275.93				C														2	588	0.0034			
30X 2 92-94	276.32				A														70	4094	0.0171			
30X 2 112-114	276.52				C														2	385	0.0052			
30X 2 133-135	276.73				R														1	5	0.2153			
30X 3 1-3	276.91																		0	0	0.1938			
30X 3 15-17	277.05																		0	0	0.1052			
30X 3 43-45	277.33																		0	0	0.2326			
30X 3 65-67	277.55																	x	1	5	0.1831			
30X 3 84-86	277.74																		0	0	0.0034			
30X 3 103-105	277.93																		0	0	0.2354			
30X 3 117-119	278.07																		0	0	0.0036			
30X 3 138-140	278.28																		0	0	0.2149			
30X 4 9-11	278.49																		0	0	0.0039	BBc		
30X 4 32-34	278.72						?												<1	0	0.2206			
30X 4 48-50	278.88						?												<1	0	0.0032			
30X 4 73-75	279.13						?												<1	0	0.2133			
30X 4 93-95	279.33					R	?												2	11	0.1760			
30X 4 113-115	279.53					R	?												13	28	0.4699			
30X 4 135-137	279.75					R	?												2	13	0.1498			
30X 5 6-8	279.96						?												<1	0	0.0144			
30X 5 15-17	280.05						?												<1	0	0.0035			

B. metzmacheri s.s. BBm-593/A

B. gracilireticulata

lower Tongaporutuan

Upper Miocene

Appendix 3.1 – Bolboform distribution and abundance data: (4 of 6)

DSDP Site 593 Core-Section Depth (cm)	Depth (mbsf)	*B. praeintermedia*	*B. metzmacheri ornata*	*B. metzmacheri* s.s. (ogival)	*B. metzmacheri* s.s. (cylindrical)	*B. gracilireticulata* s.s.	*B. gracilireticulata* s.l.	*B. pentaspinosa*	*B. capsula*	*B. gruetzmacheri* n. sp.	*B.* sp. spirospinosa	*B.* sp. spirospinosa x serrata	*B.* sp. serrata	*B. subfragoris* s.s.	*B.* sp. echinus	*B.* sp. spinulosa	*B.* sp. spinulosax spirospinosa	*B.* sp. indet. (smooth-walled)	Bolboform count (n)	Normalized abundance	Picked or scanned (g)	Southwest Pacific zonation	New Zealand Stage	Epoch
30X 5 35-37	280.25						?												<1	0	0.0047			
30X 5 84-86	280.74						?												<1	0	0.0233			
30X 5 102-104	280.92						?												<1	0	0.0028			
31X 1 1-3	283.51						?												<1	0	0.0031			
31X 1 17-19	283.67						?												<1	0	0.0182			
31X 1 44-46	283.94						?												<1	0	0.3148			
31X 1 58-60	284.08						?												<1	0	0.0148			
31X 1 83-85	284.33						?												<1	0	0.0029			
31X 1 105-107	284.55						?												<1	0	0.0044			
31X 1 118-120	284.68																		0	0	0.0187			
31X 1 138-140	284.88																		0	0	0.0029			
31X 2 9-11	285.09																		0	0	0.2821			
31X 2 29-31	285.29																		0	0	0.0027			
31X 2 48-50	285.48																		0	0	0.2821			
31X 2 73-75	285.73																		0	0	0.0028			
31X 2 88090	285.88																		0	0	0.3642			
31X 2 110-112	286.10																		0	0	0.0034			
31X 2 134-136	286.34																		0	0	0.2143			
31X 3 1-3	286.51																		0	0	0.0044			
31X 3 23-25	286.73																		0	0	0.2827			
31X 3 38-40	286.88																		0	0	0.0029			
31X 3 57-59	287.04																		0	0	0.0218			
31X 3 82-84	287.32							R											1	5	0.2005	BBc		
31X 3 102-104	287.52							R											1	4	0.2447			
31X 3 117-119	287.67																		0	0	0.1524			
31X 3 141-143	287.91							R											1	52	0.0192			
31X 4 8-10	288.08							R											1	38	0.0264			
31X 4 30-32	288.30							R											2	99	0.0202			
31X 4 55-57	288.55							A											5	1020	0.0049			
31X 4 70-72	288.70							C											16	821	0.0195			
31X 4 89-91	288.89							A											8	2581	0.0031			
31X 4 110-112	289.10							A											96	4384	0.0219			
31X 4 134-136	289.34							A											251	11840	0.0212			
31X 5 0-2	289.50							A											190	9223	0.0206			
31X 5 23-25	289.73							A	C										356	2383	0.1494			
31X 5 43-45	289.93							R	A										282	2051	0.1375			
31X 5 62-64	290.12								A										6	1667	0.2089			
31X 5 83-85	290.33							R	A										58	2929	0.0198			
31X 5 101-103	290.51								A										10	2703	0.0037			
31X 5 120-122	290.70								A										28	2000	0.0140			
31X CC 0-2	290.74								C										2	526	0.0038			
32X 1 1-3	293.11								A										8	2581	0.0031			
32X 1 23-25	293.33								R										2	17	0.1185			
32X 1 41-43	293.51								C										19	137	0.1387			
32X 1 61-63	293.71																		0	0	0.1156			
32X 1 83-85	293.93																		0	0	0.1339			
32X 1 102-104	294.12																		0	0	0.0032			
32X 1 121-123	294.31																		0	0	0.1517			
32X 1 141-143	294.51																		0	0	0.0053			
32X 2 11-13	294.71																		0	0	0.1177			
32X 2 30-32	294.90																		0	0	0.0899			
32X 2 52-54	295.12									R									0	0	0.1153			
32X 2 73-75	295.33									R									1	8	0.1323			
32X 2 93-95	295.53									R									14	63	0.2218			
32X 2 113-115	295.73									C									3	882	0.0034			
32X 2 133-135	295.93									A								X	854	3514	0.2430	BBg		
32X 3 1-3	296.11									C									12	882	0.0136			
32X 3 40-42	296.50									R									2	8	0.2581			
32X 3 62-64	296.72									R									2	20	0.1022			
32X 3 83-85	296.93									C									1	270	0.0037			
32X 3 102-104	297.12									C									3	168	0.0179			
32X 3 123-125	297.33									C									1	286	0.0035			
32X 3 140-142	297.50									C									12	502	0.0239			
32X 4 10-12	297.70									C									2	364	0.0055			
32X 4 30-32	297.90									C									9	427	0.0211			
32X 4 48-50	298.08									A									10	2632	0.0038			

Appendix 3.1 – Bolboform distribution and abundance data: (5 of 6)

DSDP Site 593 Core-Section Depth (cm)	Depth (mbsf)	*B. praeintermedia*	*B. metzmacheri ornata*	*B. metzmacheri* s.s. (ogival)	*B. metzmacheri* s.s. (cylindrical)	*B. gracilireticulata* s.s.	*B. gracilireticulata* s.l.	*B. pentaspinosa*	*B. capsula*	*B. gruetzmacheri* n. sp.	*B.* sp. spirospinosa	*B.* sp. spirospinosa x serrata	*B.* sp. serrata	*B. subfragoris* s.s.	*B.* sp. echinus	*B.* sp. spinulosa	*B.* sp. spinulosax spirospinosa	*B.* sp. indet. (smooth-walled)	Bolboform count (n)	Normalized abundance	Picked or scanned (g)	Southwest Pacific zonation	New Zealand Stage	Epoch
32X 4 68-70	298.28									C									15	785	0.0191	B. gruetz.		
32X 4 92-94	298.52									R									3	14	0.2113			
32X 4 110-112	298.70									R									3	21	0.1433			
32X 4 133-135	298.93									R									<1	0	0.1739			
32X 5 1-3	299.11																		0	0	0.1348			
32X 5 28-30	299.38																		0	0	0.2265			
32X 5 40-42	299.50																		0	0	0.1864			
32X CC 2-4	299.67								R	R									9	52	0.1715			
33X 1 1-3	302.71																		0	0	0.1171	BBg		
33X 1 27-29	302.97																		0	0	0.0039			
33X 1 40-42	303.10																		0	0	0.0750			
33X 1 59-61	303.29																		0	0	0.0044			
33X 1 83-85	303.53																		0	0	0.0611			
33X 1 107-109	303.77																		0	0	0.0044			
33X 1 121-123	303.91																		0	0	0.0526			
33X 1 143-145	304.13																		0	0	0.0040			
33X 2 9-11	304.29																		0	0	0.0039			
33X 2 27-29	304.47																		0	0	0.0057			
33X 2 46-48	304.66										R								1	10	0.1021	BBs	lower Tongaporutuan	Upper Miocene
33X 2 82-84	305.02										R								1	10	0.0995			
33X 2 95-97	305.15										R								1	8	0.1247			
33X 2 114-116	305.34										R		R						8	41	0.1963			
33X 2 135-137	305.55										R	R							4	48	0.0832			
33X 3 1-3	305.71											R		R					2	15	0.1373			
33X 3 23-25	305.93										R								3	27	0.1098			
33X 3 41-43	306.11										C								42	419	0.1003			
33X 3 57-59	306.27										C								46	337	0.1336			
33X 3 84-86	306.54										C	R							59	586	0.1007			
33X 3 105-107	306.75											A		R					189	2239	0.0844			
33X 3 116-118	306.86											A		R					414	5214	0.0794			
33X 3 138-140	307.08											A		R					182	1959	0.0929			
33X 4 10-12	307.30											C		R					109	864	0.1262			
33X 4 29-31	307.49											C		R					19	219	0.0866			
33X 4 50-52	307.70											R							1	28	0.1152			
33X 4 73-75	307.93																		0	0	0.1702			
33X 4 94-96	308.14																		0	0	0.0039			
33X 4 110-112	308.30																		0	0	0.0035			
33X 4 133-135	308.53																		0	0	0.0040			
33X 5 1-3	308.71																		0	0	0.1765			
33X 5 29-31	308.99											R							1	8	0.1190			
33X 5 41-43	309.11																		0	0	0.2067			
33X 5 58-60	309.28											R							2	11	0.1899			
33X 5 84-86	309.54												C	R					23	158	0.1455			
33X 5 104-106	309.74												C	R	R				36	281	0.1281			
34X 1 1-3	312.31												R						3	26	0.1153			
34X 1 24-26	312.54																		0	0	0.1006			
34X 1 37-39	312.67												R						2	15	0.1379			
34X 1 57-59	312.87																	X	0	0	0.1018			
34X 1 77-79	313.07																	X	0	0	0.0873			
34X 1 101-103	313.31																	X	0	0	0.2148			
34X 1 123-125	313.53																R		1	6	0.1796			
34X 1 141-143	313.71											R				R			3	19	0.1601			
34X 2 10-12	313.90																	X	0	0	0.1278			
34X 2 29-31	314.09											R							1	10	0.1000			
34X 2 49-51	314.29																		0	0	0.0035			
34X 2 65-67	314.45																		0	0	0.1706			
34X 2 89-91	314.69											R							2	16	0.1262			
34X 2 110-112	314.90											R							1	6	0.1598			
34X 2 133-135	315.13											R							10	71	0.1405			
34X 3 0-2	315.30											R							8	50	0.1599			
34X 3 22-24	315.52											C							2	645	0.0031			
34X 3 41-43	315.71											C							79	551	0.1435			
34X 3 76-78	316.06											R							1	13	0.0796			
34X 3 97-99	316.27											R							1	12	0.0815			
34X 3 118-120	316.48																		0	0	0.0808			
34X 3 137-139	316.67																		0	0	0.0035			

BBs-593/E

BBs-593/D

Waiauan

Appendix 3.1 – Bolboform distribution and abundance data: (6 of 6)

DSDP Site 593 Core-Section Depth (cm)	Depth (mbsf)	*B. praeintermedia*	*B. metzmacheri ornata*	*B. metzmacheri* s.s. (ogival)	*B. metzmacheri* s.s. (cylindrical)	*B. gracilireticulata* s.s.	*B. gracilireticulata* s.l.	*B. pentaspinosa*	*B. capsula*	*B. gruetzmacheri* n. sp.	*B.* sp. spirospinosa	*B.* sp. spirospinosa x serrata	*B.* sp. serrata	*B. subfragoris* s.s.	*B.* sp. echinus	*B.* sp. spinulosa	*B.* sp. spinulosax spirospinosa	*B.* sp. indet. (smooth-walled)	Bolboform count (n)	Normalized abundance	Picked or scanned (g)	Southwest Pacific zonation	New Zealand Stage	Epoch
34X 4 8-10	316.88																		0	0	0.0548			
34X 4 30-32	317.10																		0	0	0.0034			
34X 4 50-52	317.30																		0	0	0.1032			
34X 4 70-72	317.50																		0	0	0.0039			
34X 4 88-90	317.68																		0	0	0.0786			
34X 4 110-112	317.90																		0	0	0.0031			
34X 4 133-135	318.13																		0	0	0.0469			
34X 5 5-7	318.35																		0	0	0.0037			
34X 5 30-32	318.60																		0	0	0.0045			
35X 1 1-3	321.91																		0	0	0.0037			
35X 1 23-25	322.13																		0	0	0.1504			
35X 1 43-45	322.33																		0	0	0.0043			
35X 1 64-66	322.54																		0	0	0.0778			
35X 1 82-84	322.72														C				18	136	0.1320			
35X 1 100-102	322.90														R				4	33	0.1230			
35X 1 119-121	323.09														R				2	17	0.1197			
35X 1 141-143	323.31														R				1	10	0.1033			
35X 2 8-10	323.48														C				8	127	0.0630			
35X 2 32-34	323.72														R				8	61	0.1320			
35X 2 51-53	323.91														C				10	110	0.0912			
35X 2 90-92	324.30														R				1	7	0.1428			
35X 2 110-112	324.50																		0	0	0.0329			
35X 2 130-132	324.70																		0	0	0.0589			
35X 3 1-3	324.91																		0	0	0.0026			
35X 3 22-24	325.12																		0	0	0.0780			
35X 3 43-45	325.33																		0	0	0.0038			
35X 3 67-69	325.57																		0	0	0.0598			
35X 3 81-83	325.71																		0	0	0.0037			
35X 3 104-106	325.94																		0	0	0.0040			
35X 3 117-119	326.07																		0	0	0.0472			
35X 3 138-140	326.28																		0	0	0.0644			
35X 4 10-12	326.50															R			5	68	0.0733			
35X 4 30-32	326.70															A			5	1563	0.0032	BBs		
35X 4 48-50	326.88															C			32	411	0.0779			
35X 4 69-71	327.09															A			20	6452	0.0031			
35X 4 88-90	327.28															R			7	78	0.0903			
35X 4 110-112	327.50															R			2	32	0.0634			
35X 4 134-136	327.74																		0	0	0.0637			
35X 5 1-3	327.91												R						6	25	0.2370			
35X 5 16-18	328.06												R	R					6	48	0.1245			
35X 5 37-39	328.27												C	C		R			57	356	0.1600			
35X 5 57-59	328.47												R	R				R	4	20	0.2048			
35X 5 82-84	328.72													R		R	R		8	51	0.1555			
36X 1 19-21	331.69													R		R			8	59	0.1348			
36X 1 40	331.90																		0	0				
36X 1 61-63	332.11																		0	0	0.1800			
36X 1 101	332.51																		0	0				
36X 1 118-120	332.68																		0	0	0.0036			
36X 1 130	332.80																R		2	32	0.0627			
36X 1 148-150	332.98																R		1	9	0.1074			
36X 2 18	333.18																		0	0				
36X 2 40-42	333.40																R		9	84	0.1076			
36X 2 61	333.61																R		13	95	0.1374			
36X 2 100-102	334.00																A		9	2571	0.0035			
36X 2 130	334.30																A		191	5489	0.0348			
36X 2 136-138	334.36																A		178	1660	0.1072			
36X 2 143	334.43																C		39	319	0.1221			
36X 3 37-39	334.87																		0	0	0.2059			
36X 3 80	335.30																		0	0				
36X 3 97-99	335.47																		0	0	0.0026			
36X 3 118	335.68																		0	0				
36X 3 138-140	335.88																		0	0	0.0025			
36X 3 148	335.98																		0	0				
36X 4 20-22	336.20																		0	0	0.0029			
36X 4 60-62	336.60																		0	0	0.0027			
36X 4 80	336.80																		0	0				

Appendix 3.2 – New Zealand bolboform occurrences, from onland sections and petroleum exploration wells (see locality map).

Locality	NZ Fossil Record	Lab No.	Identification	Stratigraphic position and comments		specimens (n)
Tukemokihi Stream (Wairoa)						
ICW-7			*B.metzmacheri*	above Tukemokihi Coiling Zone (788 m, TCZ 612-714 m)	lower Tt	
MC97/3/12			*B.metzmacheri*	within Tukemokihi Coiling Zone (90 m, TCZ 31-131 m)	lower Tt	1
MC97/2/29			*B.subfragoris* s.l.	below Mapiri Coiling Zone (17 m, MCZ 20-66 m)	lower Tt	1
MC97/5/02			*B.subfragoris* s.l.	below Mapiri Coiling Zone (4 m, MCZ 20-66 m)	lower Tt	
MC97/5/01			*B.subfragoris* s.l.	below Mapiri Coiling Zone (0 m, MCZ 20-66 m)	lower Tt	13
Auroa Point - Table Cape section (Mahia)						
MC97/6/42	Y19/f193	F31774	*B.metzmacheri*	within Tukemokihi Coiling Zone (90 m, TCZ 73-161 m)	lower Tt	>8
MC97/5/24	Y19/f142	F31723	*B.subfragoris* s.l.?	Top of Kaiti Coiling Zone	lower Tt	1
MC97/6/03			*B.subfragoris* s.l.?	just below Kaiti Coiling Zone	upper Sw	2
Opoho-1 (Wairoa)						
1020-1050 ft	X19/f157	F31953	*B. subfragoris* s.l.		Sw-Tt	>30
1080-1110 ft	X19/f157	F31953	*B. subfragoris* s.l.		Sw-Tt	>3
Kaiti Beach (Gisborne)						
BDF 49-40	Y18/f511	F29212	*B.subfragoris* s.l.	within Kaiti Coiling Zone (178 m, KCZ 132-227 m)	lower Tt	9
BDF 49-39	Y18/f510	F29211	*B.subfragoris* s.l.	within Kaiti Coiling Zone (175 m, KCZ 132-227 m)	lower Tt	20
BDF 49-38	Y18/f509	F29210	*B.subfragoris* s.l.	within Kaiti Coiling Zone (172 m, KCZ 132-227 m)	lower Tt	10
BDF 49-37	Y18/f508	F29209	*B.subfragoris* s.l.	within Kaiti Coiling Zone (170 m, KCZ 132-227 m)	lower Tt	4
BDF 49-36	Y18/f507	F29208	*B.subfragoris* s.l.	within Kaiti Coiling Zone (167 m, KCZ 132-227 m)	lower Tt	6
Tahora South (Wanganui Basin)						
PJJK-Tahora	R19/f20		*B.subfragoris* s.l.	associated with sinistral G.miotumida		17
North Taranaki Coastal Section: (McKenzies Farm)						
JM-06	Q18/f168	F30702	*B.metzmacheri*	within Tukemokihi Coiling Zone (468 m, TCZ 345-715 m)	lower Tt	2
JM-09	Q18/f171	F30705	*B.metzmacheri*	within Tukemokihi Coiling Zone (472 m, TCZ 345-715 m)	lower Tt	1
JM-10	Q18/f172	F30706	*B.metzmacheri*	within Tukemokihi Coiling Zone (473 m, TCZ 345-715 m)	lower Tt	1
JM-12	Q18/f174	F30708	*B.metzmacheri*	within Tukemokihi Coiling Zone (478 m, TCZ 345-715 m)	lower Tt	3
JM-22	Q18/f184	F30718	*B.metzmacheri*	within Tukemokihi Coiling Zone (491 m, TCZ 345-715 m)	lower Tt	1
N100/f580	Q18/f9580		*B.metzmacheri*	within Tukemokihi Coiling Zone, picked by Graham Gibson	lower Tt	2
N100/f583	Q18/f9583		*B.metzmacheri*	within Tukemokihi Coiling Zone, picked by Graham Gibson	lower Tt	4
	R18/f66	F25496	*B. gruetzmacheri*	upper part Purupuru Member, below Tt stratotype	lower Tt	29
MC00/05/22			*B. gruetzmacheri*	upper part Purupuru Member, below Tt stratotype	lower Tt	4
Pukearuhe-1: (Taranaki Basin)						
860-870 m ctgs			*B. subfragoris* s.l.	just below Tukemokihi Coiling Zone (disrupted sequence?)	lower Tt	5
870-880 m ctgs			*B. pentaspinosa*	just below Tukemokihi Coiling Zone (disrupted sequence?)	lower Tt	5
890-900 m ctgs			*B. subfragoris* s.l.	just below Tukemokihi Coiling Zone (disrupted sequence?)	lower Tt	1
900-910 m ctgs			*B. pentaspinosa*	just below Tukemokihi Coiling Zone (disrupted sequence?)	lower Tt	2
1020-1030 m ctgs			*B. gruetzmacheri*	just above HO *N. mayeri* s.l.	lower Tt	18
1050-160 m ctgs			*B. subfragoris* s.l.	associated with lower Glomar Coiling Zone?	lower Tt	1
Cardiff-1: (Taranaki Basin)						
1725-30 m ctgs	Q20/f41	F28624	*B. subfragoris* s.l.	intermediate phases, ca. 175 m below HO *Gq. dehiscens*	lower Tt	11
Kongahu-1 (offshore Westland Basin)						
1389-1392 m ctgs	L27/f94	F24362	*B. subfragoris* s.l.		Sw-Tt	8
Bryce Burn (Southland)						
C45/f102		F23278	*B. subfragoris* s.l.	with *Bolivinita quadrilatera* + *Nq. continuosa*	lower Tt	>10
Whaka Nui-1 (offshore Northland Basin)						
2300 m ctgs	SE36172/f1		*B. subfragoris* s.l.	intermediate phases, 20 m below HO *Gq. dehiscens*	lower Tt	>30
Resolution-1 (Canterbury Basin)						
1040-1050 m ctgs			*B. subfragoris* s.l.	with Bolivinita cf. pohana	lower Tt	5
1100-1110 m ctgs			*B. subfragoris* s.l.	with N. continuosa/mayeri + B. medialis (near base Tt)	lower Tt	20
1140-1150 m ctgs			*B. subfragoris* s.l.			5
Galleon -1 (Canterbury Basin)						
1090-1100 m ctgs			*B. subfragoris* s.l.	with *Gc. cf. miozea, Gc. conica, Nq. mayeri* s.l.	???	1

Study 4

Intraspecific morphological variation in late Miocene bolboforms: Implications for the classification, ecology, and biostratigraphic utility of *Bolboforma*

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ABSTRACT: A preliminary morphological study of large well preserved bolboform populations from the late Miocene section of DSDP Site 593, in the southern Tasman Sea, reveals a relationship between test size and intraspecific morphological variation involving a gradual transformation in test shape and surface ornamentation in single-chambered species. The transformation begins with a small, smooth, thin-walled subspheroidal-shaped test and as size increases rudimentary ornaments become more common and the test shape becomes more lagenoid. As the test further increases in size, test walls thicken and ornaments become more structured, but specimens still retain a rounded lagenoid shape. In still larger tests, the ornament becomes more prominent – most notably on meridional surfaces – and tests develop a squatter shape with flatter aboral surfaces. The morphological transformation generally ends with large, thick-walled, highly ornate phases with squat lagenoid-shaped tests, robust meridional ornaments, and relatively flat aboral surfaces. Although the size of the test increases notably through the transformation, there appears to be no corresponding change in the size of the internal chamber – the transformation is largely due to the addition of calcite to the outer surface of the test wall. This appears to be an inherent biological feature and does not involve calcite dissolution or other retrograde processes. The detail of the transformation varies between species, although the pattern is similar for *Bolboforma subfragoris* s.l., *B. gruetzmacheri,* and *B. metzmacheri* s.s. that have different types of ornament – spinose, irregularly-ridged, and cancellate, respectively.

Because different morphological phases in the transformation have contrasting test shapes and ornaments they have the potential to be interpreted as different species, even when they occur in the same sample and belong to the same species. Taxonomic confusion is further compounded by the morphological similarity of many small, smooth-walled, and weakly ornamented phases of different species. These features are common in bolboform populations and have contributed to the misinterpretation of some species. Differences in test shape and ornament are most notable in large ornate phases and taxonomic interpretations should be based wherever possible on such phases.

For the studied populations, the transformation involving the addition of calcite to the outer surface of the test wall appears to have occurred while the bolboforms were entrained in subsurface flows of Southern Component Intermediate Water (SCIW). In this respect, the increased complexity of ornamentation may have been a morphological adaptation to counter the loss of buoyancy as calcite was added to the outer surface of the test wall. This would have presumably contributed to the entrainment and dispersal of bolboforms in the flow of subsurface water masses, and it suggests the tests of some bolboforms at least may represent a disseminal phase in the lifecycle of this enigmatic group of microfossils.

Keywords: *Bolboforma*; intraspecific variation; morphological transformation; classification; ecology; late Miocene; DSDP Site 593; Tasman Sea.

INTRODUCTION

Most bolboform studies to date have focused on the documentation of species and their ranges based on morphotypic isolates, and little attention has been given to the description of morphological variation within large bolboform populations. As a consequence, species have often been identified on the basis of poorly defined criteria that constitute only a part of a species range of morphological variation. This has reduced the reliability of many bolboform identifications and has introduced an element of taxonomic confusion in the literature, as noted by Poag (1987). Such confusion can only be resolved through the careful analysis and comparison of large well-preserved populations. This study adopts such an approach and describes intraspecific morphological variation in three late Miocene bolboform populations from Deep Sea Drilling Project (DSDP) Site 593 on the western margin of the Challenger Plateau, a relatively shallow subcontinental platform 470 km west of central New Zealand (Figure 4.1). Here the sedimentary sequence involves 470 m of Neogene carbonate ooze with virtually no terrigenous component (Nelson 1986). Since the beginning of the Neogene, Site 593 has been located well above the CCD and lysocline (Nelson 1986). Neogene calcareous microfossil assemblages are extremely well preserved and there is no substantive evidence of calcite dissolution (Jenkins & Srinivasan 1986).

The distribution of bolboforms in the older part of the late Miocene section of Site 593, between 593-36X-2, 143 cm and 593-26X-1, 102-104 cm (334.43-236.52 mbsf), is described in Study 3. The record includes a well defined sequence of narrow subzonal bolboform occurrences ranging from 1.6 to 5.8 m thick (c. 50 to 330 k.y. duration) punctuated by intervals without bolboforms (Figure 4.2). Specimen numbers are often low,

although most intervals have conspicuous spikes in abundance with up to several thousand specimens per gram in the greater than 150 μm sediment size fraction. Populations in the lower part of the bolboform sequence, within the *Bolboforma subfragoris* s.l. Zone (BBs), are largely heterogeneous and include two or more morphotypic variants, while populations from the upper part of the sequence, including the *B. gruetzmacheri* (BBg), *B. capsula* (BBc), *B. metzmacheri* (BBm), and *B. intermedia* (BBi) Zones, are largely monospecific. These features provide important insights into the ecology and potential biostratigraphic and paleoceanographic utility of this enigmatic group of microfossils (Study 3).

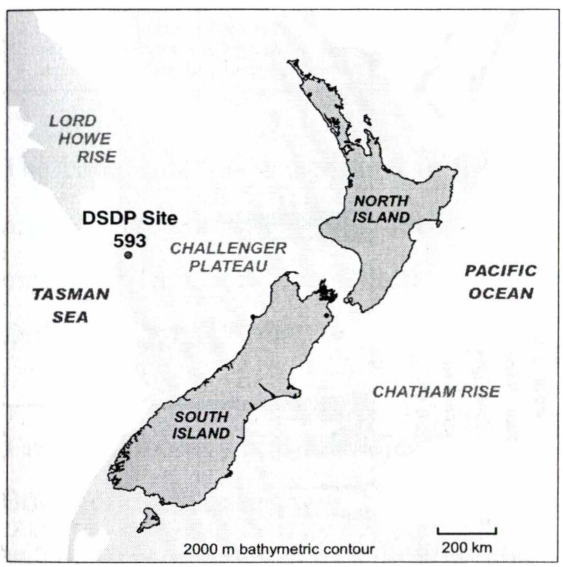


Figure 4.1 – Locality map showing DSDP Site 593.

Materials and methods

Following cursory examination of the bolboform samples under a binocular microscope, three large bolboform populations from different late Miocene bolboform zones were selected for morphological analysis (Figure 4.2): (BBs-Zone) *Bolboforma subfragoris* s.l. 593-33X-3, 138-140 cm (307.08 mbsf); (BBg-Zone) *B. gruetzmacheri* 593-32X-2, 133-135 cm (295.93 mbsf); and (BBm-Zone) *B. metzmacheri* s.s. 593-30X-1, 103-105 cm (274.93 mbsf). The species are all single-chambered forms and were chosen to be representative of the most common types of ornament – spirospinose, irregularly-ridged, and cancellate. The >63 μm (sand-sized) sediment fractions of disaggregated and washed samples were sieved into 63-125 μm, 125-150 μm, and >150 μm size fractions, and 50 bolboforms were randomly selected from each fraction and mounted for examination under a scanning electron microscope (SEM). Digital SEM images were then acquired of each specimen in axial orientation and the maximum axial and meridional dimensions of the

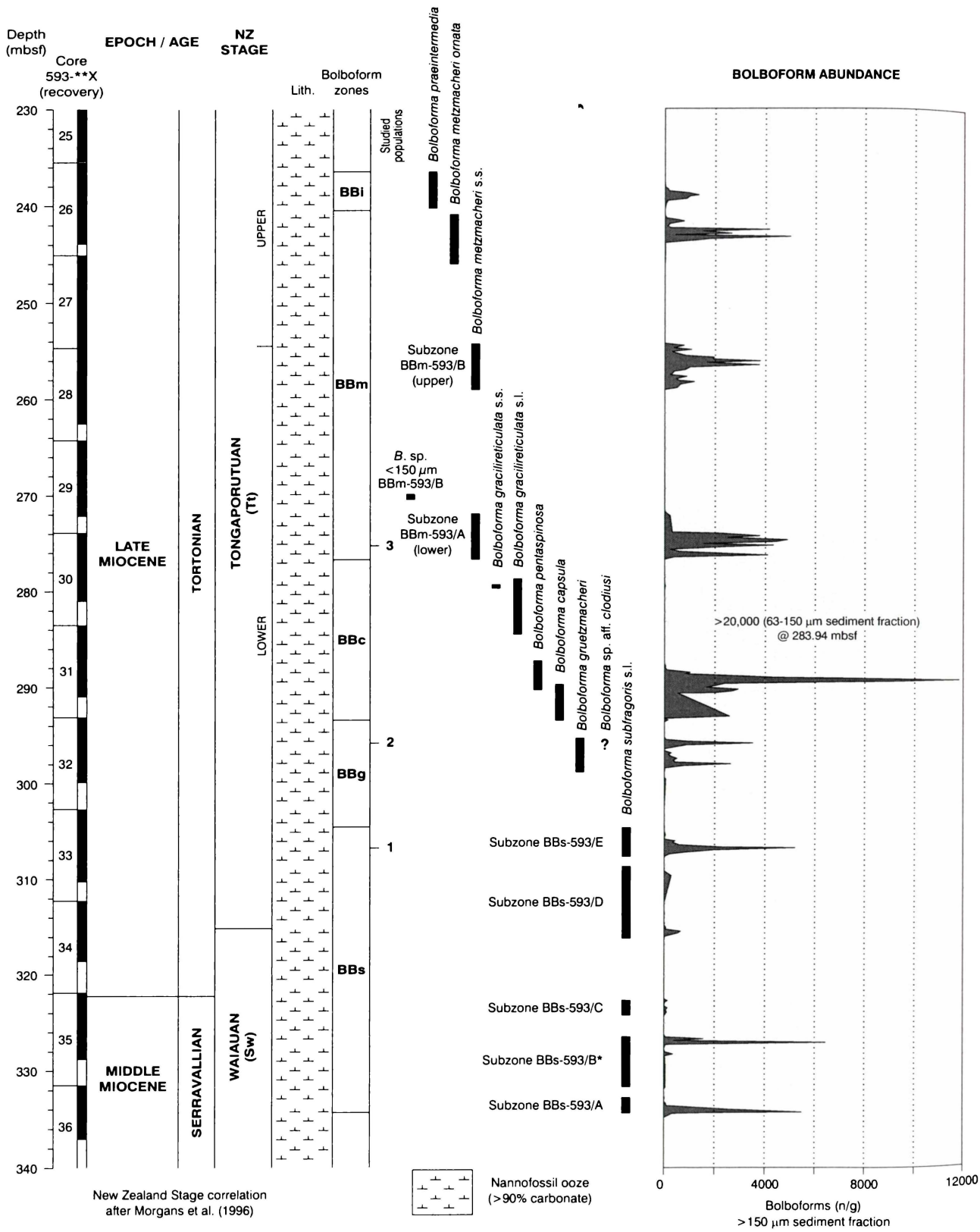


Figure 4.2 – Bolboform distribution, abundance, zonation, and stage correlation at Site 593 (Study 3). Numbered stratigraphic horizons correspond to studied populations: 1) *Bolboforma subfragoris* s.l.; 2) *Bolboforma gruetzmacheri* and *Bolboforma* sp. (cf. *B. clodiusi*); 3) *Bolboforma metzmacheri* s.s.

test, including the neck and ornament, were measured from the scaled images. Each specimen was classified in terms of their test shape and ornament into one of six morphological categories, encompassing smooth-walled to highly ornate phases (Table 4.1). Measurements of wall thickness (the average of eight sectored measurements) were also recorded for dissected and broken specimens of *B. gruetzmacheri* in order to compare wall thickness, internal chamber size, and test size.

Table 4.1 – Morphological classification of bolboform populations.

	Bolboforma subfragoris s.l. (Figure 4.3)	*Bolboforma gruetzmacheri* (Figure 4.4)	*Bolboforma metzmacheri* s.s. (Figure 4.6)
A	small smooth-walled phase	small smooth-walled phase	small smooth-walled phase
B	small phase, rudimentary ornament	small phase, rudimentary ornament	small phase, rudimentary ornament
C	intermediate phase, nodular ornament	intermediate phase, weak ornament	intermediate phase, weakly-ridged ornament
D	intermediate phase, spinose ornament	intermediate phase, ridged ornament	intermediate phase, cancellate-ridged ornament
E	large ornate phase, spirospinose ornament	large ornate phase, irregulary-ridged ornament	large ornate phase, cancellate-ridged ornament
F	large ornate phase, partially fused ornament	large ornate phase, partially embracing ornament	large ornate phase, flat/concave aboral surface

The cored interval is measured in metres below seafloor (mbsf) and sample identification numbers include: site, core number, core type, section number, and interval in centimetres, measured from the top of section. This follows the shipboard procedures of the Ocean Drilling Program (ODP), which succeeded the Deep Sea Drilling Project (DSDP).

Test morphology and classification

Bolboform tests are made of imperforate monocrystalline calcite and comprise a single bulbous or lagenoid-shaped hollow chamber, or two embracing or totally encapsulated chambers of unequal size (Spiegler 1987). Tests range in size from about 70-250 μm and they have a simple circular aperture surrounded by an extruded apertural neck with a tubular channel connecting to the chamber lumen. Surface morphology is highly variable and ranges from smooth-walled to extremely ornate, with spines, nodules, pustules, flanges, ribs, ridges, blades, reticulations, and corrugations. Chamber shapes are also variable and include subspheroidal, subellipsoidal, pear-shaped, oblate and squat lagenoid-shaped tests with flattened aboral surfaces. Taxonomic value has sometimes been assigned to different chamber shapes (e.g. Daniels & Spiegler 1974), although Willems (1976) and Poag (1987) have noted considerable intraspecific variation. This suggests test shape *per se* is a poor criterion for the interpretation of species.

Surface ornament is the single most important morphological feature used in taxonomic assignments, but there exists a poor understanding of intraspecific morphological variation. Several authors have alluded to intraspecific variation in surface ornament. For example,

Qvale & Spiegler (1989) noted transitional forms between well defined species such as *B. metzmacheri* and *B. laevis*, and Spiegler (1991) recorded difficulty in separating *B. laevis* from small smooth-walled phases of other species. However, the only substantive account of morphological variation in bolboform populations is by Poag (1987), who noted an intraspecific retrograde transformation from highly ornate to smooth-walled forms of *Bolboforma.* An example, which Poag (1987) attributed to progressive calcite dissolution, involved a transformation from strongly reticulate forms of *B. metzmacheri* into smooth-walled forms resembling *B. laevis* – a similar population is studied here (see later).

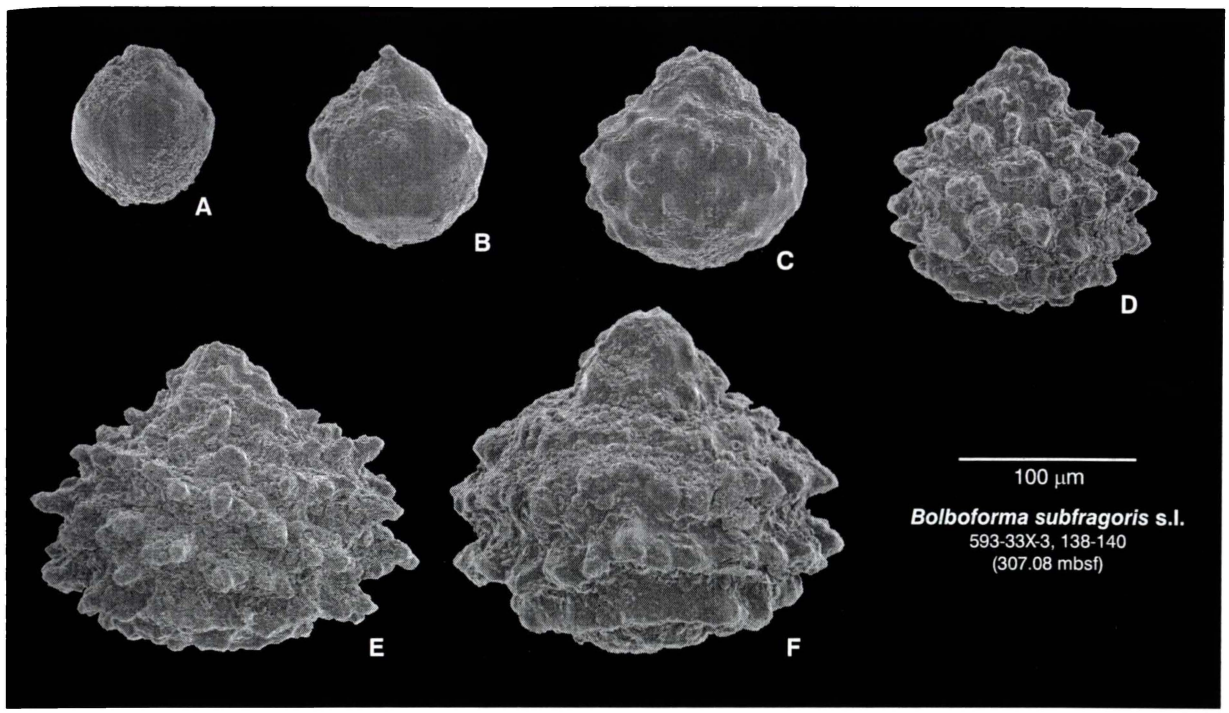
INTRASPECIFIC MORPHOLOGICAL VARIATION

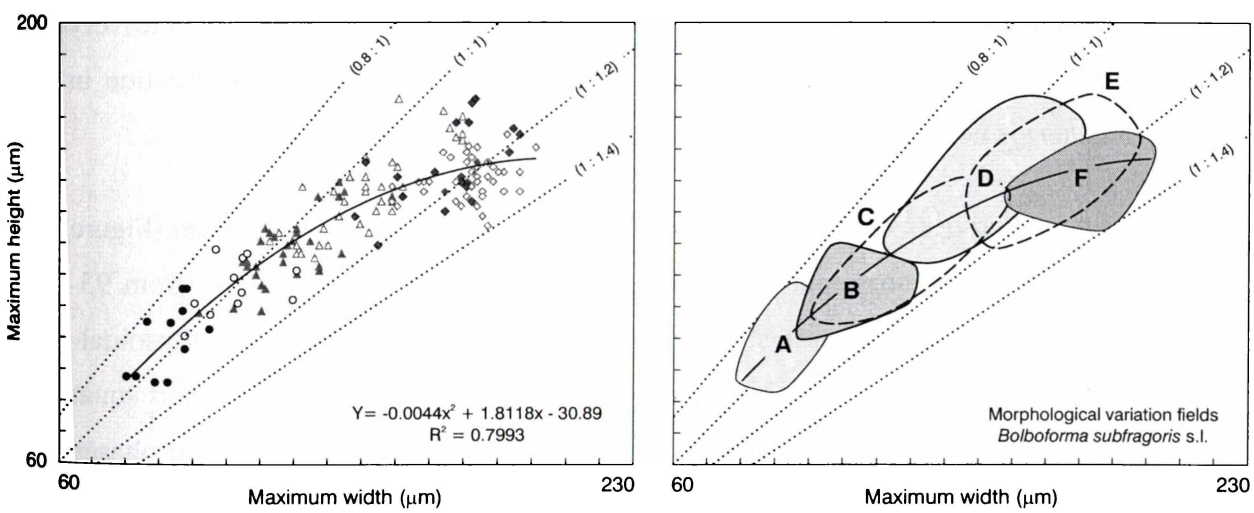
Intraspecific morphological variation is described here for three large well preserved bolboform populations from Site 593, including *Bolboforma subfragoris* s.l., *B. gruetzmacheri,* and *B. metzmacheri* s.s. A small nodular species that is associated with the population of *B. gruetzmacheri* is also described. The observations relate primarily to test shape, ornament, and size (Figures 4.3-4.6).

Bolboforma subfragoris Spiegler s.l.

The population comes from 593-33X-3, 138-140 cm (307.08 mbsf) – a rich bolboform sample with about 2000 specimens per gram in the greater than 150 μm sediment size fraction (Figure 4.2). It is associated with subzone BBs-593/E in the uppermost part of the BBs-Zone and is dominated by *B.* sp. spirospinosa x serrata morphotypes, but also includes rare flanged morphotypes that resemble *B. subfragoris* s.s.

Very small tests of *B. subfragoris* s.l., ranging in size from 80-100 μm, have subspheroidal to subellipsoidal shaped tests with very poorly developed apertural necks and relatively smooth walls, occasionally with vestiges of rudimentary nodular ornament (Figure 4.3/A). Rudimentary nodular ornaments become more common in larger 100-130 μm tests and the apertural neck begins to develop as a conical projection of the oral surface (Figure 4.3/B). The shape of the apertural neck is reflected in the fundamental lagenoid shape of larger phases and can vary from short and squat with a relatively large circular apertural opening, to long and narrow with a very small circular opening. Distinctly nodular ornaments appear in test sizes ranging from 100-160 μm, but the tests still retain a basic lagenoid shape with well rounded aboral surfaces (Figure 4.3/C). Subradial spinose ornaments that are sometimes spirally arranged appear in 120-180 μm tests (Figure 4.3/D). The spinose





A ● small smooth-walled phase (n=11)

B ○ small phase with rudimentary ornament (n=11)

C ▲ intermediate phase with nodular ornament (n=31)

D △ intermediate phase with spinose ornament (n=34)

E ◆ large ornate phase with spinose ornament (n=23)

F ◇ large ornate phase with fused ornament (n=40)

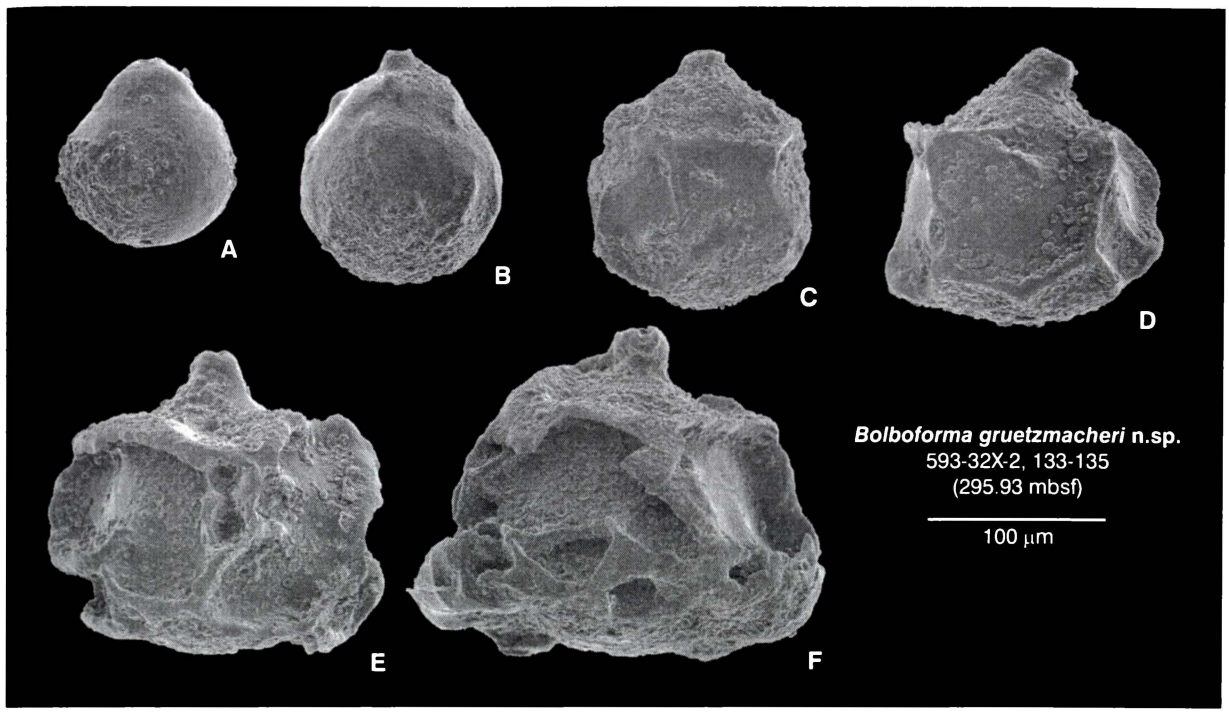
Figure 4.3 – Intraspecific morphological variation in *Bolboforma subfragoris* s.l. based on a single species population from 593-33X-3, 138-140 cm (307.08 mbsf). Annotated specimens (A–F) correspond to morphological classes given in Table 4.1. Cross plots of maximum meridional diameter (width) versus maximum axial length (height) showing the variation fields associated with visually assigned morphological classes (A–F). The morphological trend of the population is highlighted by a polynomial curve fitted to the data (solid line). Selected linear trend-lines (dotted lines) are shown for comparison.

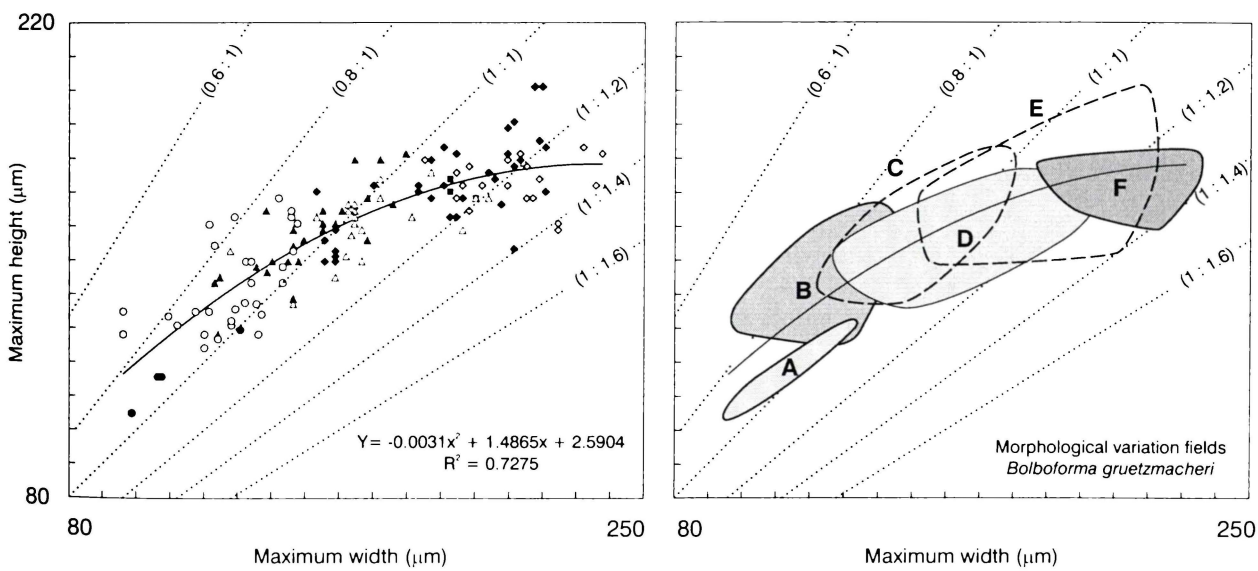
ornaments tend to be more strongly developed on meridional surfaces and tests are typically squatter and generally wider than they are long. In larger tests ranging from 150-195 μm, spinose ornaments tend to be more strongly developed on meridional surfaces and the tests have flatter aboral surfaces (Figure 4.3/E). In the largest tests ranging from 170-205 μm, there is a tendency for the spinose ornament to coalesce laterally and form irregular spiral-flanged segments that are sometimes continuous, and aboral surfaces become moderately flattened (Figure 4.3/F).

***Bolboforma gruetzmacheri* Crundwell**

The population comes from 593-32X-2, 133-135 cm (295.93 mbsf) – a rich bolboform sample in the upper part of the *Bolboforma gruetzmacheri* range zone with about 3500 specimens per gram in the greater than 150 μm sediment size fraction (Figure 4.2). It is dominated by *B. gruetzmacheri,* but also includes rare nodular specimens that are distinct from *B. gruetzmacheri.* Care was taken to separate these nodular specimens, although it is possible that some very small smooth-walled phases have been unintentionally included in the *B. gruetzmacheri* population. Because the taxonomic uncertainty only extends to very small smooth-walled phases, the interpretation of intraspecific morphological variation in *B. gruetzmacheri* is not adversely affected.

Small smooth-walled tests of *B. gruetzmacheri* that range in size from 95-120 μm (Figure 4.4/A), and phases with rudimentary irregular ridged ornaments ranging in size from 95-150 μm, display a variety of test shapes including subspheroidal- and subellipsoidal-shaped lagenoid tests with conical apertural necks, and pear-shaped tests with short squat apertural necks (Figure 4.4/B). The variety of test shapes pervades all subsequent phases and the shape is to some extent reflected in the pattern of ornament. Irregular, interconnected low-ridged ornaments appear in test sizes ranging from 120-180 μm (Figure 4.4/C), and strongly ridged ornaments appear in 150-205 μm tests, but they still retain the rounded lagenoid shape of smaller phases (Figure 4.4/D). In larger 155-220 μm tests, there is a tendency for the ridged and bladed ornament to mask the lagenoid shape of smaller phases (Figure 4.4/E). While subspheroidal lagenoid-shaped tests and pear-shaped tests generally develop a subquadrate axial profile, subellipsoidal-shaped tests develop a subtriangular profile. Although the ridged and bladed ornaments are irregular, they tend to be more strongly developed on the lower part of meridional surfaces and tests become squatter and generally wider than they are long. The largest test sizes, ranging from 195-





A ● small smooth-walled phase (n=4)

B ○ small phase with rudimentary ornament (n=30)

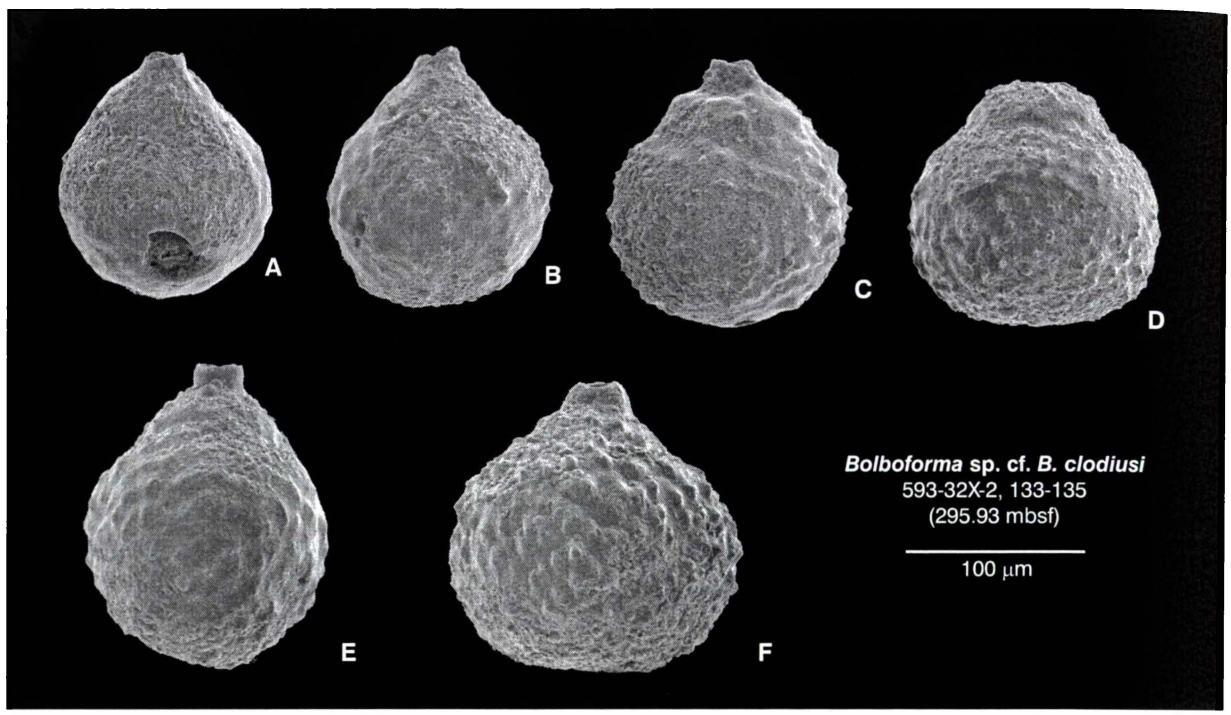
C ▲ intermediate phase with weak ornament (n=24)

D intermediate phase with ridged ornament (n=23)

E ◆ large ornate phase with ridged ornament (n=35)

F ◇ large ornate phase with embracing ornament (n=23)

Figure 4.4 – Intraspecific morphological variation in *Bolboforma gruetzmacheri*, based on a population from 593-32X-2, 133-135 cm (295.93 mbsf). Annotated specimens (A–F) correspond to morphological classes given in Table 4.1. Cross plots of maximum meridional diameter (width) versus maximum axial length (height) showing the variation fields associated with each visually assigned morphological class (A–F). The morphological trend of the population is highlighted by a polynomial curve fitted to the data (solid line). Selected linear trend-lines (dotted lines) are shown for comparison.



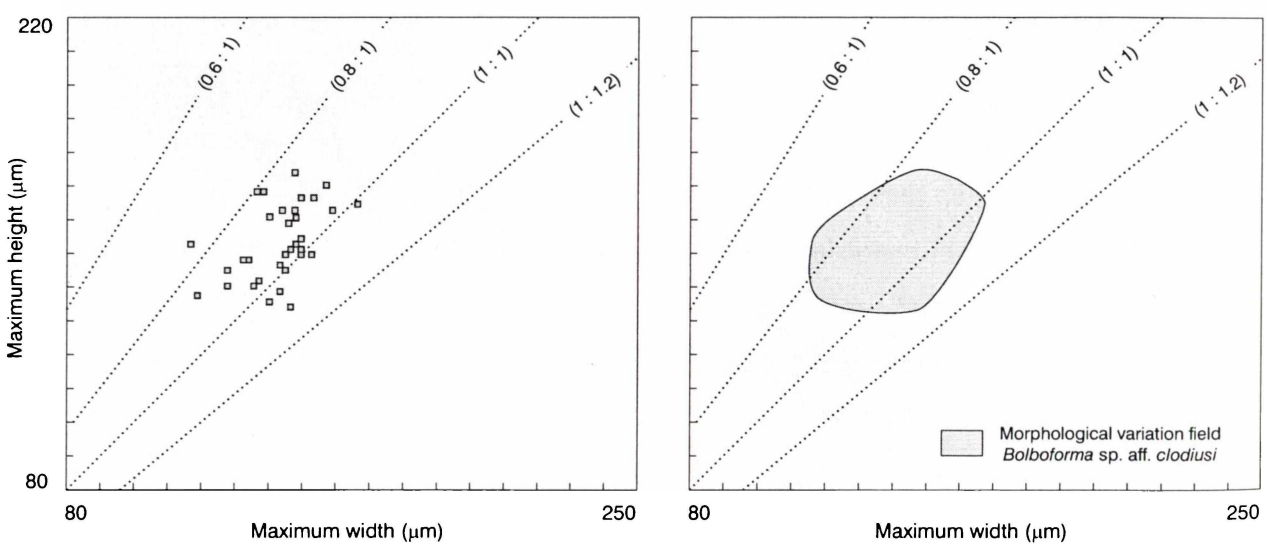


Figure 4.5 – Intraspecific morphological variation in *Bolboforma* sp. cf. *B. clodiusi*, a small nodular species found in the same sample as *B. gruetzmacheri*, 593-32X-2, 133-135 cm (295.93 mbsf). Cross plots of maximum meridional diameter (width) versus maximum axial length (height) showing the species variation field. Selected linear trend-lines (dotted lines) are shown for comparison.

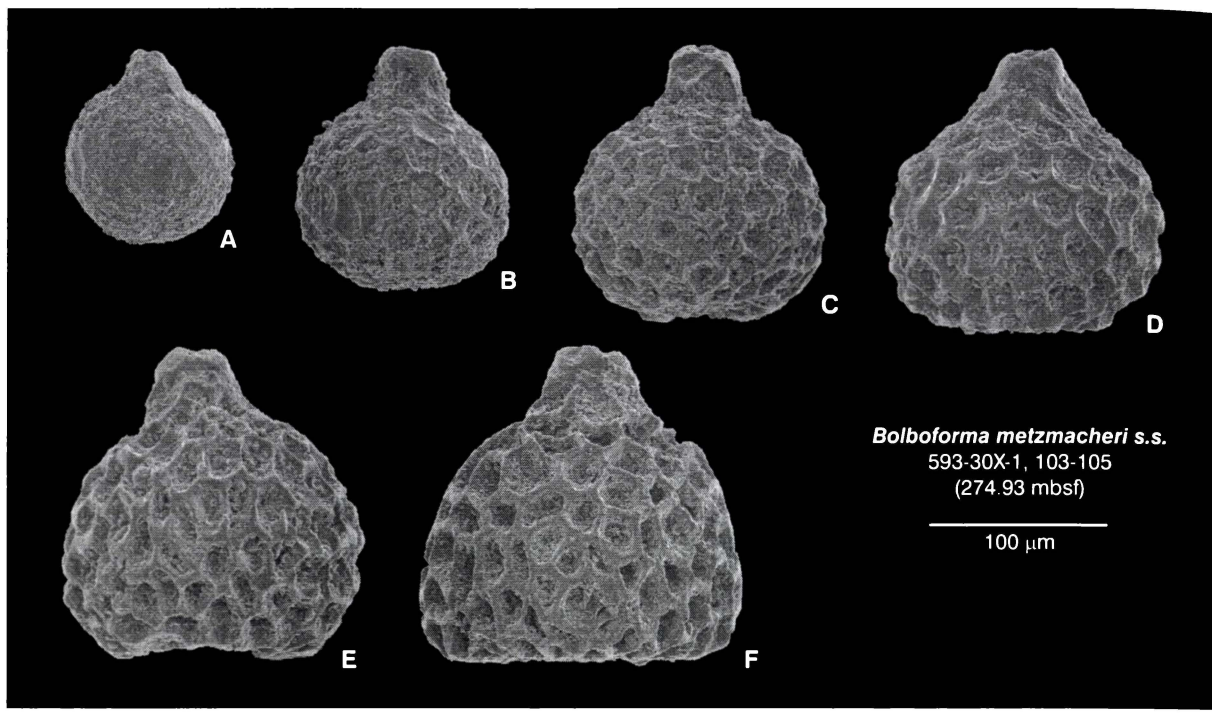
240 μm, have very strongly developed ridged and bladed meridional ornaments that fuse with the bases of the original lagenoid-shaped tests to produce relatively flat aboral surfaces. The extremities of the ridged and bladed ornaments also have a tendency to flex parallel to the surface of the test and become partially embracing, particularly in subquadrate-shaped tests (Figure 4.4/F).

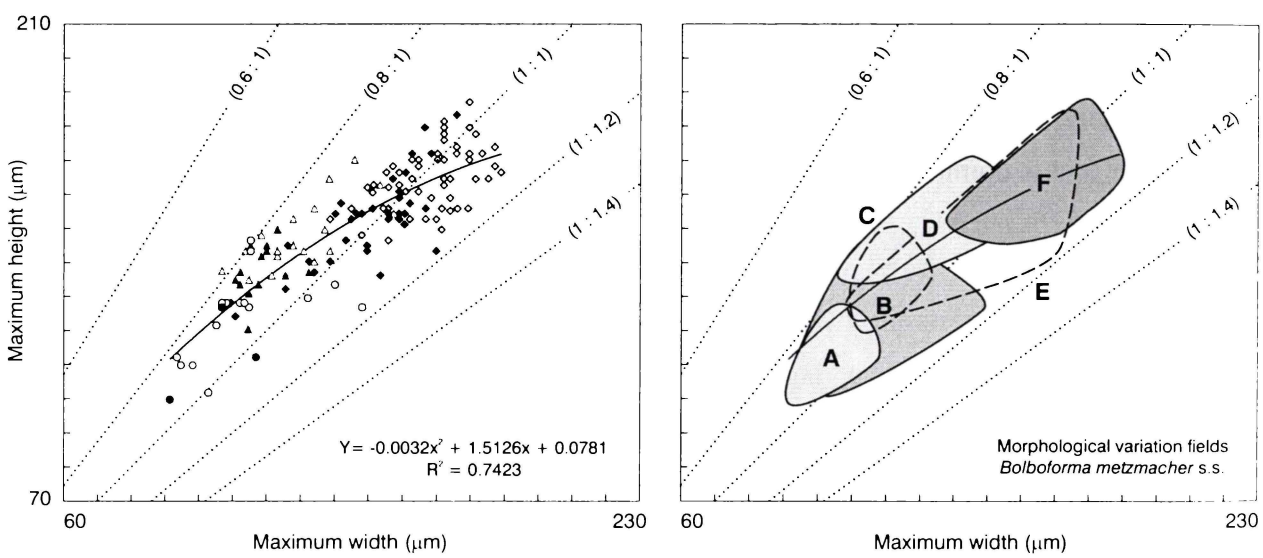
The nodular specimens show a comparatively limited range of morphological variation (Figures 4.5). Tests are relatively small (115-170 μm) and are generally pear-shaped with a short conical apertural neck and have rudimentary or weakly nodular ornaments. The absence of large ornate phases precludes a reliable taxonomic assignment, although the specimens resemble *Bolboforma clodiusi* Daniels and Spiegler, a long-ranging middle to late Miocene species with short spines and a small aborally flattened test (Daniels & Spiegler 1974; Spiegler & Daniels 1991).

***Bolboforma metzmacheri* s.s. (Clodius)**

The population comes from 593-30X-1, 103-105 cm (274.93 mbsf) – a rich bolboform sample with about 4400 specimens per gram in the greater than 150 μm sediment size fraction (Figure 4.2). It is associated with subzone BBm-593/A in the lowermost part of the BBm-Zone, and is dominated almost exclusively by cylindrical morphotypic variants of *B. metzmacheri* s.s.

Small smooth-walled tests of *B. metzmacheri* s.s. that range in size from 90-120 μm have subspheroidal to subellipsoidal, lagenoid-shaped tests with conical apertural necks that vary from being short and squat with large circular apertures to long and narrow with small apertures (Figure 4.6/A). The basic shape of the apertural neck is retained in larger phases and is to some extent reflected in the fundamental lagenoid shape of tests. Rudimentary cancellate-ridged ornaments first appear in test sizes ranging from 90-150 μm (Figure 4.6/B). The ornament develops evenly over most of the test surface, except in forms with short-squat apertural necks where the ornament appears to nucleate on the aboral surface before spreading over the entire test. Weakly ornamented tests ranging from 110-135 μm and cancellate-ridged tests ranging from 110-160 μm still retain a lagenoid shape with rounded to subrounded aboral surfaces (Figure 4.6/C). Tests ranging from 110-180 μm have more strongly developed cancellate ornaments, particularly on meridional surfaces, but the ornament tends to be more poorly developed on aboral surfaces, resulting in squatter tests that are slightly wider than they are long (Figure 4.6/D). Aboral surfaces in





A ● small smooth-walled phase (n=3)

B ○ small phase with rudimentary ornament (n=15)

C ▲ intermediate phase with weakly-ridged ornament (n=13)

D △ intermediate phase with cancellate-ridged ornament (n=21)

E ◆ large ornate phase with canellate-ridged ornament (n=35)

F ◇ large ornate phase with flat/concave aboral surface (n=62)

Figure 4.6 – Intraspecific morphological variation in *Bolboforma metzmacheri* s.s., based on a single species population from 593-30X-1, 103-105 cm (274.93 mbsf). Annotated specimens (A–F) correspond to morphological classes given in Table 4.1. Cross plots of maximum meridional diameter (width) versus maximum axial length (height) showing the variation fields associated with each visually assigned morphological class (A–F). The morphological trend of the population is highlighted by a polynomial curve fitted to the data (solid line). Selected linear trend-lines (dotted lines) are shown for comparison.

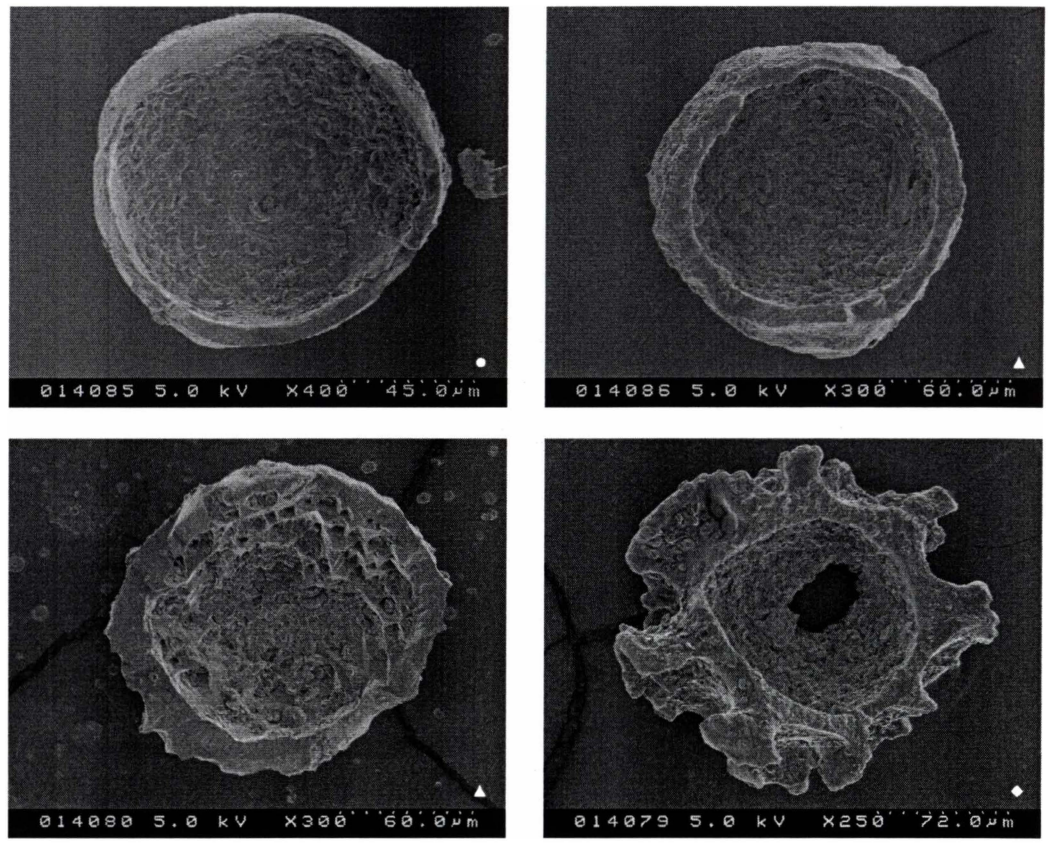
tests of this size also tend to be flatter (Figure 4.6/E). In the largest tests ranging from 160-190 μm, the meridional and aboral surfaces are clearly differentiated (Figure 4.6/F). While meridional surfaces have strongly developed cancellate ornaments, aboral surfaces tend to be flat or slightly concave and have weakly developed ornaments, particularly near the centre of aboral surfaces where the ornament often disappears altogether.

Morphological trends

Size data for each population reveal significant overlaps between some visually assigned morphological classes, in what appears to be a continuum of morphological variation between small smooth-walled phases (c. 70 μm) and large highly ornate phases (>180 μm) (Figures 4.3-4.6). The gradual transformation in test shape and surface ornament is intimately related to test size and is similar for all three species, even though they have fundamentally different types of ornament.

The transformation begins with small smooth-walled phases that have subspherical, subellipsoidal, or pear-shaped chambers, often without apertural necks. As tests increase in size rudimentary ornaments become more common and test shapes generally become more lagenoid as the apertural neck develops. The shape of the apertural neck can vary from short and squat with a large circular aperture to long and narrow with a very small circular aperture. In combination with the variable chamber shape this has a profound influence on the fundamental lagenoid shape of the test that pervades all subsequent phases. As test sizes increase further the ornament becomes more structured and it gradually develops a closer affinity to the ornaments of large ornate phases as tests continue to increase in size. Despite these changes, tests still retain a basic lagenoid shape with rounded to subrounded aboral surfaces. The most notable feature of the morphological transformation is the development in larger phases of robust ornaments on the meridional surfaces of test walls. This leads to the development of squat lagenoid-shaped profiles, as tests generally become wider than they are long. Meridional and aboral surfaces also become more differentiated as test sizes continue to increase, and this further enhances the squat lagenoid test shape. In the largest tests, meridional ornaments often coalesce and they form very robust ornaments, and the differentiation of meridional and aboral surfaces becomes even more pronounced – as demonstrated in *B. subfragoris* s.l. (Figure 4.3).

Data on wall thickness are too few to be considered conclusive, but measurements of broken and dissected specimens of *B. gruetzmacheri* suggest wall thickness may increase



TIFF Image	Wall - W (µm)	Test - T (µm)	Chamber - C (µm)	Ratio W/T	Ratio C/T
◆ 14079	23.3	162	115	0.14	0.71
△ 14077	15.3	154	123	0.10	0.80
△ 14081	14.7	150	121	0.10	0.81
△ 14080	13.8	144	117	0.10	0.81
△ 14086	9.4	142	123	0.07	0.87
△ 14083	9.4	128	109	0.07	0.85
△ 14084	10.0	127	107	0.08	0.84
● 14085	4.1	114	106	0.04	0.93
● 14087	5.1	109	99	0.05	0.91

◆ ornate phase
△ intermediate phase
● small smooth-walled phase

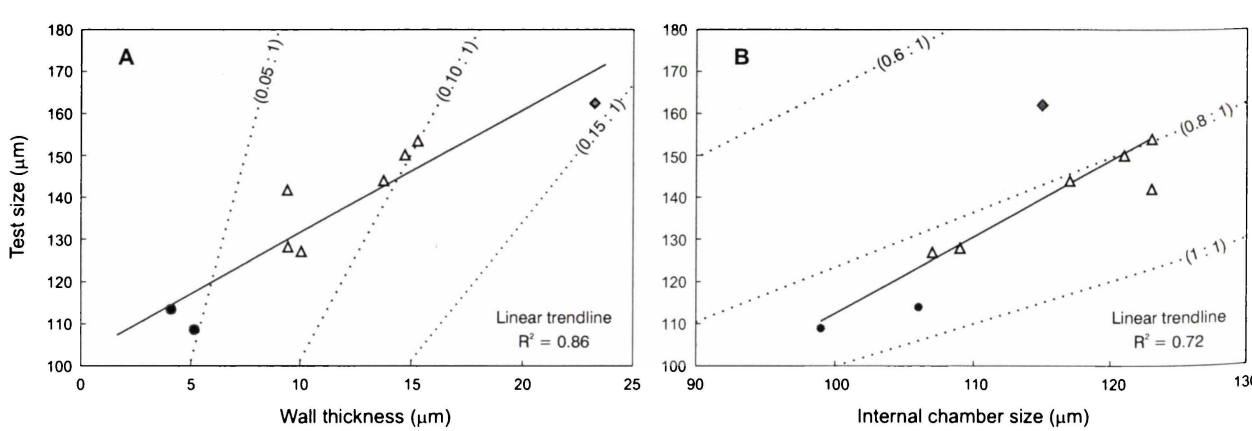


Figure 4.7 – SEM images and plots of size data for broken and dissected specimens of *Bolboforma gruetzmacheri*, 593-32X-2, 133-135 cm (295.93 mbsf), showing relationships between test size, wall thickness, and internal chamber size. Test size = maximum merdional measurement including ornament; Wall thickness = average of eight sectored measurements; Chamber size = (maximum test size – wall thickness x2).

six-fold through the morphological transformation from small smooth-walled phases to large ornate phases (Figure 4.7A). This accounts for about 70% of the increase in test size, between the smallest and largest of the measured specimens. The size of the internal chamber also varies (Figure 4.7B), although the data do not support a clear relationship between chamber-size and test-size – much of the variation appears to be intraspecific.

Bolboforma subfragoris s.l. and *B. metzmacheri* s.s. show a similar increase in wall thickness, with small smooth-walled phases generally being much thinner than large ornate phases, and as in *B. gruetzmacheri* there appears to be no increase in size of the internal chamber as tests get larger.

Bolboform ecology

The observed pattern of intraspecific morphologic variation in bolboform populations is very similar to the retrograde morphological transformation that Poag (1987) attributed to progressive calcite dissolution. At Site 593, however, late Miocene calcareous microfossils are extremely well preserved and there is virtually no evidence of calcite dissolution, other than slightly etched chamber wall-surfaces in some dissolution-susceptible planktic foraminifers (Study 2). As bolboforms have a high resistance to dissolution (Müller et al. 1985; Echols 1985) it is unlikely their tests have undergone significant retrograde modification due to dissolution, while other microfossil groups have been unaffected. The excellent preservation of microfossils also precludes mechanical abrasion and other retrograde processes, such as diagenetic modification and biological degradation. Consequently, the morphological transformation from small smooth-walled tests to large highly ornate tests is considered to be an inherent, possibly ontogenetic feature of bolboform populations. Because there is no substantive evidence of internal chamber growth, only an increase in test size, the intraspecific morphological transformation would appear to be largely due to the addition of calcite to the outer surface of the test wall. This has important implications for bolboform ecology and it argues for bolboform tests being reproductive or vegetative bodies rather than resting cysts.

The precise role of the calcareous test in the bolboform lifecycle is unclear, although bolboforms are generally considered to be phytoplanktic organisms (Spiegler & Daniels 1991). The addition of calcite to the outer surface of the test wall would have presumably caused organisms of such size to sink below the photic zone and reach the seafloor in a matter of days or weeks (Kennett & Kennett 1990). This subsurface stage of the bolboform

lifecycle is corroborated by oxygen isotope data, which suggest bolboform tests calcified at intermediate water depths (Poag 1987; Spiegler & Erlenkeuser 2001). The increased complexity of ornamention in larger bolboform tests and the associated increase in friction drag would have presumably helped to counter the loss of buoyancy as calcite was added to the outer surface of the test wall. The retention of bolboform tests in the water column for longer periods of time may have facilitated their entrainment and dispersal in subsurface water masses. Cooke et al. (2002) have recently suggested the entrainment of bolboform tests in the flow of Southern Component Intermediate Water (SCIW) may have facilitated genetic exchange across regions of low latitude and contributed to their bipolar mid- to high-latitude distribution (Spiegler & Daniels 1991). In this respect the development of thick tests and complex ornaments may be important features of bolboform ecology, and they may have contributed to the survival and dispersal of bolboforms during entrainment.

The suggestion that bolboforms represent an encystment phase of phytoplanktic organisms (e.g. Tappan 1980; Murray 1984) was questioned by Kennett & Kennett (1990) on the grounds that the deposition of tests, in large numbers, at paleodepths well below the photic zone in the open ocean, is an unlikely strategy for an encystment phase of a phytoplanktic organism. The production, however, of large numbers of cysts is a common biological response to environmental stress and a likely adaptation for phytoplanktic organisms living at high latitudes where there is a need to endure extended periods of winter darkness. The subduction and entrainment of phytoplanktic organisms in subsurface water masses as suggested by Cooke et al. (2002), would almost certainly have contributed to a high-level of environmental stress and it is speculated that this may have initiated the development of a protective encystment phase, similar to seasonally produced cysts. Bolboforms that were entrained in the flow of subsurface water masses may seldom have reached sites suitable for the completion of their lifecycle, as indicated by the deposition of large numbers of bolboform tests in the open ocean (Kennett & Kennett 1990), although this must have occurred often enough to have maintained bipolar mid- to high-latitude populations (Spiegler & Daniels 1991). A similar analogy may be drawn from the disseminal phase of terrestrial plants, where large numbers of seeds are dispersed widely and only a small number germinate and go on to reproduce. The suggestion that bolboform tests may represent a disseminal phase in the bolboform lifecycle is highly speculative, but plausible, and warrants further investigation.

CONCLUSIONS

An intraspecific morphological transformation in single-chambered bolboforms, from small smooth-walled and rudimentary ornamented phases, through intermediate phases with rounded lagenoid shaped profiles, to large ornate phases with robust meridional ornaments and flattened aboral surfaces, has been described for three late Miocene species at a single oceanic site from Tasman Sea. The transformation, which involves calcite being added to the outer surface of the test wall, appears to be an inherent biological feature of single-chambered bolboforms. Because species identifications are often based on morphological features that are typical of only part of a species range of morphological variation, there is the potential for taxonomic assignments to be confused and this may lead to false stratigraphic and paleoceanographic assumptions. This highlights the need for a thorough taxonomic review of bolboform species based on the analysis and comparison of large populations, particularly where taxonomic assignments have been based on assemblages without large ornate phases, and assemblages with more than one species.

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Appendices

Appendix 4.1: Size data *Bolboforma subfragoris* s.l., 593-33X-3, 138-140 cm (307.08 mbsf).

Image no.	Width (µm)	Height (µm)	Morph. class	Image no.	Width (µm)	Height (µm)	Morph. class	Image no.	Width (µm)	Height (µm)	Morph. class
14091	124.2	132.2	C	14151	180.8	159.0	F	14211	151.2	146.5	D
14093	125.5	133.5	D	14153	183.9	154.3	F	14212	160.5	151.2	E
14094	128.2	129.5	C	14154	201.0	160.5	F	14213	144.9	143.4	D
14095	130.8	134.8	C	14155	179.5	170.2	D	14214	137.5	122.8	C
14096	118.8	120.2	C	14156	188.6	149.6	F	14215	155.8	148.1	D
14097	80.4	87.9	A	14157	191.7	152.7	F	14216	143.4	144.9	C
14098	105.2	107.5	B	14158	183.9	160.5	F	14217	176.1	157.4	F
14099	114.5	114.5	B	14159	148.1	138.7	E	14218	171.4	152.7	E
14100	92.6	86.0	A	14160	188.6	154.3	F	14219	174.5	140.3	E
14101	86.5	105.2	A	14161	188.6	154.3	F	14220	168.3	146.5	F
14102	114.8	125.5	B	14162	179.2	151.2	E	14221	151.2	148.1	D
14103	104.9	102.9	A	14163	177.7	143.4	F	14222	152.2	133.5	D
14104	113.4	111.0	B	14164	190.1	152.7	F	14224	136.2	125.5	D
14105	83.2	87.9	A	14165	183.3	175.8	E	14225	137.1	144.9	C
14108	93.5	104.9	A	14166	177.7	149.6	F	14226	162.1	148.1	D
14109	98.2	115.7	A	14168	191.7	146.5	F	14227	159.0	143.4	C
14110	97.7	96.6	A	14169	183.9	141.8	F	14228	159.0	155.8	D
14111	129.7	112.2	B	14170	196.4	146.5	F	14229	159.0	140.3	D
14113	97.0	108.7	A	14171	185.5	146.5	F	14230	143.4	149.6	C
14115	118.8	122.8	C	14172	180.8	144.9	F	14231	155.8	143.4	D
14116	88.8	86.0	A	14173	185.5	144.9	F	14232	151.2	151.2	D
14117	112.2	119.2	B	14174	193.2	159.0	E	14233	160.5	154.3	D
14118	106.8	128.2	B	14175	183.9	154.3	E	14234	179.2	149.6	E
14119	130.8	121.5	B	14176	187.0	155.8	F	14235	182.3	152.7	F
14120	130.9	120.4	C	14178	183.9	151.2	F	14237	151.2	157.4	D
14121	101.8	108.1	C	14179	187.0	135.6	F	14238	143.4	138.7	D
14122	97.0	115.7	A	14180	182.3	174.5	E	14239	140.2	129.5	D
14123	97.7	100.8	B	14181	162.1	144.9	E	14240	183.9	149.6	F
14124	116.2	126.8	B	14182	192.6	164.6	F	14241	144.2	126.8	C
14125	100.5	111.0	B	14183	180.8	149.6	E	14242	159.0	144.9	C
14126	114.8	124.2	C	14185	180.8	148.1	E	14244	168.3	149.6	F
14127	121.6	115.7	C	14186	182.3	148.1	F	14245	151.2	155.8	E
14129	120.4	108.7	C	14189	177.7	163.6	D	14246	169.9	149.6	F
14130	137.5	121.5	C	14191	179.5	162.7	D	14247	141.8	146.5	D
14131	122.8	133.5	C	14192	181.4	160.8	F	14248	146.5	151.2	D
14132	130.8	129.5	D	14193	173.9	172.1	D	14249	137.5	129.5	D
14133	122.8	130.8	D	14194	196.4	164.6	E	14250	159.0	143.4	F
14135	130.8	126.8	D	14195	183.9	155.8	E	14251	134.8	130.8	C
14136	112.1	109.5	C	14196	180.8	155.8	F	14252	149.5	136.2	D
14138	126.8	126.8	C	14197	187.0	151.2	F	14253	154.9	129.5	E
14139	132.5	148.1	D	14198	179.5	164.6	D	14254	154.3	140.3	D
14140	132.2	126.8	D	14199	160.8	175.8	D	14255	179.2	141.8	F
14141	130.8	133.5	C	14201	182.3	157.4	F	14256	138.8	134.8	D
14142	129.5	130.8	C	14202	196.4	152.7	F	14257	185.5	138.7	F
14143	121.5	134.8	C	14203	182.3	143.4	E	14258	144.9	146.5	C
14144	116.2	122.8	C	14204	194.5	166.4	E	14259	166.8	149.6	F
14145	120.4	116.9	C	14206	174.5	146.5	E	14260	160.5	141.8	F
14146	120.2	130.8	C	14207	181.4	168.3	E	14261	159.0	148.1	F
14147	126.8	124.2	C	14209	175.8	166.4	D	14262	165.2	140.3	E
14149	116.2	124.2	C	14210	177.7	168.3	E	14263	173.9	159.0	F

A small smooth-walled phase
B small phase, rudimentary ornament
C intermediate phase, nodular ornament
D intermediate phase, spinose ornament
E large ornate phase, spirospinose ornament
F large ornate phase, partially fused ornament

Appendix 4.2: Size data *Bolboforma gruetzmacheri*, 593-32X-2, 133-135 cm (295.93 mbsf).

Image no.	Width (μm)	Height (um)	Morph. class	Image no.	Width (μm)	Height (um)	Morph. class	Image no.	Width (μm)	Height (um)	Morph. class
13878	135.6	148.1	C	13940	207.6	166.4	E	13996	164.6	164.6	D
13879	132.5	149.6	B	13941	211.3	190.8	E	13997	140.3	149.6	C
13881	129.4	135.6	B	13942	192.6	173.9	E	13999	164.6	166.4	D
13882	120.2	124.2	B	13943	181.4	162.7	D	14000	159.0	160.8	C
13885	121.5	134.8	B	13945	209.5	179.5	F	14001	166.8	159.0	D
13886	112.1	130.8	B	13946	231.9	183.3	F	14002	163.6	157.4	D
13887	128.2	130.8	B	13947	196.4	159.0	D	14003	166.8	149.6	D
13889	98.7	104.9	A	13948	183.3	170.2	E	14004	168.3	168.3	D
13890	143.4	143.4	B	13949	192.6	170.2	E	14005	155.2	164.6	C
13891	96.1	128.2	B	13950	194.5	181.4	E	14015	137.1	134.0	B
13892	106.4	115.7	A	13951	237.5	181.4	F	14018	135.6	137.1	B
13893	109.5	133.5	B	13952	198.2	177.7	F	14019	142.1	168.3	B
13894	136.2	128.2	B	13953	203.8	168.3	D	14021	146.5	152.7	B
13895	138.7	146.5	C	13954	217.4	201.0	E	14042	147.7	160.8	B
13896	96.1	134.8	B	13955	187.0	179.5	E	14044	146.5	138.7	C
13897	107.5	115.7	A	13957	209.5	181.4	E	14045	145.9	162.7	B
13899	130.8	129.5	A	13959	209.5	181.4	F	14047	143.4	148.1	B
13901	129.0	162.7	B	13960	209.5	172.1	F	14048	134.0	143.4	B
13902	134.0	149.6	B	13961	179.5	181.4	C	14050	145.9	164.6	B
13904	124.2	128.2	C	13962	209.5	188.9	E	14051	146.5	137.1	D
13905	120.2	128.2	B	13964	220.7	183.3	E	14052	168.3	168.3	C
13906	127.8	152.7	D	13965	224.4	160.8	F	14053	146.5	159.0	C
13907	124.2	126.8	B	13966	187.0	168.3	E	14055	159.0	152.7	E
13908	121.6	160.5	B	13967	187.0	175.8	D	14056	155.8	155.8	E
13909	128.2	132.2	B	13969	185.1	179.5	F	14058	155.2	159.0	C
13913	132.2	137.5	B	13970	219.7	201.0	E	14059	162.7	166.4	D
13914	123.1	154.3	B	13971	176.1	148.1	F	14060	146.5	137.1	D
13916	124.7	144.9	C	13972	196.4	168.3	E	14061	164.6	179.5	C
13917	123.1	143.4	C	13973	218.8	173.9	F	14062	170.2	172.1	E
13918	117.5	134.8	B	13974	172.1	173.9	D	14063	153.4	170.2	E
13919	164.6	162.7	D	13975	198.2	164.6	F	14064	153.4	162.7	D
13920	224.4	159.0	F	13976	190.8	172.1	E	14066	159.0	159.0	E
13921	220.7	170.2	E	13977	200.1	168.3	D	14067	155.2	160.8	C
13922	215.1	168.3	F	13978	183.3	172.1	E	14068	147.7	160.8	B
13923	211.3	153.4	E	13979	205.7	173.9	E	14069	175.8	166.4	C
13924	216.9	168.3	F	13980	213.2	179.5	F	14070	155.8	149.6	E
13925	194.5	175.8	F	13981	235.6	172.1	F	14071	211.3	177.7	E
13926	218.8	185.1	E	13982	215.1	177.7	F	14072	159.0	151.2	E
13928	213.2	179.5	E	13984	196.4	172.1	F	14073	164.6	160.8	D
13929	192.6	162.7	E	13985	162.1	151.2	D	14075	159.0	144.9	D
13930	213.2	181.4	F	13986	160.8	164.6	C	14076	148.1	149.6	C
13931	202.0	172.1	F	13987	172.1	179.5	C				
13932	194.5	168.3	F	13988	159.0	149.6	E				
13933	194.5	162.7	E	13989	149.6	155.8	C				
13935	172.1	168.3	D	13990	168.3	155.8	C				
13936	200.1	168.3	E	13991	144.9	149.6	C				
13937	190.8	183.3	E	13993	146.5	154.3	C				
13938	203.8	175.8	E	13994	138.4	164.6	C				
13939	209.5	179.5	F	13995	162.7	164.6	D				

A small smooth-walled phase
B small phase, rudimentary ornament
C intermediate phase, weak ornament
D intermediate phase, ridged ornament
E large ornate phase, irregulary-ridged ornament
F large ornate phase, partially embracing ornament

Appendix 4.3: Size data *Bolboforma* sp. cf. *B. clodiusi*, 593-32X-2, 133-135 cm (295.93 mbsf).

Image no.	Width (μm)	Height (um)	Morph. class	Image no.	Width (μm)	Height (um)	Morph. class	Image no.	Width (μm)	Height (um)	Morph. class
13883	127.8	144.9	?	14011	149.6	149.6	?	14032	140.3	135.6	?
13898	116.9	152.7	?	14012	157.1	170.2	?	14034	136.5	168.3	?
13900	138.4	168.3	?	14013	149.6	151.2	?	14035	143.4	146.5	?
13903	134.0	148.1	?	14016	146.5	151.2	?	14036	135.6	140.3	?
13910	127.8	140.3	?	14017	152.7	149.6	?	14037	136.5	168.3	?
13911	118.8	137.5	?	14020	149.6	154.3	?	14038	144.9	144.9	?
13915	132.5	148.1	?	14022	148.1	160.5	?	14039	147.7	162.7	?
14006	149.6	166.4	?	14023	153.4	166.4	?	14040	140.3	160.8	?
14007	147.7	173.9	?	14024	166.4	164.6	?	14046	144.9	149.6	?
14008	144.0	162.7	?	14028	146.5	134.0	?	14049	145.9	159.0	?
14009	159.0	162.7	?	14029	137.1	141.8	?				
14010	148.1	152.7	?	14030	143.4	138.7	?				

Appendix 4.4: Size data *Bolboforma metzmacheri* s.s., 593-30X-1, 103-105 cm (274.93 mbsf).

Image	Width (um)	Height (um)	Morph. class	Image	Width (um)	Height (um)	Morph. class	Image	Width (um)	Height (um)	Morph. class
14277	110.8	134.8	C	14341	172.1	181.4	F	14396	134.0	140.3	D
14278	108.1	128.2	B	14342	159.0	162.7	F	14397	169.9	152.7	F
14279	102.9	101.8	B	13345	155.2	166.4	F	14398	137.1	149.6	D
14280	115.3	144.9	C	14346	172.1	175.8	F	14399	155.8	152.7	E
14281	116.9	112.2	A	14347	172.1	177.7	F	14400	166.8	155.8	E
14284	110.8	124.2	E	14348	168.3	172.1	E	14401	143.4	146.5	E
14285	120.0	144.9	C	14350	170.2	172.1	F	14402	159.0	152.7	E
14287	106.8	137.5	D	14352	172.1	162.7	F	14403	153.5	136.2	E
14289	134.0	140.3	D	14353	162.7	170.2	F	14404	155.8	146.5	F
14293	138.7	140.3	E	14354	164.6	170.2	F	14405	159.0	154.3	F
14294	91.4	99.7	A	14355	185.1	164.6	F	14406	151.5	162.7	F
14295	114.8	126.8	B	14356	162.7	164.6	F	14407	155.8	154.3	E
14296	123.1	141.8	D	14357	157.1	168.3	F	14408	140.3	154.3	E
14297	114.8	134.8	D	14358	171.4	155.8	F	14409	146.5	154.3	E
14298	123.1	149.6	C	14359	170.2	170.2	F	14410	160.5	151.2	E
14299	117.5	133.5	C	14360	173.9	155.2	F	14411	148.1	154.3	E
14300	132.2	129.5	B	14361	164.6	170.2	F	14412	151.2	160.5	F
14301	118.4	148.1	D	14362	183.3	172.1	F	14414	148.2	126.8	B
14302	132.5	140.3	E	14363	187.0	168.3	F	14415	157.4	154.3	D
14303	123.1	143.4	D	14364	175.8	172.1	F	14416	138.4	164.6	D
14304	106.8	128.2	B	14365	164.6	160.8	F	14417	149.6	143.4	E
14305	115.3	143.4	B	14366	168.3	172.1	F	14418	171.4	149.6	F
14306	118.4	141.8	C	14367	172.1	162.7	F	14419	160.5	154.3	E
14308	125.5	136.2	C	14368	172.1	177.7	F	14420	134.0	155.8	D
14309	126.2	144.9	E	14369	155.8	155.8	F	14421	159.0	152.7	E
14311	105.2	121.6	B	14370	159.0	166.4	F	14422	155.8	162.1	F
14312	114.8	130.8	C	14371	166.8	152.7	F	14423	149.6	162.1	F
14313	125.5	132.2	E	14372	179.5	187.0	F	14424	153.4	162.7	D
14314	120.0	143.4	C	14373	172.1	164.6	F	14425	168.3	159.0	F
14315	112.1	133.5	C	14374	176.1	155.8	F	14426	155.8	146.5	F
14316	115.3	146.5	B	14375	164.6	168.3	F	14427	160.8	166.4	E
14319	125.5	136.2	D	14376	175.8	183.3	E	14428	144.9	155.8	F
14320	121.5	136.2	D	14377	172.1	162.7	F	14429	144.9	152.7	E
14321	114.5	120.4	C	14378	169.9	143.4	E	14430	157.1	164.6	E
14322	112.2	137.1	C	14379	160.8	160.8	F	14431	140.2	133.5	B
14323	130.9	143.4	D	14380	179.5	179.5	F	14432	154.3	155.8	F
14324	109.5	128.2	E	14381	166.4	179.5	E	14433	138.7	152.7	F
14325	113.8	143.4	D	14382	175.8	173.9	F	14434	145.9	170.2	D
14327	127.8	144.9	D	14383	187.0	173.9	F	14435	162.1	152.7	F
14328	134.0	137.1	E	14384	179.5	170.2	F	14436	141.8	157.4	E
14329	106.8	126.8	A	14386	173.9	164.6	F	14437	138.7	143.4	D
14330	98.2	109.9	B	14387	173.9	159.0	F	14439	159.0	154.3	E
14333	93.5	112.2	B	14388	172.1	164.6	F	14440	151.2	155.8	E
14334	94.7	109.9	B	14389	179.2	155.8	F	14441	149.6	144.9	E
14335	112.1	128.2	B	14390	181.4	177.7	F	14442	162.1	157.4	E
14336	127.8	152.7	D	14391	172.1	179.5	F	14443	162.1	152.7	F
14337	114.8	130.8	D	14392	172.1	170.2	F	14444	148.1	148.1	F
14338	132.5	137.1	C	14393	188.9	166.4	F	14446	159.0	160.8	E
14339	113.5	128.2	B	14394	179.5	172.1	F	14447	159.0	159.0	E
14340	181.4	164.6	F	14395	162.7	172.1	E				

A small smooth-walled phase
B small phase, rudimentary ornament
C intermediate phase, weakly-ridged ornament
D intermediate phase, cancellate-ridged ornament
E large ornate phase, cancellate-ridged ornament
F large ornate phase, flat/concave aboral surface

Study 5

A magnetostratigraphically constrained chronology for late Miocene bolboforms and planktic foraminifers in the temperate Southwest Pacific

A magnetostratigraphically-constrained chronology for late Miocene bolboforms and planktic foraminifers in the temperate Southwest Pacific

ABSTRACT: High-resolution bolboform and planktic foraminiferal distribution data from the late Miocene section of ODP Site 1123, Chatham Rise, New Zealand, have been integrated with the magnetostratigraphic record from the same site to establish a magnetobiochronology based on the geomagnetic polarity time scale (GPTS-95). Although the late Miocene sequence is adversely affected by dissolution, 33 bioevents are identified based on dissolution resistant taxa that are also found at DSDP Site 593 – an important biostratigraphic reference section for the Neogene in the Tasman Sea. A scatter-plot based on the stratigraphic positions of shared bioevents at the oceanic sites approximates a linear line of correlation. The tight grouping of the biostratigraphic data around the line of correlation, and the consistency of their stratigraphic order, suggest most events are synchronous or near-synchronous, even though the sites are more than 1500 km apart and associated with different water masses. This implies that even though the biostratigraphic construct is based on only two oceanic sites, it provides a robust late Miocene biochronostratigraphic framework for the temperate Southwest Pacific.

Shared bolboform events include the appearances and disappearances of *B. subfragoris* s.l. (11.56-10.61 Ma), *Bolboforma* sp. H (10.46-10.31 Ma), *B. capsula* (10.20-10.13 Ma), *B. pentaspinosa* (10.15-10.08 Ma), *B. gracilireticulata* s.l. (9.75-9.61 Ma), *B. metzmacheri* s.s. (lower subzone 9.54-9.34 Ma, upper subzone 9.01-8.78 Ma), *B. metzmacheri ornata* (8.45-8.28 Ma), *B. praeintermedia* (8.25-8.21 Ma), and abundance spikes associated with the uppermost *B. subfragoris* s.l. subzone (10.61 Ma) and the lower *B. metzmacheri* s.s. subzone (9.54 Ma). Shared planktic foraminiferal events include dextral-coiling excursions in *Globoconella miotumida* (10.93-10.82 Ma and 9.62-9.42 Ma), the regional disappearance of *Globoquadrina dehiscens* (8.88 Ma), and the evolutionary appearances of *Globoconella conomiozea* (c. 6.87 Ma), *Globoconella mons* (c. 5.72 Ma), *Globoconella sphericomiozea* (c. 5.53 Ma), *Globoconella pliozea* (c. 5.39 Ma), *Truncorotalia crassaformis* (c. 5.15 Ma), and *Globoconella puncticulata* (c. 5.11 Ma).

Keywords: late Miocene; biostratigraphy; biochronology; *Bolboforma*; planktic foraminifers; ODP Site 1123; DSDP Site 593; New Zealand; temperate Southwest Pacific.

INTRODUCTION

High quality age models for deep-sea sections are a key component in the correlation and synthesis of global data sets for the study of oceanographic processes. The establishment of a robust biochronostratigraphic framework for marine microfossils is complex and often involves several correlation steps – the most important being the correlation between biostratigraphic events and the global polarity time scale (GPTS). Although microfossil events have been calibrated to the GPTS in different parts of the world (e.g. Hodell & Kennett 1986; Chaisson & Leckie 1993; Sprovieri et al. 1996), no reliable late Miocene biochronostratigraphic framework exists for the temperate Southwest Pacific. Presently, chronologies in this region are based on a small number of tenuous paleontological, magnetostratigraphic, and stable isotope correlations with dated horizons or interpolated horizons from uplifted marine sections on land in New Zealand (e.g. Kennett & Vella 1975; Wright et al. 1985; Edwards 1987; Roberts et al. 1994), and from outside of the region (e.g. Lazarus et al. 1995; Spencer-Cervato 1999). Because these data are not always interpreted consistency by different operators, and biostratigraphic events are often diachronous across major water mass boundaries (Spencer-Cervato et al. 1994), there is a need to establish a more reliable, highly refined regional biochronostratigraphic framework in order to gain a better perspective of oceanographic and climatic changes in southern mid-latitudes. This is particularly important in the late Miocene where there is a paucity of reported events suitable for biostratigraphic correlation.

Ocean Drilling Program (ODP) Site 1123, Chatham Rise, New Zealand, allows for the first time the development of a high quality magnetostratigraphically constrained late Miocene magnetobiochronology in the temperate Southwest Pacific. Late Miocene calcareous microfossil assemblages at the site have been variably affected by differential dissolution, but dissolution-resistant bolboforms and planktic foraminifers are sufficiently well represented to establish a sequence of bioevents that can be correlated with Deep Sea Drilling Project (DSDP) Site 593, an important regional biostratigraphic reference section for the Neogene in the Tasman Sea (Jenkins & Srinivasan 1986; Lohmann 1986; Hoskins 1990; Scott 1992; Grützmacher 1993) (Figure 5.1). The primary aim of this paper is to establish a regional magnetobiochronology for these data based on bioevents at Site 1123 and the geomagnetic polarity time scale GPTS-95 (Berggren et al. 1995; Cande & Kent 1992, 1995).

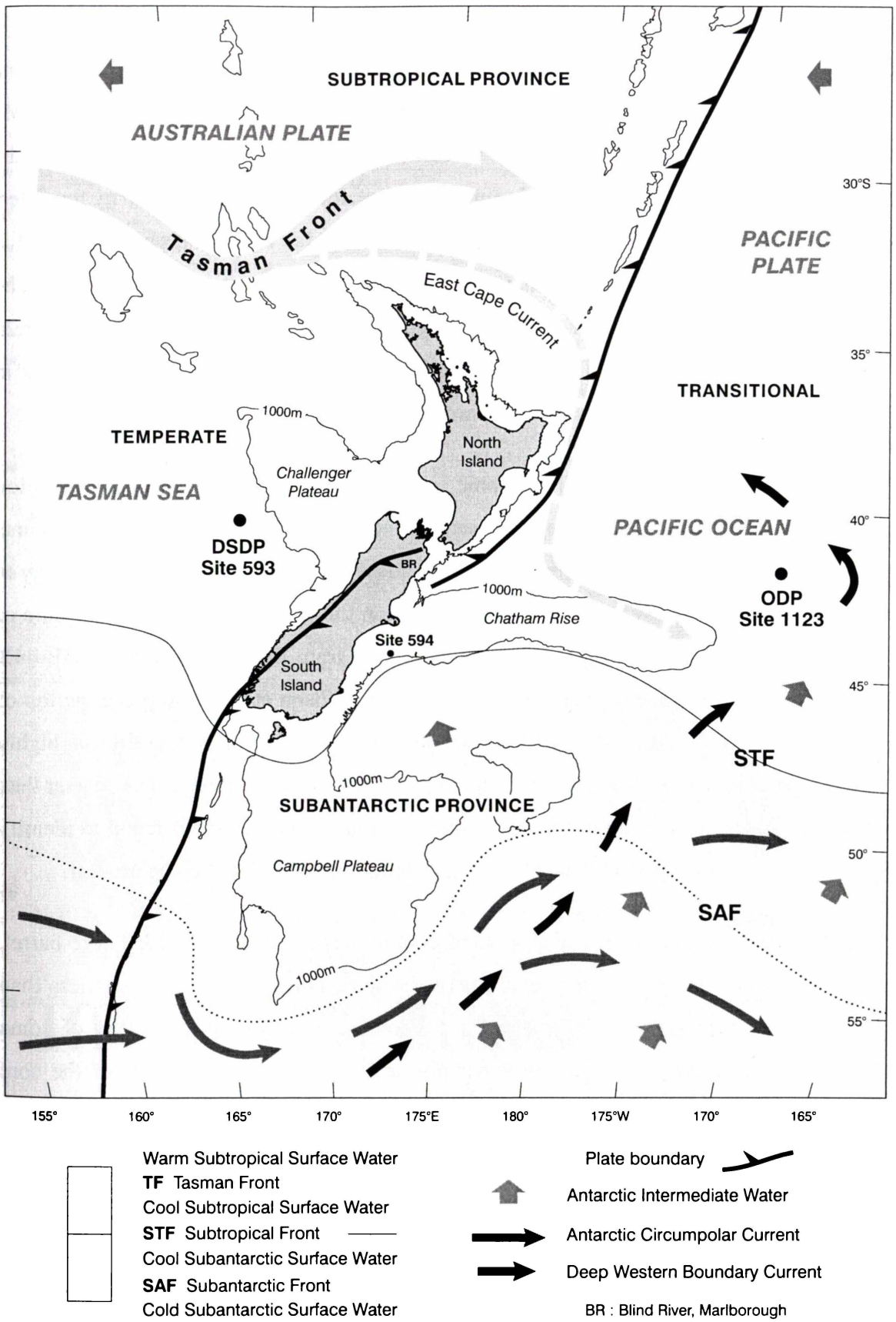


Figure 5.1 – Bathymetric map of the New Zealand subcontinental region (1000 m contour), Tasman Sea, and Southwest Pacific Ocean, showing the location of ODP and DSDP sites, the positions of major fronts at the ocean surface (summer situation), and the flow of Antarctic Intermediate Water, Antarctic Circumpolar, and Pacific Deep Western Boundary currents (Shipboard Scientific Party 1999a). Biogeographic provinces follow Kennett & Srinivasan (1983).

Material and methods

ODP Site 1123 was noted in the Initial Reports of Leg 181 to have a virtually complete Neogene magnetostratigraphic record that extends back to Chron C6r – c. 20 Ma (Shipboard Scientific Party 1999b). However, a subsequent review of the magnetostratigraphy by Wilson et al. (in prep.) has identified an interval in the latest Miocene between Chron C3Br.2n to C3n.1n (7.34-4.29 Ma) where the polarity record is ambiguous – it encompasses the upper part of the studied section (Figure 5.2). The magnetostratigraphy of the older part of the section, between Chron C5An.1r to C3Br.2n (12.18-7.34 Ma) has a virtually complete polarity record, but there is a suspected break in the sequence of less than 100 k.y. within Chron C4Ar.2r (Wilson et al. in prep.).

The resolution of shipboard biostratigraphic sampling was adequate for the interpretation of the paleomagnetic record, although the sample interval (c. 190-320 k.y.) was too coarse to identify or define short-lived bioevents and to allow a reliable biomagnetochronology to be established. To improve biostratigraphic resolution through the late Miocene, a suite of 353 micropaleontological samples has been examined from the base of core 1123B-44X (427.40 r-mcd; revised metres composite depth, *sensu* Wilson et al. in prep.) to the top of core 1123B-18X (170.20 r-mcd). All samples are fossiliferous, but preservation is highly variable. The adopted sample spacing c. 75 cm (c. 22 k.y.) is about three times coarser than the biostratigraphic resolution of Site 593 (Study 3), but is considered sufficient to identify most short-lived bolboform and planktic foraminiferal events should they be present.

The interval reported in this study was cored continuously with the extended core barrel, but there are potential gaps in the record between some cores where there was less than 100% recovery (Table 5.1). This places a cautionary caveat on the location of some bioevents in the cored succession, although physical property measurements of the core and downhole logging (Shipboard Scientific Party 1999b) suggest much of the variability in core recovery was probably caused by core deformation during coring and retrieval operations.

All paleontological data from the site relate to ODP Hole 1123B and depths are reported in revised metres composite depth (r-mcd). Depth translations from metres below seafloor (mbsf) to r-mcd are based on core splice data from Wilson et al. (in prep.) and linear transforms given in Table 5.1. Biostratigraphic events are reported in the text in terms of the sample in which they are found, but magnetostratigraphic and chronostratigraphic

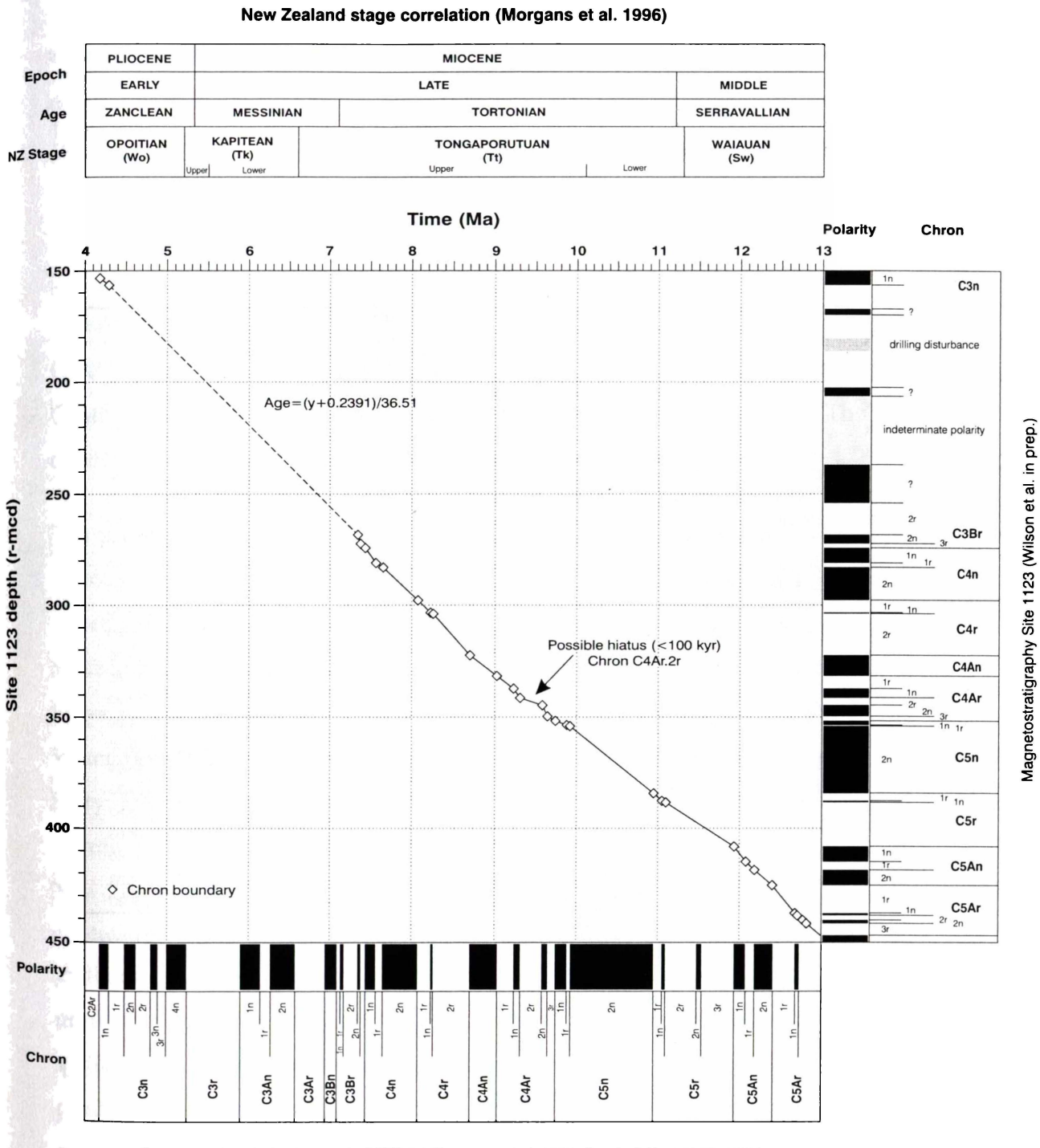


Figure 5.2 – ODP Site 1123 magnetostratigraphic record. Cross-plot of magnetostratigraphic data from Site 1123 and the geomagnetic polarity time scale (GPTS-95), the basis of the sites chronology. The older part of the magnetostratigraphic sequence is virtually complete, but there is the possibility of a short hiatus within Chron C4Ar.2r. The younger part of the magnetostratigraphic sequence from the top of Chron C3Br.2r to the base of C3n.1n is poorly constrained. All ages for this interval have been interpolated (dashed line).

assignments are based on horizons between the sample with the named event and the closest constraining sample (i.e. interpolated depth).

Table 5.1 – Coring summary and core splice data, Hole 1123B-18X to 44X. Core deformation during the coring and retrieval operation accounts for most of the variability in core recovery (average recovery 97.5%) (Shipboard Scientific Party 1999b). For cores 23X, 26X, and 41X-44X that have less than 90% recovery this table gives a slope (m) and intercept (b) for a linear transformation from reported mbsf to stretched mbsf. Stretched mbsf = (m x mbsf) + b. To subsequently translate a sample to stretched r-mcd, add the offset in the last column of this table. For the other cores listed in this table, to translate a sample from mbsf to r-mcd, just add the offset.

Hole	Core	Top (mbsf)	Bottom (mbsf)	Recovered core (m)	Section drilled	Recoverey (%)	Slope (*m*)	Intercept (*b*)	Offset (*M*)
1123-B	18X	155.40	163.79	8.39	7.30	114.9			14.80
1123-B	19X	162.70	172.41	9.71	9.50	102.2			14.80
1123-B	20X	172.30	182.05	9.75	9.50	102.6			14.80
1123-B	21X	181.90	191.37	9.47	9.50	99.7			14.80
1123-B	22X	191.60	201.47	9.87	9.50	103.9			14.80
1123-B	23X	201.20	208.96	7.76	9.50	81.7	1.2703	-54.40	14.80
1123-B	24X	210.80	220.55	9.75	9.50	102.6			14.80
1123-B	25X	220.40	230.10	9.70	9.50	102.1			14.80
1123-B	26X	230.00	234.18	4.18	9.50	44.0	2.500	-345.06	14.80
1123-B	27X	239.60	249.42	9.82	9.50	103.4			14.80
1123-B	28X	249.20	258.79	9.82	9.50	103.4			14.80
1123-B	29X	258.80	268.59	9.79	9.50	103.1			14.80
1123-B	30X	268.40	278.05	9.65	9.50	101.6			14.80
1123-B	31X	278.10	287.59	9.49	9.50	99.9			14.80
1123-B	32X	287.70	296.41	8.71	9.50	91.7			14.80
1123-B	33X	297.30	306.95	9.65	9.50	101.6			14.80
1123-B	34X	306.90	316.68	9.78	9.50	102.9			14.80
1123-B	35X	316.50	326.12	9.62	9.50	101.3			14.80
1123-B	36X	325.90	335.57	9.67	9.50	101.8			14.80
1123-B	37X	335.50	345.30	9.80	9.50	103.2			14.80
1123-B	38X	345.10	354.89	9.79	9.50	103.1			14.80
1123-B	39X	354.70	364.58	9.88	9.50	104.0			14.80
1123-B	40X	364.40	374.16	9.76	9.50	102.7			14.80
1123-B	41X	374.10	382.30	8.20	9.50	86.3	1.2703	-101.13	14.80
1123-B	42X	383.70	388.54	4.84	9.50	50.9	2.1364	-436.08	14.80
1123-B	43X	393.40	399.62	6.22	9.50	65.5	1.5932	-233.39	14.80
1123-B	44X	403.00	408.42	5.42	9.50	57.1	1.8725	-351.65	14.80

Distribution (presence/absence) data were initially compiled for all planktic foraminifers from systematic scans of the >150 μm fractions. No foraminifers were removed from samples, but all bolboforms were picked and mounted onto two-hole slides to allow identifications to be checked before bolboform census data were compiled. The bolboform data were then supplemented with total bolboform picks from the >125 μm fraction to provide more detailed census information. Planktic-benthic foraminiferal ratios and coiling data for *Globoconella miotumida* and *Gc. conomiozea* were also compiled, based wherever possible on counts of at least 100 specimens in the >150 μm fraction. All fossil materials from this study – washed residues, mounted slides, and figured specimens – are lodged in the collections of the DSDP/ODP Micropaleontological Reference Centre at Geological and Nuclear Sciences, Lower Hutt, New Zealand.

The adopted bolboform taxonomy is based on Spiegler & Daniels (1991), Grützmacher (1993), and Spiegler (1999). To a great extent, the higher taxonomy of planktic foraminifers follows Kennett & Srinivasan (1983), except that the genus/subgenus ranking of each phylogenetic group is raised to the level of a genus (e.g. *Globorotalia* (*Globoconella*) = *Globoconella*). Adopted species concepts are largely based on Hornibrook (1982), Hornibrook et al. (1989), and Scott et al. (1990). The type references of bolboform and planktic foraminiferal species identified at Site 1123 are listed in Appendix 5.1 and an explanation of bioevents is given in Appendix 5.2.

Oceanographic setting

ODP Site 1123 is located at 42°47.147'S, 171°29.941'W on the northeastern slope of the Chatham Rise, about 1000 km east of central New Zealand (Figure 5.1). The site lies at a depth of 3290 m and it is about 500 km north of the Subtropical Front.

The present-day pattern of oceanic circulation in the Southwest Pacific and Tasman Sea regions (Figure 5.1) is strongly influenced by the New Zealand subcontinent and the easterly-directed flow of southern mid-latitude water masses. Presently, warm Subtropical Surface Water associated with the East Cape Current – an offshoot of the Tasman Front – flows south-eastwards across Site 1123, while cooler oxygen-rich Antarctic Intermediate Water flows northwards at depths of 600 to 1450 m (Wyrtki 1962; Shipboard Scientific Party 1999a). Circumpolar Deep Water associated with the Deep Western Boundary Current also flows northwards across the site, along the eastern submerged margin of the New Zealand subcontinent, below 1450 m (Shipboard Scientific Party 1999a). A seasonal northwards-directed flow of Subantarctic Mode Water also flows across the site during winter months, at depths of 150-450 m (Wyrtki 1962; Thompson & Edwards 1981).

Although seafloor spreading between Australia and Antarctica has shifted the western side of the New Zealand subcontinent (including Site 593) northwards by at least 5° of latitude since the beginning of the late Miocene (Weissel at al. 1977; Sutherland 1995), and there has been significant Neogene deformation of the New Zealand continent along the Alpine Fault (Sutherland 1995), the present-day pattern of oceanic circulation in the region has remained substantially unchanged since the beginning of the late Miocene (Edwards 1975; Nelson & Cooke 2001).

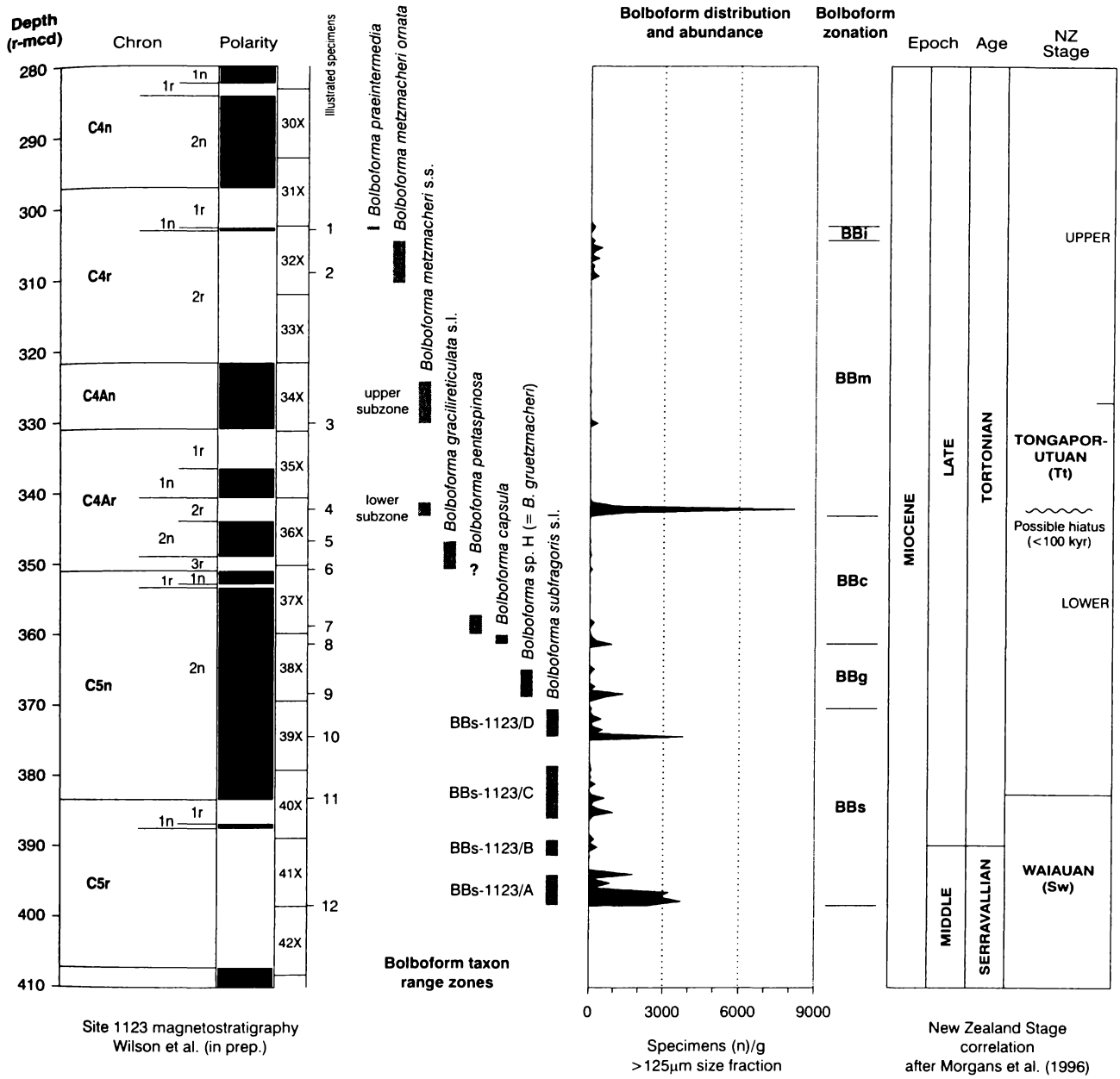
BIOSTRATIGRAPHY AND BIOCHRONOLOGY

Bolboform events

Bolboforms are important index fossils and supplement calcareous nannofossil and planktic foraminiferal zonations in mid- to high-latitude regions of Europe and the Atlantic and southern Indian oceans (Spiegler & Daniels 1991; Spiegler & Müller 1992). Their high resistance to dissolution makes them particularly important for the correlation of oceanic sequences affected by calcite dissolution (Müller et al. 1985). The discovery of bolboforms in late Miocene oceanic sequences of the Southwest Pacific and Tasman Sea regions (Poag & Karowe 1986; Grützmacher 1993) and in uplifted marine sequences in New Zealand (Crundwell et al. 1997a) offers considerable scope for improving biostratigraphic resolution and global correlations in this region. The most studied bolboform sequence in this region is at DSDP Site 593, where there is a well-defined succession of short-lived appearances and disappearances of monospecific bolboform populations, with peak abundances sometimes reaching several thousand specimens per gram of sediment (Grützmacher 1993; Crundwell et al. 1997a). Bolboforms have also been noted at other oceanic sites in the Southwest Pacific and Tasman Sea regions – DSDP Sites 594 (46° S), 592 (36° S), and 590B (31° S) – but their abundance and diversity generally decreases at lower latitudes (Grützmacher 1993).

Bolboforms are reported to be rare in the Initial Reports of ODP Site 1123 (Shipboard Scientific Party 1999b), but the present study identifies a well defined sequence of short-lived appearances and disappearances of monospecific bolboform populations between cores 1123B-41X and 32X. Bolboforms are moderately well preserved, even in samples where planktic foraminifers are severely affected by dissolution. The predominantly early late Miocene bolboform succession spans about 3.4 million years and it is very similar to the succession at DSDP Site 593. It includes at least 18 well defined events – lowest and highest occurrences, and distinctive abundance spikes (Figure 5.3). The persistence of monospecific populations is relatively high (60-100%) and the disappearance of each species is usually followed by an interval of about 30-330 k.y. where there are no bolboforms. The taxon-range zones of most species are well defined, although infill samples may extend the ranges of some species, particularly where specimen numbers are low.

The distribution and abundance of bolboforms are shown in Figure 5.3 and species are illustrated in Figure 5.4. All biostratigraphic data have been integrated with the emended



Species	Depth (r-mcd)	Max abundance	Species	Depth (r-mcd)	Max abundance
Bolboforma praeintermedia	302.50 - 303.00	171	*Bolboforma capsula*	360.00 - 361.40	918
Bolboforma metzmacheri ornata	304.50 - 310.50	480	*Bolboforma* sp. H	364.90 - 368.90	1385
Bolboforma metzmacheri s.s.			*Bolboforma subfragoris* s.l.		
– upper subzone	324.20 - 330.20	310	– D (upper subzone)	370.50 - 374.50	3791
– lower subzone	341.30 - 343.30	8189	– C (small cyst-like phases)	378.50 - 386.20	978
Bolboforma gracilireticulata s.l.	346.80 - 350.80	109	– B (small cyst-like phases)	389.02 - 391.43	341
Bolboforma pentaspinosa	358.30 - 360.00	188	– A (lower subzone)	393.97 - 398.42	2836

Figure 5.3 – Bolboform distribution and abundance at ODP Site 1123 (data are given in Appendix 5.2). The numbered horizons of illustrated specimens (1–12) correspond to Figure 5.4. Max abundance = specimens (n) /g in the >125 μm sediment size fraction. Bolboform zonation based on Spiegler & Daniels (1991), Grützmacher (1993), and Study 3. BBi = *Bolboforma intermedia* Zone, BBm = *B. metzmacheri* Zone, BBc = *B. capsula* Zone, BBg = *B. gruetzmacheri* Zone (Study 3), BBs = *B. subfragoris* s.l. Zone.

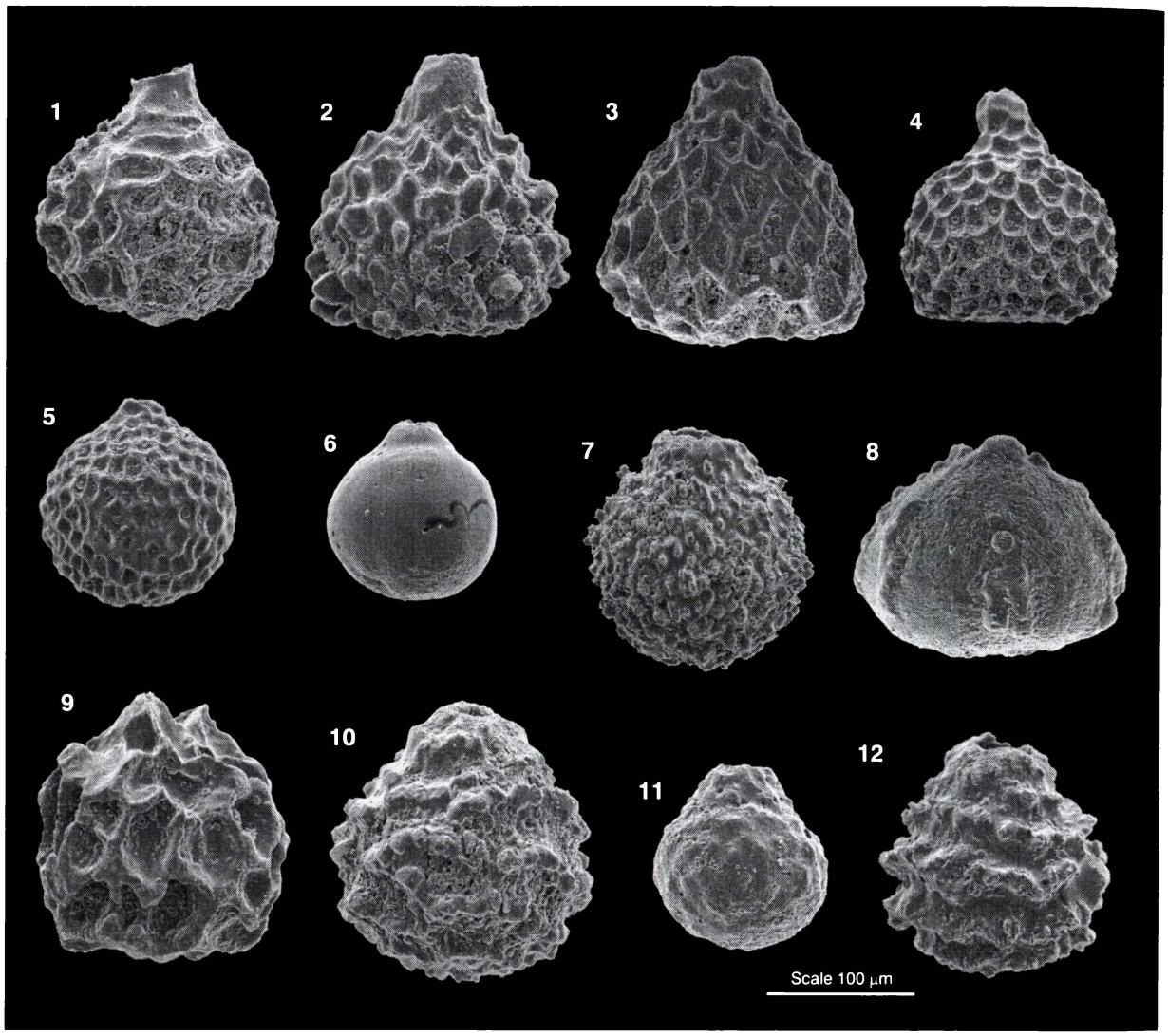


Figure 5.4 – SEM photomicrographs of bolboforms from the interval 123B-41X to 31X. All images are shown to the same scale.

1. *Bolboforma praeintermedia*; 1123B-32X-1, 50-55 cm
2. *Bolboforma metzmacheri ornata*; 1123B-32X-5, 50-55 cm
3. *Bolboforma metzmacheri* s.s. upper subzone; 1123B-34X-6, 100-105 cm
4. *Bolboforma metzmacheri* s.s. lower subzone; 1123B-36X-2, 10-14 cm
5. *Bolboforma gracilireticulata* s.s.; 1123B-36X-5, 10-14 cm
6. *Bolboforma gracilireticulata* s.l.; 1123B-37X-1, 50-54 cm
7. *Bolboforma pentaspinosa*; 1123B-37X-6, 100-104 cm
8. *Bolboforma capsula*; 1123B-38X-2, 0-4 cm
9. *Bolboforma* sp. H of Grützmacher (1993); 1123B-38X-6, 100-104 cm
10. *Bolboforma subfragoris* s.l. (BBs-1123/D subzone); 1123B-39X-4, 50-53 cm
11. Small smooth-walled phase *B. subfragoris* s.l. (BBs-1123/C subzone); 1123B-40X-3, 100-103 cm
12. *Bolboforma subfragoris* s.l. (BBs-1123/A subzone); 1123B-41-6, 0-5 cm

magnetostratigraphy of ODP Site 1123 (Wilson et al. in prep.) and ages have been assigned to lowest and highest occurrences and prominent abundance spikes based on interpolations of GPTS-95 Chron ages from Cande & Kent (1995). These data are shown in Appendix 5.3.

***Bolboforma subfragoris* s.l. taxon-range zone (11.56-10.50 Ma):** In the context of this account, *B. subfragoris* s.l. encompasses several morphologically related spirospinose species, subspecies and morphotypes. The taxon-range zone of *B. subfragoris* s.l. (BBs-Zone) includes four subzones that are separated by intervals without bolboforms – in ascending order, they are referred to as subzones BBs-1123/A to BBs-1123/D. Subzones BBs-1123/A and BBS-1123/D) include highly serrated spiral-flanged specimens (Figure 5.4/12 and 5.4/10) that closely resemble spirospinose forms of *B. subfragoris* from Site 593 (Grützmacher 1993), and those near the middle of the BBs-Zone (subzones BBs-1123/B and BBs-1123/C) include small cyst-like phases with weak nodular surface ornament (Figure 5.4/11).

The lowest occurrence of *B. subfragoris* s.l. is at the base of the BBs-1123/A subzone in sample 1123B-41X-6, 0-5 cm. This is close to the base of core 1123B-41X, which has only 86.3% of core recovery, although downhole logs and shipboard measurements of physical core properties suggest the core is relatively complete and that the datum is reliably located. The lowest occurrence datum is 14 m below the base of the *Gc*-1123/A coiling zone – a distinctive interval of dextrally-coiled *Globoconella miotumida* (Figure 5.6), which is correlated with the base of the Tongaporutuan Stage (Study 7). It occurs in Chron C5r.2r(0.55) and has an interpolated magnetochronologic age of 11.56 Ma.

The highest occurrence of *B. subfragoris* s.l. occurs at the top of the BBs-1123/D subzone. Immediately prior to its disappearance in sample 1123B-39X-1, 100-104 cm, it occurs in nine consecutive samples. Monospecific populations of the succeeding species *Bolboforma* sp. H first appear 1.6 m (c. 60 k.y.) higher in the core. The highest occurrence of *B. subfragoris* s.l., which marks the top of the *B. subfragoris* s.l. taxon-range zone, occurs in Chron C5n.2n(0.56) and it has an interpolated magnetochronologic age of 10.50 Ma.

The base of subzone 1123-D, the uppermost subzone of the *B. subfragoris* s.l. taxon-range zone, is marked by a prominent abundance spike in sample 1123B-39X-4, 50-53 cm where abundances in the >125 μm sediment size fraction peak at about 3800 specimens per gram.

The abundance spike occurs above the *Gc*-1123/A coiling zone in Chron C5n.2n(0.71) and it has an interpolated magnetochronologic age of 10.61 Ma.

***Bolboforma* sp. H taxon-range zone (10.46-10.31 Ma):** *Bolboforma* sp. H (= *B. gruetzmacheri* Studies 3, 4, 6, and 7) has previously been described by Grützmacher (1993) at oceanic sites in the Southwest Pacific. It is a very distinctive bolboform ornamented with irregular, widely spaced blind and interconnected blade-like ridges (Figure 5.4/9). At Site 1123 it has a very short stratigraphic range zone that extends from 1123B-38X-7, 0-4 cm to 1123B-38X-4, 50-54 cm. It is a persistent species that occurs in eight out of nine samples. It is most common near the base of its range, where abundances in the >125 µm sediment size fraction peak at 1385 specimens per gram. Very low abundances in the upper part of the species taxon-range zone diminish the reliability of its highest occurrence, although monospecific populations of the succeeding species, *Bolboforma capsula,* first appear 3.5 m (c. 120 k.y.) higher in the core. The taxon-range zone of *Bolboforma* sp. H extends from Chron C5n.2n(0.53) to C5n.2n(0.38) and it has an interpolated magnetochronologic age of 10.46-10.31 Ma.

***Bolboforma capsula* taxon-range zone (10.20-10.13 Ma):** *B. capsula* is another very distinctive species with a moderately smooth, bell-like, axially corrugate and tuberculate, encapsulated test (Figure 5.4/8). It is confined to four consecutive samples inclusive of 1123B-38X-2, 0-4 cm and 1123B-38X-1, 10-14 cm. Specimen numbers, however, are very low and there is uncertainty regarding the reliability of its lowest and highest occurrences. The *B. capsula* taxon-range zone extends from Chron C5n.2n(0.27) to C5n.2n(0.21) and it has an interpolated magnetochronologic age of 10.20-10.13 Ma.

The top of the *B. capsula* taxon-range zone overlaps with the base of the *B. pentaspinosa* taxon-range zone (Figure 5.3). It is the only such overlap noted at Site 1123 between bolboform species. Although this suggests there may have been contemporary bolboform populations in the vicinity of Site 1123, for a short period at least, the overlap is an unusual feature of the bolboform distribution and other sedimentary factors, such as bioturbation and reworking may have been involved.

***Bolboforma pentaspinosa* taxon-range zone (10.15-10.08 Ma):** *B. pentaspinosa* is distinguished from other highly spinose bolboform species by its small subspherical shell

and low collar-like apertural neck (Figure 5.4/7). It is confined to a short interval between samples 1123B-38X-1, 10-14 cm and 1123B-37X-6, 50-54 cm. The base of *B. pentaspinosa* taxon-range zone overlaps with the top of the *B. capsula* taxon-range zone. It extends from Chron C5n.2n(0.22) to C5n.2n(0.16) and has an interpolated magnetochronologic age of 10.15-10.08 Ma.

A specimen of *B. pentaspinosa* has also been noted higher in the section, in sample 1123B-37X-2, 0-4 cm, but it is an isolated occurrence and it is thought to be either reworked or a contaminant. Rare specimens of *B. pentaspinosa* were also noted in the Initial Reports of Site 1123, in samples 1123B-27X CC, 30X CC and 32X CC (Shipboard Scientific Party 1999b), but a re-examination of shipboard samples failed to confirm these occurrences.

***Bolboforma gracilireticulata* s.l. taxon range zone (9.75-9.61 Ma):** In the context of this account, *B. gracilireticulata* s.l. encompasses an intergrade of small finely sculptured cancellate forms (*B. gracilireticulata* s.s.) and smooth-walled phases that have previously been identified as bolboform cysts (e.g. Grützmacher 1993) or *B. laevis* (Figures 5.4/5 and 5.4/6). *Bolboforma gracilireticulata* s.l. is a relatively uncommon taxon that occurs in six out of nine samples between 1123B-37X-1, 50-54 cm and 1123B-36X-5, 10-14 cm. The lower part of the species stratigraphic range consists almost entirely of smooth-walled phases, and the upper part includes subequal numbers of *B. gracilireticulata* s.s. and small smooth-walled phases. The *B. gracilireticulata* s.l. taxon-range zone extends from the base of Chron C4Ar.3r to Chron C4Ar.2n(0.51) and has an interpolated magnetochronologic age of 9.75-9.61 Ma.

***Bolboforma metzmacheri* s.s. taxon-range zone (9.54-8.78 Ma):** *B. metzmacheri* s.s is ornamented with a coarsely cancellate-ridged sculpture. It superficially resembles the benthic foraminifer *Oolina hexagona*, but is distinguished by its flattened aboral surface and the more irregular pattern of its surface ornament (Figure 5.4/4). The taxon-range zone of *B. metzmacheri* s.s includes subzones in its lower and upper parts that are separated by an extended interval where there are no bolboforms. The lower subzone extends from 1123-36X-2, 110-114 cm to 1123-36X-1, 60-64 cm, and the upper subzone extends from 1123-34X-6, 100-105 cm to 1123-34X-2, 100-105 cm.

The base of the lower *B. metzmacheri* s.s. subzone occurs 2.5 m above the top of the *Gc*-1123/B coiling zone (Figure 5.6; see later discussion). This well defined subzone extends

from C4Ar.2r(0.86) to C4Ar.2r(0.11) and has an interpolated magnetochronologic age of 9.54-9.34 Ma. It includes a prominent abundance spike in sample 1123-36X-2, 10-14 cm where specimen numbers in the >125 μm sediment size fraction peak at about 8200 specimens per gram (Figure 5.3). The spike in abundance, which is the largest such spike noted at Site 1123, coincides with a possible hiatus of <100 k.y. within Chron C4Ar.2r (Wilson et al. in prep.) (Figure 5.2). It has an interpolated magnetochronologic age of 9.44 Ma, but the hiatus places a cautionary caveat on the reliability of the age.

The base of the upper *B. metzmacheri* s.s. subzone coincides with the entry of moderate numbers of bolboforms and is well defined, but bolboform numbers decrease in the upper part of the subzone and occurrences are intermittent (Appendix 5.3). The upper *B. metzmacheri* s.s. subzone extends from C4An(0.94) to C4An(0.25) and has an interpolated magnetochronologic age of 9.01-8.78 Ma. The regional disappearance of the planktic foraminifer *Globoquadrina dehiscens* occurs near the middle of the upper *B. metzmacheri* s.s. subzone.

***Bolboforma metzmacheri ornata* taxon-range zone (8.45-8.28 Ma):** *B. metzmacheri ornata* is distinguished from *B. metzmacheri* s.s. by the presence of short aborally-pointing spines at the junctions of the cancellate-ridged ornament (Figure 5.4/2). It first appears in sample 1123-32X-6, 50-55 cm and its stratigraphic range extends upward to 1123-32X-2, 50-55 cm. *B. metzmacheri ornata* is a relatively common and persistent species that occurs in 12 out of 13 samples that span the species range zone (Appendix 3). Its lowest occurrence is close to the base of core 1123-32X, for which there was only 91.7% recovery, but downhole logs and shipboard logs of physical parameters suggest the core is relatively complete and the datum is reliably located. The *B. metzmacheri ornata* taxon-range zone extends from Chron C4r.2r(0.44) to C4r.2r(0.06) and has an interpolated magnetochronologic age of 8.45 to 8.28 Ma.

***Bolboforma praeintermedia* taxon-range zone (8.25-8.21 Ma):** The irregular spiro-concentric ridged ornament of *B. praeintermedia* (Figure 5.4/1) represents a marked morphological change from the cancellate ornament of *B. metzmacheri* species that precede it. It superficially resembles *Bolboforma* sp. H, but the ridged-ornament tends to be more evenly spaced and better interconnected. At Site 1123, it is confined to a very short interval that extends over three consecutive samples, from 1123B-32X-1, 50-55 cm

to 1123-31X-7, 0-5 cm. The *B. praeintermedia* taxon-range zone extends from the base of Chron C4n.1n to C4n.1r(0.81) and it has an interpolated magnetochronologic age of 8.25-8.21 Ma.

The entry of *B. praeintermedia* marks the base of the *B. intermedia* Zone (Spiegler & Daniels 1991) and its disappearance represents the regional extinction of bolboforms in the Southwest Pacific (Grützmacher 1993).

Bolboform zonation and correlation

Despite the taxonomic confusion and uncertainty surrounding this enigmatic group of calcareous microfossils (Poag & Karowe 1986), bolboform assemblages from Site 1123 and other oceanic sites in the temperate Southwest Pacific share many common species with assemblages in the North Atlantic (e.g. Spiegler & Daniels 1991; Spiegler 1999). The order of species appearances and disappearances and ages of important zonal events are also very similar (Table 5.2). This allows the North Atlantic bolboform zonation to be used with minimal modification in the Southwest Pacific (Grützmacher 1993). Although this suggests it may be possible to establish a global bolboform zonation, more detailed taxonomic and biostratigraphic studies are needed and it is unlikely that correlations would be comparable to highly refined local correlations.

Paleoceanographic implications of the bolboform record

The well defined sequence of short-lived appearances and disappearances of monospecific bolboform populations at Site 1123 is very similar to the sequence of appearances and disappearances at Site 593 (Table 5.3) – a much shallower oceanic site in the Tasman Sea (Figure 5.1). Although it is still only possible to speculate about the causes of these appearances and disappearances, the general increase in bolboform abundance and diversity that occurs between DSDP Sites 590 and 594 (Grützmacher 1993) favours their introduction from higher southern latitudes where it is presumed bolboform populations once lived. Because the inferred northward transport of bolboforms is orthogonal to the regional paleoceanographic pattern of surface-water circulation and oceanic fronts in the late Miocene (Edwards 1975; Nelson & Cooke 2001), it has been postulated that the bolboforms were entrained in the northward flow of subsurface water masses (Cooke et al. 2002). Furthermore, the presence of bolboforms at relatively shallow oceanic sites where the seafloor is bathed by Antarctic Intermediate Water (e.g. Sites 593 and 594) suggests the

distribution of bolboforms may have been coextensive with the distribution of this water mass. In this respect, the punctuated record of bolboform appearances and disappearances at Site 1123 – average duration 0.15 m.y. (Table 5.2) – may record periodic episodes of intensified Antarctic Intermediate Water flow.

Table 5.2 – Comparison of dated bolboform datums between Site 1123 and North Atlantic. North Atlantic bolboform datums have been dated from interpolations of second-order nannofossil and planktic foraminiferal correlations with GPTS-95 (Spiegler 1999). Bolboform zonation emended after Spiegler & Daniels (1991) and Grützmacher (1993) for use in the Southwest Pacific (Study 3). HO = highest occurrence, LO = lowest occurrence; IZ = Interval Zone, TRZ = Taxon-range Zone.

Event	Site 1123 (Ma)	subzone duration (myr)	Bolboform zonation	North Atlantic (Ma)
HO *Bolboforma praeintermedia*	8.21	0.03	*B. intermedia* IZ (BBi)	
LO *Bolboforma praeintermedia*	8.25			7.7
HO *Bolboforma metzmacheri ornata*	8.28	0.16		
LO *Bolboforma metzmacheri ornata*	8.44			
HO *Bolboforma metzmacheri* s.s. (top upper subzone)	8.78	0.23	*B. metzmacheri* TRZ (BBm)	
LO *Bolboforma metzmacheri* s.s. (base upper subzone)	9.01			
HO *Bolboforma metzmacheri* s.s. (top lower subzone)	9.34	0.20		
LO *Bolboforma metzmacheri* s.s. (base lower subzone)	9.54			9.7
HO *Bolboforma gracilireticulata* s.l.	9.61	0.14		
LO *Bolboforma gracilireticulata* s.l.	9.75			
HO *Bolboforma pentspinosa*	10.08	0.07		
HO *Bolboforma capsula*	10.13		*B. capsula* IZ (BBc)	
LO *Bolboforma pentaspinosa*	10.15	0.07		
LO Bolboforma capsula	10.20			
HO *Bolboforma* sp. H	10.31	0.15		
LO *Bolboforma* sp. H	10.46			
HO *Bolboforma subfragoris* s.l. (top subzone BBs-1123/D)	10.50	0.15		10.6
Base subzone BBs-1123/D	10.65			
Top subzone BBs-1123/C	10.77	0.27		
Base subzone BBs-1123/C	11.04		*B. subfragoris s.l.* TRZ (BBs)	
Top subzone BBs-1123/B	11.15	0.13		
Base subzone BBs-1123/B	11.28			
Top subzone BBs-1123/A	11.36	0.20		
LO *Bolboforma subfragoris* s.l. (base subzone BBs-1123/A)	11.56			11.7

The extinction of bolboforms in the Southwest Pacific occurs about 4 m.y. before their extinction in the North Atlantic and in the southern Indian Ocean – in the late early Pliocene, Zanclean Age (Spiegler & Daniels 1991; Mackensen & Spiegler 1992). The reason for the early extinction of bolboforms in the Southwest Pacific is not known, but it is presumably linked to changes in paleoceanographic circulation patterns in the Southwest Pacific. It is speculated, however, that the late Miocene restriction of the Indonesian Gateway (Gasperi & Kennett 1993) and subsidence of the Norfolk Ridge (Herzer et al. 1997) may have lead to the establishment of a regional counter-flow of intermediate water, similar to that of the present-day that interrupts the northward flow of AAIW in the Tasman Basin (Wyrtki 1962). The northward flow of AAIW is unlikely to have ceased completely, but a reduction in the intensity of the flow may have been sufficient to

interrupt the entrained supply of bolboforms in such a water mass (Cooke et al. 2002). Further studies of bolboform distribution patterns are clearly needed on regional and global scales.

Planktic foraminiferal events

The distribution of planktic foraminifers (presence/absence) is shown in Appendix 5.3. The biostratigraphic data have been integrated with the magnetostratigraphy of Site 1123 (Wilson et al. in prep.) and ages have been assigned to bioevents based on interpolations of GPTS-95 Chron ages from Cande & Kent (1995). Illustrations of key species and their ranges are shown in Figure 5.5 and other species are illustrated in Plates 5.1 and 5.2.

Planktic foraminifers are present throughout the late Miocene section of Site 1123, although their preservation and abundance is highly variable. The large number of fragmented and partially dissolved shells in many samples and the dominance of heavily encrusted morphotypes, particularly *Globoconella*, *Zeaglobigerina*, and *Neogloboquadrina*, suggest calcareous faunas were subject to strong differential dissolution. Faunas that have been severely affected by dissolution contain relatively sparse foraminiferal assemblages that are dominated by benthic species. This reduces potential biostratigraphic resolution and adversely affects the reliability of correlations with other oceanic sequences.

A dissolution proxy provided by the relative abundance of benthics in foraminiferal assemblages (e.g. Hooper et al. 1991; Parker & Berger 1971) suggests the seafloor at the site was periodically bathed by increased flows of corrosive bottom waters during the late Miocene (Figure 5.6). The dissolution signature shows high-amplitude oscillations during the late Miocene superimposed on c. 300-600 k.y. and c. 2.5-2.9 m.y. periodicities. The last major dissolution event occurs in core 1123B-20X (c. 5.3-5.1 Ma). Above this through to the top of the cored Plio-Pleistocene section assemblages are much less affected by dissolution (Hayward et al. in press). Short-term perturbations in dissolution are probably related to climatic variations in the flow of corrosive bottom waters, while perturbations that extend over longer periods are more likely to be associated with regional, and possibly global, changes in oceanic circulation patterns and the depth of the CCD. Changes in bathymetry associated with local tectonic uplift and subsidence may also affect dissolution, but benthic foraminifers provide no substantive evidence of significant bathymetric change at the site, at least not since the beginning of the late Miocene. Consequently, the

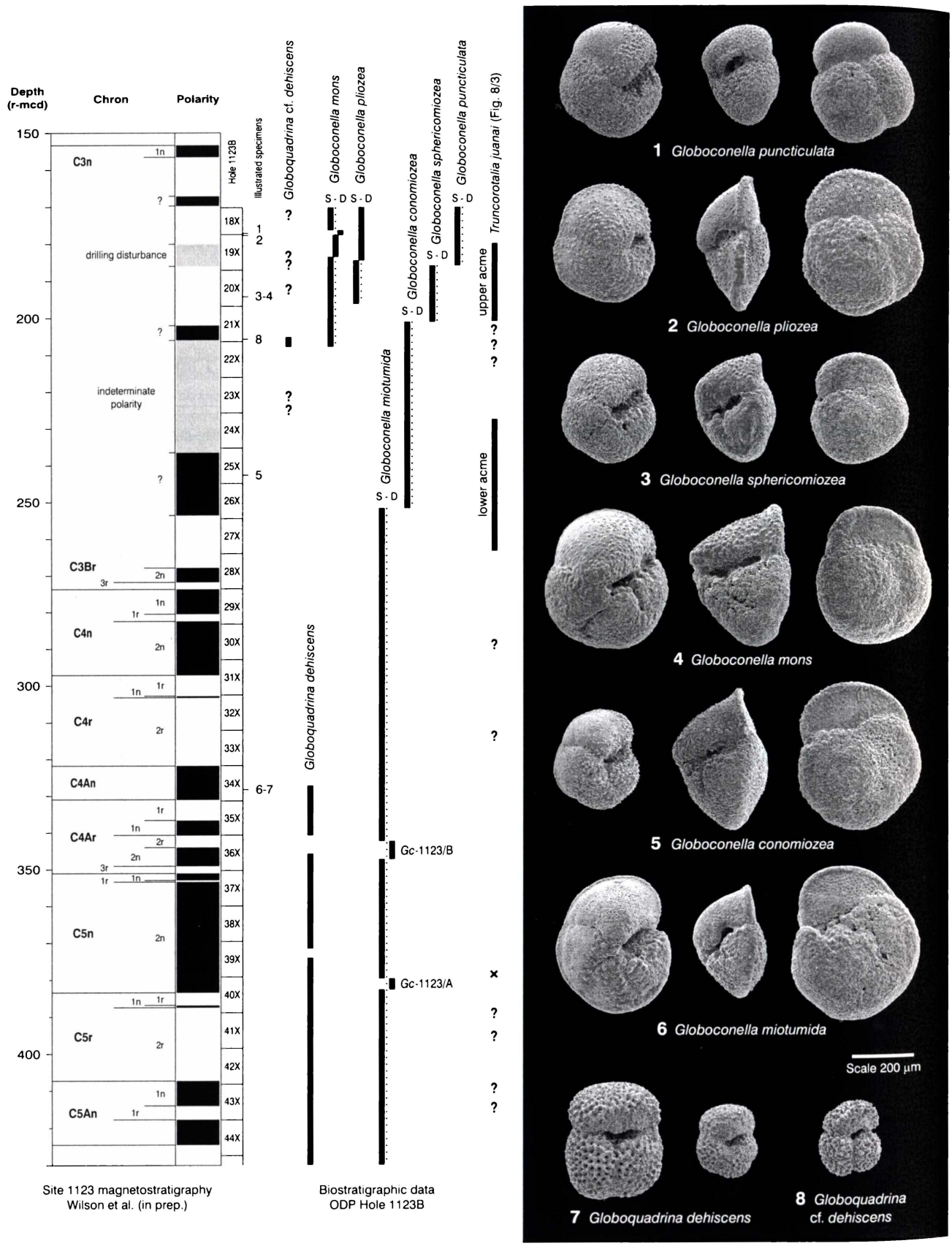


Figure 5.5 – Distribution of important dissolution-resistant planktic foraminifers 1123B-18X to 44X. The numbered horizons of illustrated specimens (1–7) correspond to the adjacent SEM images. All images are shown to the same scale. *Gc*-1123/A and *Gc*-1123/B (see explanation Figure 5.5). S = sinistral-coiled, D = dextral-coiled.

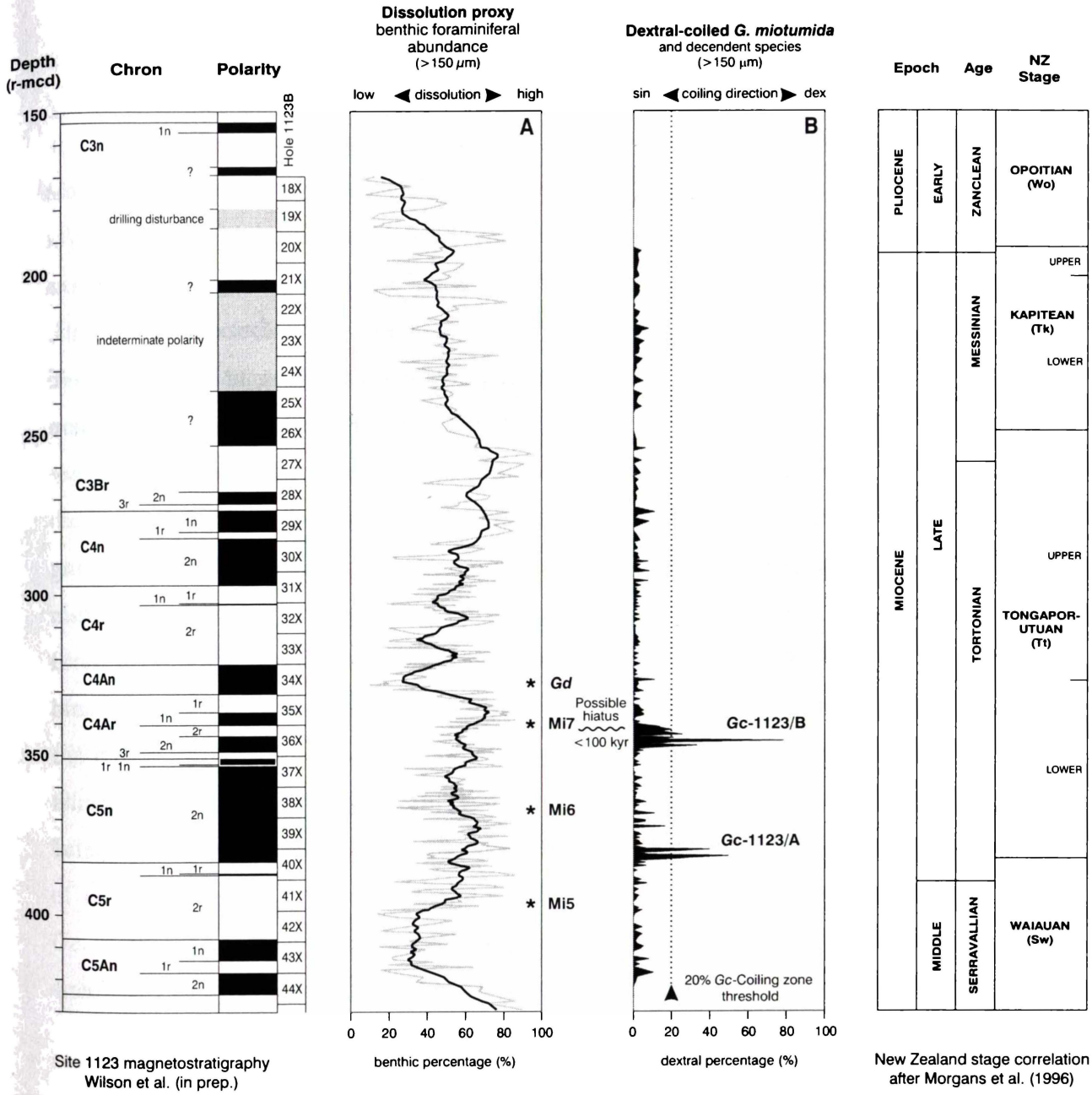


Figure 5.6 – Stratigraphic plots 1123B-18X to 44X. A) Benthic foraminiferal abundance data (dissolution proxy), grey curve = benthic percentage, black curve = 11-point moving average. High benthic abundances correspond to high dissolution. Positions of oxygen isotope events Mi5, Mi6, and Mi7 based on GPTS-95 correlation (Wright & Miller 1992). *Gd* = Regional disappearance *Globoquadrina dehiscens*. B) *Globoconella miotumida* coiling data. *Gc*-1123/A corresponds to the Kaiti Coiling Zone (Scott 1995), and *Gc*-1123/B corresponds to the Tukemokihi Coiling Zone identified at Site 593 and uplifted marine sections in New Zealand (Crundwell et al. 1997b; Study 7).

dampened dissolution signal through the Plio-Pleistocene (4.6-0 Ma) is presumed to be related to a less corrosive pattern of deep-water circulation, than that which existed at the site through the late Miocene.

The late Miocene biostratigraphic data (Appendix 5.3) identify at least 13 planktic foraminiferal events in the dissolution-affected section of Site 1123 that are potentially useful for biostratigraphic correlation. They include dextral-coiling excursions in *Globoconella miotumida,* the regional disappearance of *Globoquadrina dehiscens,* an acme zone of *Truncorotalia juanai*, and the evolutionary appearances of *Globoconella conomiozea, Gc. mons, Gc. sphericomiozea, Gc. pliozea,* and *Gc. puncticulata.* These taxa are all robust, thick-walled forms that have a high-resistance to dissolution. Although the ranges of these taxa are generally well constrained, datums that occur in intervals where there is a high level of dissolution are less reliable than those that occur in intervals where there is good preservation.

Taxa that are less resistant to dissolution are poorly represented at Site 1123, including species like *Globigerina bulloides, Neogloboquadrina pachyderma,* and *Hirsutella scitula* that are relatively common in well preserved late Miocene temperate planktic foraminiferal assemblages from the New Zealand region (Scott 1992). Their poor preservation and patchy distribution at Site 1123 adversely affects the reliability of their ranges, which are very poorly constrained (Appendix 5.1). Consequently, the following review of bioevents focuses only on those that have well defined stratigraphic ranges and are potentially useful biostratigraphic markers.

***Gc*-1123/A coiling zone (10.93-10.82 Ma):** The *Gc*-1123/A coiling zone is clearly defined in coiling data from Site 1123 (Figure 5.6). It is associated with intermittent acmes of dextral-coiled shells that interrupt the long-term succession of sinistrally-dominated populations of *Globoconella miotumida,* near the base of the late Miocene (Tongaporutuan Stage). Even though the abundance of planktic foraminifers is highly variable through the late Miocene section, most faunas have sufficient whole and fragmented specimens of *Gc. miotumida* to give reliable estimates of coiling directions. The base of the *Gc*-1123/A coiling zone is placed at the horizon where populations of *Gc. miotumida* first contain 20% or more of dextral shells. This occurs in 1123B-40X-3, 50-53 cm. The datum is correlated with Chron C5n.2n(0.98) and has an interpolated magnetostratigraphic age of 10.93 Ma.

Although the relative abundance of dextral shells within the coiling zone sometimes drops below 20%, the top of the zone is placed at the level where there is a persistent return to *Gc. miotumida* populations with less than 20% and in most instances less than 5% of dextral shells. The top of the *Gc*-1123/A coiling zone, so defined, occurs in sample 1123B-40X-1, 50-53 cm, within Chron C5n.2n(0.87), and has an interpolated magnetochronologic age of 10.82 Ma.

On the basis of its position near the base of the late Miocene, the *Gc*-1123/A coiling zone is correlated with the Kaiti Coiling Zone – a coiling zone that has been recognized in neritic and marginal oceanic sequences exposed in New Zealand and at oceanic sites in the Tasman Sea, including Site 593 (Scott 1995). It occurs immediately above the base of the Tongaporutuan Stage (Scott 1992) and provides a useful criterion for the stage boundary in oceanic and deep-water sequences lacking age diagnostic benthic species of the *Bolivinita quadrilatera* group. Morgans et al. (1996) have previously assigned an age of 11.26 Ma to the base of the Tongaporutuan Stage, but the present study suggests the boundary may be as young as 10.93 Ma.

***Gc*-1123/B coiling zone (9.62-9.42 Ma):** The *Gc*-1123/B coiling zone has previously been identified at Site 593 and at uplifted marine sequences in New Zealand (Crundwell et al. 1997b). It is a very short and well-defined zone associated with acmes of dextrally-coiled *Globoconella miotumida,* similar to the *Gc*-1123/B coiling zone, but is distinguished by being closely associated with *Bolboforma metzmacheri* s.s. and the regional disappearance of *Globoquadrina dehiscens.* An arbitrary 20% threshold of dextral-coiled specimens of *Gc. miotumida* – about three-times the long-term dextral average at Site 1123 – defines the stratigraphic limits of the coiling zone, although the relative abundance of dextral shells within the zone is highly variable and sometimes falls below 20%. It extends from 1123B-36X-5, 60-64 cm to 1123B-36X-2, 10-14 cm. The base of the coiling zone is correlated with Chron C4Ar.2n(0.71) and the top of the coiling zone Chron C4Ar.2r(0.41). It has an interpolated magnetochronologic age of 9.62-9.42 Ma.

HO *Globoquadrina dehiscens* (8.88 Ma): *Globoquadrina dehiscens* is a warm-water species that occurs in low numbers throughout the older part of the late Miocene section of Site 1123. It is relatively persistent and is found in 85% of early late Miocene samples, including 19 out of 20 samples in the interval immediately prior to its disappearance

(Appendix 5.3). Most specimens are small and heavily encrusted and this appears to have been a factor in their preservation, particularly in intervals severely affected by dissolution. The highest occurrence of *Gq. dehiscens* is in sample 1123B-34X-4, 100-105 cm. In the interval immediately prior to the species disappearance there is an abrupt change from high to low dissolution (Figure 5.6), the largest and most rapid baseline shift in the late Miocene dissolution curve. The highest occurrence of *Gq. dehiscens* occurs within Chron C4An(0.57) and it has an interpolated magnetochronologic age of 8.88 Ma.

The highest occurrence of *Globoquadrina dehiscens* is well defined at Site 1123, although very rare late Miocene specimens of *Gq.* cf. *dehiscens* occur higher in the section, most notably between samples 1123B-22X-1, 140-145 cm and 1123B-21X-6, 90-95 cm (Appendix 5.3). These specimens are very small and they resemble the Paleogene taxon *Acarinina primitiva* in having a strongly muricate test and only three to three and one-half chambers in the outer whorl (Figure 5.5/8). Most have a flattened, steeply inclined umbilical face and an exteriomarginal-umbilical aperture, but they lack the well developed tooth-like projection that is typical of large specimens of *Gq. dehiscens*. As there is no evidence to substantiate reworking, the specimens are considered to be expatriates that have been reintroduced to the New Zealand region from low latitudes, where the range of *Gq. dehiscens* extends up to the Miocene/Pliocene boundary (Kennett & Srinivasan 1983; Berggren et al. 1995). Similar enigmatic occurrences of *Gq. dehiscens* have also been noted in the latest Miocene and early Pliocene in Marlborough and eastern North Island, New Zealand (Edwards 1987), but there are no records of expatriates in oceanic sequences from similar latitudes in the Tasman Sea (Jenkins & Srinivasan 1986). This suggests that in the latest Miocene there may have been a flow or periodic flow of relatively warm subtropical surface water along the Pacific Ocean side of New Zealand, similar to the present-day East Cape Current.

***Truncorotalia juanai* abundance zone (7.23-6.23 Ma):** *Tr. juanai* is a relatively uncommon species and it has a patchy distribution in the late Miocene section of Site 1123. Persistent records of *Tr. juanai* are only found between 1123B-27X-7, 0-5 cm to 1123B-24X-2, 50-55 cm, and 1123B-21X-3, 40-45 cm to 1123B-17X-7, 0-5 cm (Appendix 5.3). The lower interval is moderately well defined and includes spirally-domed morphotypes of *Tr. juanai* similar to those found in the middle abundance zone of *Tr. juanai* at Site 593. It extends from Chron C3Br.2r to the older part of an interval of indeterminate polarity and

has an interpolated magnetostratigraphic age of c. 7.23-6.23 Ma. The upper interval of *Tr. juanai* is in the vicinity of the Miocene/Pliocene boundary. It is a poorly defined interval and includes a range of biconvex to ventroconical morphotypes (*Truncorotalia* aff. *crassaformis*). It corresponds to the upper *Tr. juanai* abundance zone at Site 593.

LO *Globoconella conomiozea* (c. 6.87 Ma): There is considerable confusion concerning *Gc. conomiozea,* with some biostratigraphers considering it to be an intraspecific variant of *Gc. miotumida* (Scott 1979; Cifelli & Scott 1986; Scott et al. 1990), while others argue that it evolved from *Gc. miotumida* as a discrete taxonomic entity (Kennett 1966; Malmgren & Kennett 1981, 1982; Hornibrook 1982). Despite these opposing views, nearly all workers agree that although the degree of conicity may vary within late Miocene elements of the *Gc. miotumida* plexus, there is a modal decrease in the number of chambers in the outer whorl in successively younger populations. For the purpose of this study, the entry of *Gc. conomiozea* is placed at the horizon where 10% or more of adult specimens in late Miocene anagenetic populations of *Gc. miotumida-conomiozea* with high-arched apertures, have less than four and one-half chambers in the outer whorl (Figure 5.5/5). This occurs in core 1123B-26X-2, 30-35 cm, within the middle *Tr. juanai* abundance zone, and it is correlated with the older part of an interval of indeterminate polarity. The lowest occurrence of *Gc. conomiozea* has an interpolated magnetochronologic age of c. 6.87 Ma.

LO *Globoconella mons* (c. 5.72 Ma): The entry of *Gc. mons* is marked by compactly coiled four-chambered variants of the *Gc. miotumida* plexus with reduced or closed umbilici, slit-like apertures, and conical to subconical axial profiles (Figure 5.5/4). The first such specimens are found in 1123B-22X-1, 140-145 cm, between the top of the middle *Tr. juanai* subzone and the lowest occurrence of *Gc. sphericomiozea.* This occurs within the older part of an interval of indeterminate polarity and the datum has a poorly constrained interpolated age of c. 5.72 Ma.

LO *Globoconella sphericomiozea* (c. 5.53 Ma): The morphological transformation in anagenetic populations of *Gc. conomiozea-sphericomiozea* occurs in an interval where globoconellids are relatively common, but most specimens are heavily encrusted and keels are often obscured by calcite overgrowth. This makes identification of the lowest occurrence of *Gc. sphericomiozea* difficult and reduces the reliability of the datum. Very rare non-carinate morphotypes are first noted in sample 1123B-27X-6, 50-55 cm, but they

become more persistent above 1123B-22X-1, 140-145 cm. However, based on the population threshold for the lowest occurrence of *Gc. sphericomiozea – sensu* Scott (1980) where 5% or more of specimens are non-carinate – the species lowest occurrence is identified in 1123B-21X-2, 90-95 cm. The datum occurs within an unidentified interval of reversed polarity and has an interpolated age of c. 5.53 Ma.

At Blind River, an uplifted marine section in New Zealand, the lowest occurrence of *Gc. sphericomiozea* occurs within Chron C3r (Roberts et al. 1994) and it has an assigned age of 5.5 Ma (Morgans et al. 1996). Despite the potential errors involved in locating the datum at Site 1123, it would appear to be reliably correlated with the GPTS.

LO *Globoconella pliozea* (c. 5.39 Ma): The adopted species concept for *Gc. pliozea* is based on relatively compressed, compactly coiled, biconvex, keeled morphotypes within the *Gc. miotumida* plexus with less than four and one-half chambers in the outer whorl of adult specimens (Figure 5.5/2). The entry of such specimens occurs in 1123B-20X-2, 9-14 cm, within the younger part of an unidentified interval of reversed polarity. In terms of the GPTS-95 time scale (Berggren et al. 1995; Cande & Kent 1992, 1995), the interpolated age of 5.39 Ma is consistent with the datum occurring within the older part of an interval of reversed polarity (Chron C3r).

LO *Truncorotalia crassaformis* (c. 5.15 Ma): The lowest occurrence of *Tr. crassaformis* is marked by the appearance of distinctly ventroconical morphotypes in anagenetic populations of *Tr. juanai-crassaformis*. This occurs in sample 1123B-20X-1, 10-14 cm in an unidentified interval of reversed polarity, and it has an interpolated age of c. 5.15 Ma. Below this horizon, however, planktic foraminiferal assemblages are very poor and it is unlikely that the lowest occurrence of *Tr. crassaformis* is located accurately.

The morphological transformation between *Tr. juanai* and *Tr. crassaformis* occurs rapidly at Site 1123 and intermediate morphotypes (*Tr.* aff. *crassaformis*) are confined to an interval of less than 20 m (c. 0.5 m.y.). More detailed study of this plexus is needed, but it may be possible to refine correlations near the Miocene-Pliocene boundary and establish a morphometrically-based phylo-zonation in well preserved sequences (e.g. Malmgren & Kennett, 1982).

LO *Globoconella puncticulata* (c. 5.11 Ma): The lowest occurrence of *Gc. puncticulata* is placed at the level where more than 95% of large adult specimens in anagenetic *Gc. sphericomiozea-puncticulata* populations are non-carinate. Based on this population concept, the lowest occurrence of *Gc. puncticulata* is identified in 1123B-19X-7, 0-5 cm, in an interval with large well preserved populations of encrusted specimens. The datum, however, is associated with an interval of drilling disturbance and indeterminate polarity and its position is unlikely to be accurate. It has an interpolated age of c. 5.11 Ma.

At subtropical DSDP Sites 590 and 516, the lowest occurrence of *Gc. puncticulata* occurs close to the base of Chron C3n.4n (Dowsett 1989) and it has an assigned age of 5.2 Ma (Morgans et al. 1996). Given the uncertainty of the magnetostratigraphic correlation associated with the entry of *Gc. puncticulata* at Site 1123 and the difficulty of locating the entry of the species in rapidly evolving anagenetic populations (e.g. Scott et al. 1980), the species entry would appear to be a more or less synchronous southern mid-latitude event. It also suggests the interval of drilling disturbance and indeterminate polarity at Site 1123 may include Chron C3n.4n and that the underlying interval of reversed polarity, where *Gc. pliozea* and *Gc. sphericomiozea* enter, may correspond to Chron C3r. This interpretation of the magnetostratigraphy is consistent with the entry of the latter species at Blind River (Roberts et al. 1994) and it suggests the magnetostratigraphic age calibration of bioevents at Site 1123 may be improved in the vicinity of the Miocene/Pliocene boundary.

COMPARISON OF BIOSTRATIGRAPHIC DATA IN SITES 1123 AND 593

The sequence of bolboform and planktic foraminiferal bioevents identified at Site 1123 is correlated with Site 593 in the Tasman Sea – a very well preserved late Miocene biostratigraphic reference section (Jenkins & Srinivasan 1986; Lohmann 1986; Hoskins 1990; Scott 1992; Grützmacher 1993; Studies 2 and 3). A scatter-plot (Figure 5.7) based on 33 shared bioevents (Tables 5.3 and 5.4) allows a line of correlation to be drawn between the two sections (Shaw 1964; Dowsett 1989). These biostratigraphic data approximate a linear trendline and indicate the relative rate of sediment accumulation at the two sites was more or less constant through the late Miocene, even though the sites were more that 1500 km apart, off opposite sides of New Zealand, and they were associated with different water masses. The tight grouping of the biostratigraphic data around the line of correlation (r^2 = 0.9908), and the consistency of their order, suggest most bioevents are synchronous or nearly so (Figure 5.7).

Table 5.3 – Bioevents shared between Sites 1123 and 593. LO = lowest occurrence, HO = highest occurrence. *Bioevents that do not maintain homotaxial order (see Table 5.4).

1	LO *Globoconella puncticulata* s.s. (<5% weakly carinate) **Wo/Tk proxy**	18	*Bolboforma metzmacheri* s.s. abundance spike (lower subzone)
2	LO *Truncorotalia crassaformis*	19	LO *Bolboforma metzmacheri* s.s. (lower subzone)
3	LO *Globoconella pliozea*	20	HO *Bolboforma gracilireticulata* s.l.
4	LO *Globoconella sphericomiozea* s.s. **(upper-lower Tk proxy)**	21*	Base *Gc* -1123/B coiling zone >20% Dex (= base *Gc* -593/C)
5	LO *Globoconella mons*	22	LO *Bolboforma gracilireticulata* s.l.
6*	Top *Truncorotalia juanai* acme zone (middle zone Site 593)	23	HO *Bolboforma pentaspinosa* (excludes Site 1123 outlier)
7*	LO *Globoconella conomiozea*	24	HO *Bolboforma capsula*
8	Base *Truncorotalia juanai* acme zone (middle acme zone Site 593)	25	LO *Bolboforma pentaspinosa*
9	HO *Bolboforma praeintermedia*	26	LO *Bolboforma capsula*
10	LO *Bolboforma praeintermedia*	27	HO *Bolboforma* sp. H
11	HO *Bolboforma metzmacheri ornata*	28	LO *Bolboforma* sp. H
12	LO *Bolboforma metzmacheri ornata*	29	HO *Bolboforma subfragoris* s.l. (top subzone BBs-1123/D)
13	HO *Bolboforma metzmacheri* s.s. (upper subzone)	30	*Bolboforma subfragoris* s.l. abundance spike (BBs-1123/D)
14	HO *Globoquadrina dehiscens* **(upper-lower Tt proxy)**	31	Top *Gc* -1123/A coiling zone >20% Dex (= top *Gc* -593/A)
15	LO *Bolboforma metzmacheri* s.s. (upper subzone)	32	Base *Gc* -1123/A coiling zone >20% Dex (= base *Gc* -593/A) **Tt/Sw proxy**
16	HO *Bolboforma metzmacheri* s.s. (lower subzone)	33	LO *Bolboforma subfragoris* s.l. (base BBs-1123/A subzone)
17*	Top *Gc* -1123/B coiling zone >20% Dex (= top *Gc* -593/C)		

In the lower part of the biostratigraphic sequence at Site 1123 where bioevents are closely spaced, the only demonstrably diachronous events relate to the *Gc*-1123/B coiling zone. It plots out of sequence with respect to at least four bolboform events that plot very close to the linear line of correlation between the sites (Figure 5.7): the highest occurrence of *B. gracilireticulata* s.l., the top and bottom of the lower *B. metzmacheri* s.s. subzone, and its associated abundance spike. Although Wilson et al. (in prep.) suggest there may be a short hiatus immediately above the coiling zone, this would not explain the stratigraphic transposition of the bioevents. The possibility of a hiatus at Site 1123 and the apparent diachrony of the *Gc*-1123/B coiling zone (c. 320 k.y.) between Southwest Pacific Site 1123 and Tasman Sea Site 593, place a caveat on the reliability of the coiling zone as a regional biochronostratigraphic marker, but they do not preclude its use for local correlations.

The upper part of the biostratigraphic sequence at Site 1123, following the disappearance of bolboforms, has a relatively small number of events compared to the lower part of the sequence at the same site (Figure 5.7). Most of the events in the upper part of the sequence are based on the evolutionary appearances of globoconellid species that are relatively common. The dominance, however, of heavily encrusted morphotypes and the high number of broken specimens in dissolution-affected samples make the interpretation of transitional populations difficult compared to the much better preserved microfossil succession at Site 593. Although this may adversely affect the reliability of some bioevents, most plot close to the linear line of correlation, except for events 6 and 7: the top of the *Truncorotalia juanai* acme zone and the lowest occurrence of *Globoconella conomiozea*. The order of these events is transposed and they plot some distance from the

line of correlation. This suggests they may not be reliably located in the section at Site 1123, which places a cautionary caveat on their assigned ages.

Table 5.4 – Bioevents shared between Sites 1123 and 593 (Site 593 data from Studies 2 and 3). Depths: (mbsf) metres below seafloor; (r-mcd) = revised metres composite depth (Wilson et al in prep.). Closest: constraining sample closest to a datum (see Appendix 5.3). Midpoint: between a datum and its closest constraining sample. Persistence: taxon (presence/absence) based on 20 closest samples to a datum, either before or after, depending if it is a highest or lowest occurrence. Chron/subchron: correlations give the proportional position from its younger end. Age: interpolated from the sites magnetostratigraphy (Wilson et al. in prep.). Age limit: age difference between a datum and its closest constraining sample. *Bioevents that do not maintain homotaxial order.

Site 1123 (Hole B)													Site 593
Ref.	Core	Sect.	Upp. (cm)	Low. (cm)	Depth (mbsf)	Depth (r-mcd)	Closest (m)	Midpoint (r-mcd)	Persis-tence	Chron/Subchron	Age (Ma)	Age limit (Ma)	Midpoint (mbsf)
1	19X	7	0	5	170.82	185.62	1.58	186.41	1.00	indeterminate	5.11	±0.01	123.01
2	20X	1	10	14	172.40	187.20	0.90	187.65	0.65	reversed	5.15	±0.01	129.30
3	20X	7	0	5	181.40	196.20	0.90	196.65	1.00	reversed	5.39	±0.01	130.10
4	21X	3	140	145	186.30	201.10	0.98	201.59	1.00	reversed	5.53	±0.01	143.69
5	22X	1	140	145	193.00	207.80	1.37	208.49	0.95	indeterminate	5.72	±0.02	145.72
6*	24X	2	50	55	212.80	227.60	-0.90	227.15	0.50	indeterminate	6.23	±0.01	185.27
7*	26X	2	30	35	231.80	249.24	1.50	249.99	1.00	indeterminate	6.87	±0.03	167.25
8	27X	7	0	5	248.60	263.40	1.00	263.90	0.80	C3Br.2r	7.23	±0.01	193.71
9	31X	7	0	5	287.10	301.90	-0.50	301.65	1.00	C4r.1r(0.81)	8.21	±0.01	236.42
10	32X	1	50	55	288.20	303.00	0.50	303.25	1.00	base C4n.1n	8.25	±0.01	240.42
11	32X	2	50	55	289.70	304.50	-0.50	304.25	0.92	C4r.2r(0.06)	8.28	±0.01	240.82
12	32X	6	50	55	295.70	310.50	1.70	311.35	0.92	C4r.2r(0.44)	8.45	±0.02	246.17
13	34X	2	100	105	309.40	324.20	-0.50	323.95	0.69	C4An(0.25)	8.78	±0.01	254.19
14	34X	4	100	105	312.40	327.20	-0.50	326.95	0.90	C4An(0.57)	8.88	±0.01	254.38
15	34X	6	100	105	315.40	330.20	0.50	330.45	0.69	C4An(0.94)	9.01	±0.01	259.17
16	36X	1	60	64	326.50	341.30	-0.50	341.05	1.00	C4Ar.2r(0.11)	9.34	±0.02	271.83
17*	36X	2	10	14	327.50	342.30	-0.50	342.05	0.50	C4Ar.2r(0.41)	9.42	±0.02	269.07
18	36X	2	10	14	327.50	342.30	±0.50	342.30	1.00	C4Ar.2r(0.48)	9.44	±0.04	274.72
19	36X	2	110	114	328.50	343.30	0.50	343.55	1.00	C4Ar.2r(0.86)	9.54	±0.02	276.82
20	36X	5	10	14	332.00	346.80	-0.50	346.55	0.67	C4Ar.2n(0.51)	9.61	±0.00	278.61
21*	36X	5	60	64	332.50	347.30	0.50	347.55	0.50	C4Ar.2n(0.71)	9.62	±0.00	270.82
22	37X	1	50	54	336.00	350.80	0.50	351.05	0.67	base C4Ar.3r	9.75	±0.02	284.62
23	37X	6	50	54	343.50	358.30	-0.50	358.05	0.75	C5n.2n(0.16)	10.08	±0.01	287.18
24	38X	1	10	14	345.20	360.00	-0.70	359.65	1.00	C5n.2n(0.21)	10.13	±0.01	289.62
25	38X	1	10	14	345.20	360.00	0.40	360.20	0.75	C5n.2n(0.22)	10.15	±0.01	290.42
26	38X	2	0	4	346.60	361.40	0.50	361.65	1.00	C5n.2n(0.27)	10.20	±0.01	293.61
27	38X	4	50	54	350.10	364.90	-0.50	364.65	0.89	C5n.2n(0.38)	10.31	±0.01	295.22
28	38X	7	0	4	354.10	368.90	0.60	369.20	0.89	C5n.2n(0.53)	10.46	±0.01	299.02
29	39X	1	100	104	355.70	370.50	-0.50	370.25	1.00	C5n.2n(0.56)	10.50	±0.01	304.57
30	39X	4	50	53	359.70	374.50	±0.50	374.50	1.00	C5n.2n(0.71)	10.61	±0.02	306.86
31	40X	1	50	53	364.90	379.70	-0.40	379.50	1.00	C5n.2n(0.87)	10.82	±0.01	309.05
32	40X	3	50	53	367.90	382.70	0.50	382.95	1.00	C5n.2n(0.98)	10.93	±0.01	315.24
33	41X	6	0	5	381.60	398.42	0.04	398.44	0.60	C5r.2r(0.55)	11.56	±0.00	334.65

CONCLUSIONS

The excellent biostratigraphic correlation between Southwest Pacific Site 1123 and Tasman Sea Site 593, suggests the late Miocene magnetostratigraphically-constrained biochronology from Site 1123 can be used in the temperate Southwest Pacific and Tasman Sea regions with a high degree of reliability. It also allows the ages of bioevents that are

poorly defined or missing at Site 1123, including those that are associated with other microfossils groups, to be calibrated at other sites in the region by way of second-order GPTS correlations. This will undoubtedly lead to further refinements in late Miocene biochronology in the region. It will also advance the use of modern high-resolution stratigraphic tools and our ability to orbitally-tune and correlate sedimentary sequences on a refined scale not previously possible.

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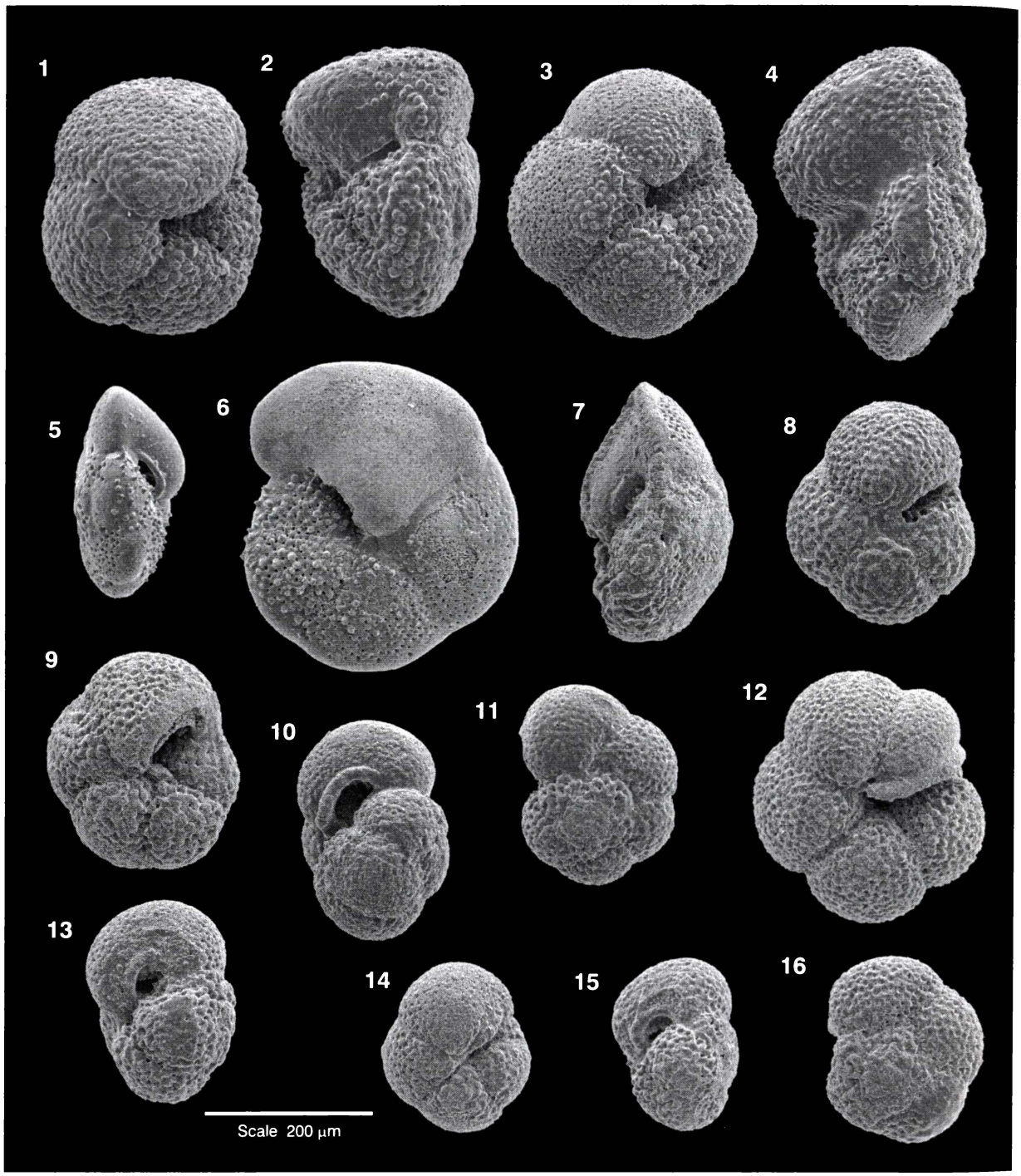


Plate 5.1 – SEM images of dissolution resistant globorotalid species 1123B-18X to 44X. All images are shown to the same scale.

1. *Truncorotalia crassaformis* (Galloway & Wissler);18X-6, 5-10 cm
2. *Truncorotalia crassaformis* (Galloway & Wissler); 18X-5, 100-105 cm
3. *Truncorotalia juanai* (Bermúdez & Bolli); 20X-5, 100-105 cm
4. *Truncorotalia aff. crassaformis*; 20X-5, 100-105 cm
5-6. *Hirsutella scitula* (Brady); 20X-5, 100-105 cm
7. *Hirsutella panda* (Jenkins); 43X-1, 100-103 cm
8. *Neogloboquadrina pachyderma* (Ehrenberg); 20X-6, 50-55 cm
9-11. *Neogloboquadrina mayeri* (Cushman & Ellisor); 43X-4, 100-105 cm
12. *Neogloboquadrina acostaensis* (Blow); 18X-6, 5-10 cm
13. *Neogloboquadrina partimlabiata* (Ruggieri & Sprovieri); 43X-4, 100-105 cm
14-16. *Neogloboquadrina continuosa* (Blow); 43X-4, 100-105 cm

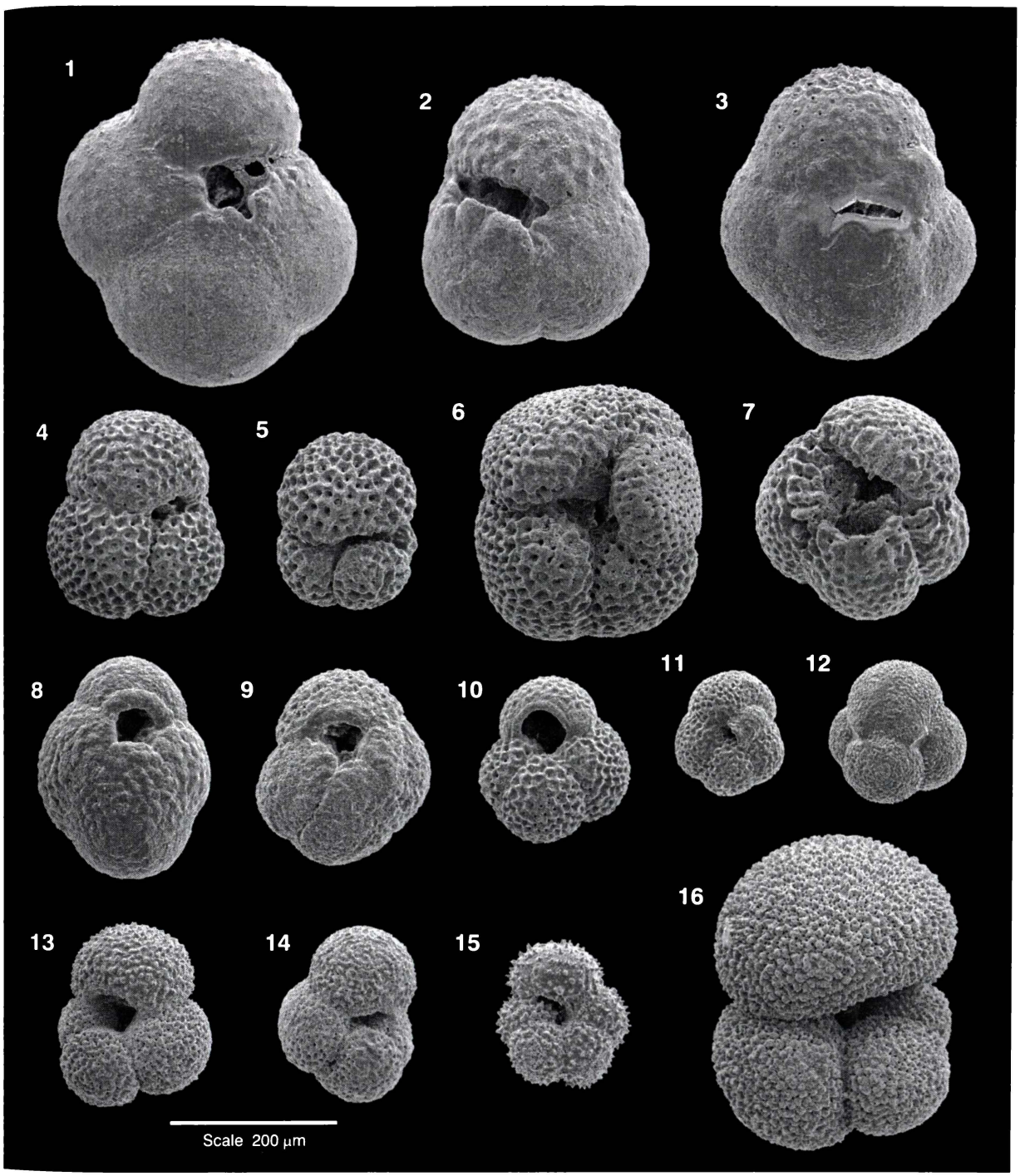


Plate 5.2 – SEM images of dissolution resistant globigerine species 1123B-18X to 44X. All images are shown to the same scale.

1-3. *Sphaeroidinellopsis seminulina* (Schwager); 32X-1, 50-55 cm
4. *Globigerinoides quadrilobatus* (d'Orbigny); 34X-5, 50-55 cm
5. *Globigerinoides trilobus* (Reuss); 34X-5, 50-55 cm
6. *Globoquadrina dehiscens* (Chapman, Parr, & Collins); 34X-5, 50-55 cm
7. *Globoquadrina venezuelana* (Hedberg); 18X-3, 0-5 cm
8. *Zeaglobigerina nepenthes* (Todd); 34X-5, 50-55 cm
9. *Zeaglobigerina druryi* (Akers); 42X-1, 50-53 cm
10. *Zeaglobigerina woodi* (Jenkins); 26X-2, 30-35 cm
11. *Catapsydrax parvulus* (Olli, Loeblich, and Tappan); 21X-7, 0-5 cm
12. *Globigerinita glutinata* (Egger); 43X-4, 100-105 cm
13. *Globigerina bulloides* d'Orbigny; 26X-2, 30-35 cm
14. *Globigerina* sp.; 42X-1, 50-53 cm
15. *Globigerina angustiumbilicata* Bolli; 21X-6, 90-95 cm
16. *Globigerinopsis obesa* (Bolli); 26X-2, 30-35 cm

Appendices

Appendix 5.1 – Type references of bolboforms and planktic foraminifers. The original reference for each species identified at Site 1123 is given below; however, in most cases, these are not included in the reference list. Complete citations can be found in Kennett & Srinivasan (1983) and Bolli & Saunders (1985).

BOLBOFORMS	Original citation
Bolboforma capsula	Spiegler, 1987, Mededelingen van de Wekgroup voor Tertiarie Kwartaire Geologie, p. 164, pl. 2, figs. 4-6; pl. 3, figs 1-4
Bolboforma gracilireticulata	Spiegler, in press, Journal of Foraminiferal Research, pl. 5, figs. 14, 15
Bolboforma laevis	Daniels and Spiegler, 1974, Paläontologische Zeitschrift 48, p. 64, pl. 7, figs. 7-9; pl. 10, fig 6, included in B. gracilireticulata s.l. (this paper)
Bolboforma metzmacheri	Clodius, 1922, Archiv Verein der Freunde der Naturgesschicte Mecklenburg, p. 108, pl. 1, fig. 2
Bolboforma metzmacheri ornata	Spiegler, in press, Journal of Foraminiferal Research, pl. 5, figs. 3,4
Bolboforma pentaspinosa	Spiegler and Daniels, 1991, Journal of Foraminiferal Research 22(2), p. 138, pl. 6, figs. 5-7
Bolboforma praeintermedia	Spiegler, in press, Journal of Foraminiferal Research, pl. 4, figs. 19, 20
Bolboforma sp. H	Grützmacher, 1993, GEOMAR Research Center for Marine Geosciences, Kiel, Report 22, p. 90, figs 7-9
Bolboforma subfragoris	Spiegler and von Daniels, 1991, Journal of Foraminiferal Research 22(2), p. 140, pl. 11, figs. 3-6

PLANKTIC FORAMINIFERS	Original citation
Catapsydrax parvulus	*Catapsydrax parvulus* Olli, Loeblich, and Tappan, 1957, US National Museum Bulletin, no. 215, p. 37, pl. 7, figs. 9a-c
Globigerina angustiumbilicata	*Globigerina ciperoensis angustiumbilicata* Bolli, 1957, US National Museum Bulletin, no. 215, p. 109, pl. 22, figs 12a-13c
Globigerina bulloides	*Globigerina bulloides* d'Orbigny, 1826, Annales des Sciences Naturelles, Paris, ser. 1, tome 7, p. 277, no. 1
Globigerina eamesi	*Globigerina eamesi* Blow, 1959, Bulletins of American Paleontology, Ithaca, N.Y. vol. 39, no. 178, p. 176, pl. 9, figs 39a-c
Globigerina quinqueloba	*Globigerina quinqueloba* Natland, 1938, Californian, University Institute of Oceanography Bulletin Technical Series, p. 149, pl. 6, figs
Globigerinella aequilateralis	*Globigerina aequilateralis* Brady, 1879, Quaterly Journal of Microscopical Science, new ser., vol. 19, p. 285, (figures in Brady, 1884: Rep. Voy. Challenger, Zool. 9, pl. 80, figs. 18-21)
Globigerinita glutinata	*Globigerina glutinata* Egger, 1893, Abhandlungen der Bayerischen Akademie der Wissenschaften, München, Math.-Physik. Cl., Abh. Bd. 18 (1895), Abth, 2, p. 371, pl. 13, figs. 19-21
Globogerinita uvula	*Pylodexia uvula* Ehrenberg, 1861, Monatsbericht der Königlichen Preussischen Akademie der Wissenschaften zu Berlin, p. 206, 207, 308; 1873, Monatsbericht der Königlichen Preussischen Akademie der Wissenschaften zu Berlin, Abh., Jahre. 1872, pl. 2, figs. 24-25
Globigerinoides bollii	*Globigerinoides bollii* Blow, 1959, Micropaleontology 27(3), p. 189, pl. 10, figs 65a-c
Globigerinoides obliquus	*Globigerinoides obliqua* Bolli, 1957, US National Museum Bulletin, no. 215, p. 113, pl. 25, figs 10a-c
Globigerinoides quadrilobatus	*Globigerina quadrilobata* d'Orbigny, 1846, Paris, Gide et Comp., p. 164, pl. 9, figs 7-10
Globigerinoides ruber	*Globigerina rubra* d'Orbigny, 1839, Histoire physique, politique et naturelle de L'île de Cuba, 8, p. 82, pl. 4, figs. 12-14

Globigerinoides sacculifer	*Globigerina sacculifera* Brady, 1877, Geological Magazine, new series, decade 2, vol. 4, no. 2, p. 604, pl. 80, figs. 11-17, pl. 81, fig. 2, pl. 82,
Globigerinoides trilobus	*Globigerina triloba* Reuss, 1850, Denkschriften der Kaiserlichen Akademie der Wissenschaften, Mathematisch-Naturwissenschafteliche Classe, Bd. 1, p. 374, pl. 477, figs. 11a-c
Globigerinopsis obesa	*Globorotalia obesa* Bolli, 1957, US National Museum Bulletin, no. 215, p. 119, pl. 29, figs. 2a-3
Globoconella conomiozea	*Globorotalia conomiozea* Kennett, 1966, Micropaleontology 12(2), p. 235, text figs. 10a-c
Globoconella miotumida	*Globorotalia menardii* (d'Orbigny) *miotumida* Jenkins, 1960, Micropaleontology 6, p. 362, pl. 4, figs. 9a-c
Globoconella mons	*Globorotalia conomiozea mons* Hornibrook, 1982, New Zealand Journal of Geology and Geophysics 25, p. 91, figs. 3a-g, 4a-i
Globoconella pliozea	*Globorotalia pliozea* Hornibrook, 1982, New Zealand Journal of Geology and Geophysics 25, p. 95, figs. 7a-g
Globoconella puncticulata	*Globigerina puncticulata* Deshayes, 1832, Encyclopédie méthodique. Histoire naturelle des Vers, vol. 2, pt 2, p. 170. Paris, Mme. V. Agasse
Globoconella sphericomiozea	*Globorotalia puncticulata sphericomiozea* Walters, New Zealand Journal of Geology and Geophysics 8(1), 1965, p. 126, figs. 8n-s
Globquadrina dehiscens	*Globquadrina dehiscens* Chapman, Parr, and Collins, 1934, journal of the Linnaean Society of London, Zoology 38(262), p. 569, pl. 11, figs.
Globoquadrina venezuelana	*Globigerina venezelana* Hedberg, 1937, Journal of Paleontology 11(8), p. 681, pl. 92, fig. 72b
Globorotalia lenguaensis	*Globorotalia lenguanesis* Bolli, 1957, US National Museum Bulletin, no. 215, p. 120, pl. 29, figs. 5a-c
Hirsutella scitula	*Pulvinulina scitula* Brady, 1880, Proceedings of the Royal Society of Edinburgh, II (III), p. 716 (Figures in Brady, Reports of the Scientific Results of of the Voyage of H.M.S. Challenger, Vol. IX (Zoology), pl. 103, figs. 7a-c, 1882). Banner and Blow, 1960, Contributions from the Cushman Laboratory for Foraminiferal Research, 11, pt. 1, p. 27, pl. 5, fig. 5 (lectotype)
Hirsutella panda	*Globorotalia menardii* (d'Orbigny) *panda* Jenkins, 1960, Micropaleontology 6(4), p. 364, pl. 4, figs. 10a-c
Neogloboquadrina acostaensis	*Globorotalia acostaensis* Blow, 1959, Bulletins of American Paleontology, Ithaca, N.Y. vol. 39, no. 178, p. 208, pl. 17, figs. 106a-c
Neogloboquadrina continuosa	*Globorotalia opima* Bolli, continuosa Blow, 1959, Bulletins of American Paleontology, Ithaca, N.Y. vol. 39, no. 178, p. 218, pl. 19,
Neogloboquadrina dutertrei	*Globigerina dutertrei* d'Orbigny, 1839, Histoire physique, politique et naturelle de L'lle de Cuba, 8, p. 84, pl. 4, figs. 19-21, Banner and Blow, 1960, Contributions from the Cushman Laboratory for Foraminiferal Research, 11, pt. 1, pl. 2, fig. 1 (lectotype)
Neogloboquadrina mayeri	*Globorotalia mayeri* Cushman and Ellisor, 1939, Contributions from the Cushman Laboratory for Foraminiferal Research, 15, pt. 1, p. 11, pl. 2, figs. 4a-c
Neogloboquadrina nympha	*Globorotalia mayeri* Cushman and Ellisor, sub sp. *nympha* Jenkins, 1967, New Zealand Journal of Geology and Geophysics, 10(4), p. 1072, fig. 3, no. 7-13
Neogloboquadrina pachyderma	*Aristospira pachyderma* Ehrenberg, 1861, K. Preuss Akad. Wiss. Berlin, Monatsber, p. 276, 277, 303, Banner and Blow, 1960, Contributions from the Cushman Laboratory for Foraminiferal Research, 11, pt. 1, p. 4, pl. 3, figs. 4a-c (lectotype)
Neogloboquadrina partimlabiata	*Globorotalia acrostoma partimlabiata* Ruggieri and Sprovieri, 1970, Lavori Dell'instituto di Geologia Della Universita' di Palmero, N. 10, p. 22, Text figs. 3, 4b
Orbulina universa	*Orbulina universa* d'Orbigny, 1839, Histoire physique, politique et naturelle de L'lle de Cuba, 8, p. 3, pl. 1, fig. 1

Sphaeroidinellopsis kochi	*Globigerina kochi* Caudri, 1934, Teriary deposits of Soemba. Amsterdam, Nederland, H.J. Paris, p. 144, Type figures in Eclogae Geologicae Helvetiae, 18(2), tf. 8a-b
Sphaeroidinellopsis paenedehiscens	*Sphaeroidinellopsis subdehiscens paenedehiscens* Blow, 1969, Proceedings of the first international conference of planktonic microfossils. Leiden, Netherlands: E. J. Brill, vol. 1, p. 386, pl. 30, figs. 4, 5, 9
Sphaeroidinellopsis seminulina	*Globigerina seminulina* Schwager, 1866, Novara Expedition 1857-1859, Geologischer Theil, vol. 2, no. 1, Geologische Beobachtungen, no. 2, Paläontologische Mittheilungen, p. 256, pl. 7, fig. 112
Tenuitella clemenciae	*Turborotalia clemenciae* Bermudez, 1961, Boletín de Geología, Publicación especial 3, Caracas, Venezuela, p. 1321, pl. 17, figs. 10a-b
Truncorotalia crassaconica	*Globorotalia crassaconica* Hornibrook, 1981, New Zealand Journal of Geology and Geophysics 24, p. 271, figs. 5g-i, 9a-c
Truncorotalia crassaformis	*Globigerina crassaformis* Galloway and Wissler, 1927, Journal of Paleontology 1, p. 41, pl. 7, fig. 12
Truncorotalia juanai	*Globorotalia juanai* Bermúdez and Bolli, 1969, Boletín Geología (Venezuela), 10(20), p. 171, pl. 14, figs. 1-6
Truncorotalia ronda	*Globorotalia crassaformis* (Galloway and Wissler), *ronda* Blow, 1969, Proceedings of the first international conference on planktonic microfossils. Leiden, Netherlands: E. J. Brill, vol. 1, p. 388, pl. 4, figs 4 6, pl. 37, figs. 6-9
Zeaglobigerina apertura	*Globigerina apertura* Cushman, 1918, US Geological Survey Bulletin 676, p. 57, pl. 12, figs. 8a-c
Zeaglobigerina decoraperta	*Globigerina druryi* Akers, sub. sp. *decoraperta* Takayanagi and Saito, 1962, Science Reports of the Tohoku University, ser. 2., Geology, Spec. Vol. 5, p. 72, text figs. 1a-c
Zeaglobigerina druryi	*Globigerina druryi* Akers, 1955, Journal of Paleontology 29(4), p. 654, pl. 65, fig. 1
Zeaglobigerina nepenthes	*Globigerina nepenthes* Todd, 1957, Professional Papers US Geological Survey 280-H, p. 301, figs. 7a-b
Zeaglobigerina woodi	*Globigerina woodi* Jenkins, 1960, Micropaleontology 6(4), p. 352, pl. 2, figs. 2a-c

Appendix 5.2 – Explanation of shared bioevents and biozones in Sites 1123 and 593.

BOLBOFORMS

***Bolboforma subfragoris* s.l. Interval Zone (BBs)**: Based on Spiegler & Daniels (1991) and extends upward from the lowest occurrence of spiro-spinose bolboforms of the *B. subfragoris* s.l. group to the highest occurrence of the same group of spiro-spinose bolboforms. The zone includes several short-lived influxes of spirospinose bolboforms (subzones BBs-1123/A, BBs-1123/B, BBs-1123/C, and BBs-1123/D) that are separated by intervals without bolboforms.

***Bolboforma* sp. H**: An irregularly ornamented bolboform with widely spaced blind and interconnected blade-like ridges – recorded by Grützmacher (1993) in the southwest Pacific region. It is being formalized by the author as a new species in another paper (Site 593 bolboform biostratigraphy).

***Bolboforma capsula* Interval Zone (BBc)**: Emended after Spiegler & Daniels (1991) for use in the Southwest Pacific as extending from immediately above the highest occurrence of *Bolboforma subfragoris* s.l. to immediately below the lowest occurrence of *Bolboforma metzmacheri* s.s. Includes the taxon-range zones of *Bolboforma* sp. H, *Bolboforma capsula, Bolboforma pentaspinosa,* and *Bolboforma gracilireticulata* s.l.

***Bolboforma gracilireticulata* s.l.**: Includes small smooth-walled phases similar to *Bolboforma laevis* that are associated in stratigraphic space with the weakly ornamented species *Bolboforma gracilireticulata* Spiegler and are considered to form part of the range of morphological variation associated with that species.

***Bolboforma metzmacheri* Interval Zone (BBm)**: Emended after Spiegler & Daniels (1991) for use in the Southwest Pacific as extending upwards from the lowest occurrence of *Bolboforma metzmacheri* s.s. to the highest occurrence of *Bolboforma metzmacheri ornata.* Includes the lower and upper *B. metzmacheri* s.s. subzones and *B. metzmacheri ornata* taxon-range zone.

***Bolboforma intermedia* Interval Zone (BBi)**: Emended after Spiegler & Daniels (1991) for use in the Southwest Pacific as extending upwards from immediately above the highest occurrence of *Bolboforma metzmacheri ornata.* Only the lowermost part of the zone with *Bolboforma praeintermedia* is represented at Site 1123. The highest occurrence of this species marks the regional extinction of bolboforms in the Southwest Pacific.

PLANKTIC FORAMINIFERS

HCO *Neogloboquadrina mayeri* s.l. : *Neogloboquadrina mayeri* s.l. is a very common and often dominant element of late middle Miocene planktic foraminiferal assemblages in the temperate Southwest Pacific, but its abundance drops rapidly in the early late Miocene before its regional disappearance. The highest common occurrence of *Neogloboquadrina mayeri* s.l. is defined here as the highest level of this species prior to its highest occurrence where it comprises at least 5% of planktic foraminifers in the 125-1000 μm size fraction.

***Globoconella miotumida* (dextral coiling excursions)**: Two short intervals are identified at Site 1123 where the prevailing sinistral coiling trend in *Gc. miotumida* is interrupted by populations with majorities or significant representations (>20%) of dextral shells. The lower interval that is referred to here as the *Gc*-1123/A coiling zone corresponds to the Kaiti Coiling Zone (Scott 1995). It occurs near the highest common occurrence of *Neogloboquadrina mayeri* s.l. The upper interval that is referred to here as the *Gc*-1123/B coiling zone corresponds to the Tukemokihi Coiling Zone identified at Site 593 and uplifted marine sections in New Zealand (Crundwell et al. 1997b; Crundwell in prep). It occurs near the regional disappearance of *Globoquadrina dehiscens*.

***Truncorotalia juanai* acme zone**: An interval between the highest occurrence of *Globoquadrina dehiscens* and the lowest occurrence of *Globoconella sphericomiozea* where spirally domed variants of *Truncorotalia juanai* are relatively common. Above and below the acme zone, *Truncorotalia juanai* occurs in small numbers and its distribution is very patchy.

HO *Neogloboquadrina mayeri* s.l.: The highest occurrence of *Neoglobquadrina mayeri* s.l. marks the regional disappearance of *N. mayeri, N. nympha* and *N. continuosa.* However rare expatriate occurrences of these species occur higher in the section near the *Gc*-1123/B coiling zone. The disappearance of *Neogloboquadrina mayeri* s.l. coincides with the regional appearance of *Neogloboquadrina pachyderma* .

HO *Hirsutella panda* : Highest occurrence of strongly keeled morphotypes – does not include weakly carinate and non-carinate specimens of *Hirsutella* cf. *ichinosekiensis* (Jenkins) that can sometimes be mistaken for *Hr. panda.*

HO *Globoquadrina dehiscens* : The late Miocene disappearance of *Globoquadrina dehiscens* is a well-defined regional event, but rare expatriate occurrences occur in some eastern North Island sequences, near the Miocene-Pliocene boundary.

LO *Truncorotalia* aff. *crassaformis* : Marked by the entry of intermediate morphological variants in the rapid anagenetic transformation between biconvex forms of *Truncorotalia juanai* and rounded forms of *Truncorotalia crassaformis*. Closely resembles *Truncorotalia crassaformis* but is more compressed ventrally and the spiral-surface is slightly convex.

LO *Truncorotalia* aff. *crassaconica*: Marked by the entry of forms similar to *Truncorotalia crassaformis,* but with more angular, slightly less inflated chambers and rudimentary keels – imperforate bands or slightly raised pustulose ridges around the peripheral margin.

LO *Truncorotalia crassaformis* : Marked by the entry of rounded forms of *Truncorotalia crassaformis* (e.g. Hornibrook et al. 1989; Scott et al. 1990).

Appendix 5.3 – Magnetostratigraphic and biostratigraphic data (planktic foraminiferal presence/absence data, bolboform census data, planktic/benthic foraminiferal data, and *Globoconella miotumida* coiling data) – follows:

SAMPLES HOLE 1123B										PLANKTIC FORAMINIFERAL DISTRIBUTION (presence/absence)
Core	Section	Interval (top)	Interval (bottom)	Depth (mbsf)	Depth (rmcd) - G Wilson March 2002	Polarity	Age (Ma)	Position in Chron	New Zealand Stage	*Catapsydrax parvulus* / *Globigerina bulloides* s.l. / *Globigerina cf. cameli* / *Globigerina falconensis* / *Globigerina* sp. / *Globigerina angustiumbilicata* / *Globigerina quinqueloba* / *Globigerinella aequilateralis* / *Globigerinita glutinata / uvula* / *Globigerinoides bollii* / *Globigerinoides obliquus* / *Globigerinoides quadrilobatus / trilobus* / *Globigerinoides ruber* / *Globigerinoides sacculifer* / *Globigerinopsis obesa* / *Globoconella conomiozea* / *Globoconella inflata* / *Globoconella miotumida* / *Globoconella mons* / *Globoconella pliozea* / *Globoconella puncticulata* / *Globoconella sphericomiozea* / *Globoquadrina dehiscens* / *Globoquadrina venezuelana* / *Globorotalia lenguaensis* / *Globorotaloides* cf. *hexagona* / *Hirsutella scitula* / *Menardella pusila* / *Neogloboquadrina continuosa* / *Neogloboquadrina dutertrei* / *Neogloboquadrina mayeri* / *Neogloboquadrina nympha* / *Neogloboquadrina pachyderma* / *Neogloboquadrina partimlabiata* / *Orbulina universa* s.l. / *Sphaeroidinellopsis kochi* / *Sphaeroidinellopsis paenedehiscens*
					156.4		4.290			Base of chron C3n.1n
					167.0		?			Base unidentified interval of reversed polarity
					169.7		?			Base unidentified interval normal polarity
18X	1	10	15	155.50	170.30		4.671		early Wo	X X X X X ? X X X X X

SAMPLES HOLE 1123B										PLANKTIC FORAMINIFERAL DISTRIBUTION (presence/absence)
Core	Section	Interval (top)	Interval (bottom)	Depth (mbsf)	Depth (mcd) - G Wilson March 2002	Polarity	Age (Ma)	Position in Chron	New Zealand Stage	*Catapsydrax parvulus*
26X	2	30	35	231.80	249.24		6.833		early Tk	X
26X	2	130	135	232.80	251.74		6.901		late Tt	X
					253.6		?			Base unidentified interval of normal polarity
26X	3	80	85	233.80	254.24		6.970		late Tt	X
27X	1	10	13	239.70	254.50		6.977		late Tt	X
27X	1	100	105	240.60	255.40		7.001		late Tt	X
27X	2	50	55	241.60	256.40		7.029		late Tt	X
27X	3	0	5	242.60	257.40		7.056		late Tt	X
27X	3	100	105	243.60	258.40		7.084		late Tt	X
27X	4	50	55	244.60	259.40		7.111		late Tt	
27X	6	50	55	247.60	262.40		7.193		late Tt	X
27X	7	0	5	248.60	263.40		7.220		late Tt	
28X	1	40	45	249.60	264.40		7.248		late Tt	
28X	1	140	145	250.60	265.40		7.275		late Tt	X
28X	2	88	93	251.58	266.38		7.302		late Tt	
28X	3	40	45	252.60	267.40		7.330		late Tt	
					267.8		7.341			Base Chron C3Br.2r
28X	3	140	145	253.60	268.40		7.346	0.15	late Tt	
28X	4	90	95	254.60	269.40		7.355	0.40	late Tt	
28X	5	40	45	255.60	270.40		7.363	0.65	late Tt	
28X	5	140	145	256.60	271.40		7.372	0.90	late Tt	
					271.8		7.375			Base Chron C3Br.2n
28X	6	90	95	257.60	272.40		7.393	0.32	late Tt	X
28X	7	0	5	258.20	273.00		7.411	0.63	late Tt	X
					273.7		7.432			Base Chron C3Br.3r
29X	1	80	85	259.60	274.40		7.446	0.10	late Tt	X
29X	2	30	35	260.60	275.40		7.465	0.25	late Tt	X
29X	2	130	135	261.60	276.40		7.484	0.40	late Tt	X
29X	3	80	83	262.60	277.40		7.504	0.55	late Tt	
29X	4	30	35	263.60	278.40		7.523	0.70	late Tt	X
29X	4	130	135	264.60	279.40		7.543	0.85	late Tt	
29X	5	78	83	265.47	280.27		7.559	0.98	late Tt	
					280.4		7.562			Base Chron C4n.1n
29X	6	30	35	266.60	281.40		7.606	0.50	late Tt	X
29X	6	130	135	267.60	282.40		7.650	1.00	late Tt	X
					282.4		7.650			Base Chron C4n.1r
30X	1	20	25	268.60	283.40		7.679	0.07	late Tt	X
30X	1	70	75	269.10	283.90		7.693	0.10	late Tt	X
30X	1	120	125	269.60	284.40		7.707	0.14	late Tt	X
30X	2	20	25	270.10	284.90		7.722	0.17	late Tt	X
30X	2	70	75	270.60	285.40		7.736	0.20	late Tt	
30X	2	120	125	271.10	285.90		7.750	0.24	late Tt	X
30X	3	30	35	271.70	286.50		7.768	0.28	late Tt	
30X	3	70	75	272.10	286.90		7.779	0.31	late Tt	
30X	3	120	125	272.60	287.40		7.794	0.34	late Tt	X
30X	4	20	25	273.10	287.90		7.808	0.37	late Tt	X
30X	4	70	75	273.60	288.40		7.822	0.41	late Tt	X
30X	4	120	125	274.10	288.90		7.837	0.44	late Tt	X
30X	5	20	25	274.60	289.40		7.851	0.48	late Tt	X
30X	5	67	72	275.07	289.87		7.864	0.51	late Tt	X
30X	5	120	125	275.60	290.40		7.880	0.54	late Tt	X
30X	6	20	25	276.10	290.90		7.894	0.58	late Tt	X
30X	6	70	75	276.60	291.40		7.908	0.61	late Tt	X
30X	6	120	125	277.10	291.90		7.923	0.65	late Tt	X
30X	7	20	25	277.60	292.40		7.937	0.68	late Tt	X
31X	1	0	5	278.10	292.90		7.951	0.71	late Tt	X
31X	1	47	51	278.57	293.37		7.965	0.75	late Tt	X
31X	1	100	105	279.10	293.90		7.980	0.78	late Tt	X
31X	2	0	5	279.60	294.40		7.994	0.82	late Tt	X
31X	2	50	55	280.10	294.90		8.009	0.85	late Tt	X
31X	2	100	105	280.60	295.40		8.023	0.88	late Tt	X
31X	3	0	5	281.10	295.90		8.038	0.92	late Tt	X
31X	3	50	55	281.60	296.40		8.052	0.95	late Tt	X
31X	3	100	105	282.10	296.90		8.066	0.99	late Tt	X
					297.1		8.072			Base Chron C4n.2n
31X	4	0	5	282.60	297.40		8.080	0.05	late Tt	X
31X	4	50	55	283.10	297.90		8.094	0.14	late Tt	X
31X	4	100	105	283.60	298.40		8.108	0.23	late Tt	X
31X	5	0	5	284.10	298.90		8.121	0.32	late Tt	X
31X	5	50	55	284.60	299.40		8.135	0.41	late Tt	X
31X	5	100	105	285.10	299.90		8.149	0.50	late Tt	X
31X	6	0	5	285.60	300.40		8.162	0.59	late Tt	X
31X	6	50	55	286.10	300.90		8.176	0.68	late Tt	X
31X	6	100	105	286.60	301.40		8.189	0.77	late Tt	X
31X	7	0	5	287.10	301.90		8.203	0.86	late Tt	X
32X	1	0	5	287.70	302.50		8.220	0.96	late Tt	X
					302.7		8.225			Base Chron C4r.1r
32X	1	50	55	288.20	303.00		8.244	0.60	late Tt	X

| SAMPLES HOLE 1123B | | | | | | | | | | | PLANKTIC FORAMINIFERAL DISTRIBUTION (presence/absence) | | | | | | | | | | |

| SAMPLES HOLE 1123B | | | | | | | | | | PLANKTIC FORAMINIFERAL DISTRIBUTION (presence/absence) | | | | | | | | | |

| SAMPLES HOLE 1123B | | | | | | | | | | | PLANKTIC FORAMINIFERAL DISTRIBUTION (presence/absence) | | | | | | | | | | |

SAMPLES HOLE 1123B											BOLBOFORM DISTRIBUTION								P/B DATA			COILING		
Core	Section	Interval (top)	Interval (bottom)	Depth (mbsf)	Depth (mcd) - G Wilson March 2002	Polarity	Age (Ma)	Position in Chron	New Zealand Stage	*Sphaeroidinellopsis seminulina*	*Tenuitella clemenciae*	*Truncorotalia crassaconica*	*Truncorotalia crassaformis*	*Truncorotalia* aff. *crassaformis*	*Truncorotalia juanai*	*Truncorotalia tonda*	*Zeaglobigerina apertura*	*Zeaglobigerina decoraperta*	*Zeaglobigerina druryi / nepenthes*	*Zeaglobigerina woodi*	*Zeaglobigerina* sp.	Planktic species (n)	*Bolboforma subfragoris* s.l.	*Bolboforma* sp. H	*Bolboforma capsula*	*Bolboforma pentaspinosa*	*Bolboforma gracilireticulata* s.l.	*Bolboforma metzmacheri* s.s.	*Bolboforma metzmacheri ornata*	*Bolboforma praeintermedia*	Planktic foraminifers (n)	Benthic foraminifers (n)	Percentage planktics (%)	*Globoconella miotumida* gp (sinistral)	*Globoconella miotumida* gp (dextral)	Dextral *G. miotumida* gp (%)
					156.4		4.290																												
					167.0		?																												
					169.7		?																												
18X	1	10	15	155.50	170.30		4.671		early Wo			?	X								X	X	16								212	31	87			
18X	1	100	105	156.40	171.20		4.695		early Wo						?							X	12								219	16	93			
18X	2	50	55	157.40	172.20		4.723		early Wo												X	X	12								187	49	79			
18X	3	0	5	158.40	173.20		4.750		early Wo						?							X	12								166	77	68			
18X	4	100	105	160.90	175.70		4.819		early Wo				X	?							X	X	13								205	19	92			
18X	5	0	5	161.40	176.20		4.832		early Wo				X	?							X	X	13								196	40	83			
18X	5	100	105	162.40	177.20		4.860		early Wo	X											X	X	10								122	105	54			
18X	6	5	10	162.95	177.75		4.875		early Wo				X						X		X	X	17								144	118	55			
19X	1	100	105	163.70	178.50		4.895		early Wo												X		10								126	129	49			
19X	2	100	105	165.22	180.02		4.937		early Wo				X						X		X	X	12								134	92	59			
19X	3	100	105	166.74	181.54		4.979		early Wo				X		?						X	X	13								197	36	85			
19X	4	100	105	168.26	183.06		5.020		early Wo					?	?							X	14								199	26	88			
19X	5	0	5	168.78	183.58		5.034		early Wo	X			X		?						X	X	16								167	68	71			
19X	5	100	105	169.78	184.58		5.062		early Wo	?			X	?		?		X			X	X	19								259	52	83			
19X	6	0	5	170.30	185.10	DISTURBED	5.076		early Wo	X			X	X						X	X	X	17								171	37	82			
19X	7	0	5	170.82	185.62		5.090		early Wo				X	?	X					?	X	X	19								257	36	88			
20X	1	10	14	172.40	187.20		5.134		early Wo				X	?	X						X	X	17								141	210	40			
20X	1	100	105	173.30	188.10		5.158		early Wo												X	X	12								45	176	20			
20X	2	9	14	173.91	188.71		5.175		early Wo					X	X						X	X	15								80	154	34			
20X	3	0	5	175.34	190.14		5.214		early Wo						X					?	X	X	13								43	191	18			
20X	4	50	55	177.36	192.16		5.269		early Wo			X									?	X	13								116	103	53	31	0	0.0
20X	5	0	5	178.36	193.16		5.297		late Tk			X			X				X	X	X	X	X								125	118	51	24	1	4.0
20X	5	100	105	179.36	194.16		5.324		late Tk			X		X	X		X	X	X	X	X	18								160	78	67	88	2	2.2
20X	6	50	55	180.38	195.18		5.352		late Tk						X		X				?	X	12								244	237	51	80	2	2.4
20X	7	0	5	181.40	196.20		5.380		late Tk						X		X				X	X	14								182	44	81	70	2	2.8
21X	1	40	45	182.30	197.10		5.405		late Tk			X			X						X	X	14								92	136	40	115	3	2.5
21X	2	90	95	184.30	199.10		5.459		late Tk												X	X	12								111	134	45	115	2	1.7
21X	3	40	45	185.30	200.10		5.487		late Tk						X					?	X	X	14								123	114	52	115	3	2.5
21X	3	140	145	186.30	201.10		5.514		late Tk						?						X	X	12								112	125	47	97	3	3.0
					202.0		?																												
21X	4	88	93	187.28	202.08		5.541		early Tk	?											X	X	12								122	119	51	115	0	0.0
21X	5	40	45	188.30	203.10		5.569		early Tk	X					?					X	?	X	13								167	63	73	115	1	0.9
21X	5	140	145	189.30	204.10		5.596		early Tk													X	10								74	143	34	87	3	3.3
21X	6	90	95	190.30	205.10		5.624		early Tk	X										X	X	X	22								213	30	88	96	3	3.0
21X	7	0	5	190.90	205.70		5.640		early Tk	X										X	X	X	19								216	37	85	91	3	3.2
					205.9		?																												
22X	1	66	77	192.26	207.06		5.677		early Tk	X								X		X	X	X	22								227	59	79	81	2	2.4
22X	1	140	145	193.00	207.80		5.698		early Tk											X		X	15								84	158	35	115	1	0.9
22X	2	120	125	194.37	209.17		5.735		early Tk	X					?							X	9								40	182	18	30	0	0.0
22X	3	73	76	195.40	210.20		5.763		early Tk						?						X	X	9								112	129	46	115	1	0.9
22X	4	20	25	196.37	211.17		5.790		early Tk											?	X	X	12								101	134	43	115	0	0.0
22X	4	120	125	197.37	212.17		5.817		early Tk												X	X	12								115	116	50	115	4	3.4
22X	5	70	75	198.37	213.17		5.845		early Tk											?	X	X	11								123	112	52	115	3	2.5
22X	6	16	20	199.33	214.13		5.871		early Tk												X	X	12								146	99	60	115	1	0.9
22X	6	120	125	200.37	215.17		5.900		early Tk											X	X	X	12								102	134	43	115	3	2.5
23X	1	10	14	201.30	216.11		5.925		early Tk												X	X	8								145	96	60	115	1	0.9
23X	1	110	115	202.30	217.38		5.960		early Tk											X	X	X	11								172	79	69	115	10	8.0
23X	2	10	14	202.80	218.02		5.978		early Tk												X	X	9								138	104	57	86	4	4.4
23X	2	110	115	203.80	219.29		6.012		early Tk											?	X	X	7								107	117	48	33	1	2.9
23X	3	10	14	204.30	219.92		6.030		early Tk	X										X	X	X	11								59	52	53	3	0	0.0
23X	3	110	115	205.30	221.19		6.065		early Tk											?	X	X	9								104	159	40	51	3	5.6
23X	4	60	65	206.30	222.46		6.099		early Tk	X											X	X	8								97	76	56	34	1	2.9
23X	5	10	14	207.30	223.73		6.134		early Tk												X	X	10								120	152	44	91	3	3.2
23X	5	110	115	208.30	225.00		6.169		early Tk	X											X	X	12								170	160	52	73	2	2.7
24X	1	10	14	210.90	225.70		6.188		early Tk	X										?	X	X	7								35	121	22	20	0	0.0
24X	1	110	115	211.90	226.70		6.215		early Tk											X	X	X	11								101	127	44	105	5	4.5
24X	2	50	55	212.80	227.60		6.240		early Tk	X					X				?	X		X	15								188	67	74	115	4	3.4
24X	3	0	5	213.80	228.60		6.267		early Tk	X					X					?	X	X	11								88	138	39	68	1	1.4
24X	3	100	105	214.80	229.60		6.295		early Tk	X					X						X	X	13								148	77	66	115	2	1.7
24X	5	0	5	216.80	231.60		6.350		early Tk						X					?	X	X	13								112	141	44	96	0	0.0
24X	5	100	105	217.80	232.60		6.377		early Tk	X							?			X	X	X	13								140	92	60	115	2	1.7
24X	6	50	55	218.80	233.60		6.404		early Tk	?							?					X	11								113	128	47	57	3	5.0
24X	7	0	5	219.80	234.60		6.432		early Tk												X	X	10								96	161	37	115	1	0.9
25X	1	40	45	220.80	235.60		6.459		early Tk	X											X	X	10								59	41	59	115	0	0.0
					236.5		?																												
25X	1	136	140	221.76	236.56		6.485		early Tk												X	X	8								49	51	49	59	0	0.0
25X	2	90	95	222.80	237.60		6.514		early Tk	X					X						X	X	14								46	54	46	89	4	4.3
25X	3	40	45	223.80	238.60		6.541		early Tk						X						X	X	12								49	51	49	115	3	2.5
25X	3	140	145	224.80	239.60		6.569		early Tk	X					X						X	X	15								63	37	63	115	2	1.7
25X	4	90	95	225.80	240.60		6.596		early Tk						X						X	X	11								55	45	55	115	2	1.7
25X	5	40	45	226.80	241.60		6.623		early Tk						X						X	X	8								48	52	48	115	5	4.2
25X	5	140	145	227.80	242.60		6.651		early Tk	X					X					?		X	11								44	56	44	115	1	0.9
25X	6	90	95	228.80	243.60		6.678		early Tk						X						X	X	11								47	53	47	96	0	0.0
25X	7	0	5	229.40	244.20		6.695		early Tk						X								9								42	58	42	115	0	0.0
26X	1	80	85	230.80	246.74		6.764		early Tk	X					X					X	X	X	13								52	48	52	84	0	0.0

| SAMPLES HOLE 1123B | | |

SAMPLES HOLE 1123B																							BOLBOFORM DISTRIBUTION								P/B DATA			COILING		
Core	Section	Interval (top)	Interval (bottom)	Depth (mbsf)	Depth (mcd) - G Wilson March 2002	Polarity	Age (Ma)	Position in Chron	New Zealand Stage	*Sphaeroidinellopsis seminulina*	*Tenuitella clemenciae*	*Truncorotalia crassaconica*	*Truncorotalia crassaformis*	*Truncorotalia* aff. *crassaformis*	*Truncorotalia juanai*	*Truncorotalia ronda*	*Zeaglobigerina apertura*	*Zeaglobigerina decoraperta*	*Zeaglobigerina druryi / nepenthes*	*Zeaglobigerina woodi*	*Zeaglobigerina* sp.	Planktic species (n)	*Bolboforma subfragoris* s.l.	*Bolboforma* sp H	*Bolboforma capsula*	*Bolboforma pentaspinosa*	*Bolboforma gracilreticulata* s.l.	*Bolboforma metzmacheri* s.s.	*Bolboforma metzmacheri ornata*	*Bolboforma praeintermedia*	Planktic foraminifers (n)	Benthic foraminifers (n)	Percentage planktics (%)	*Globoconella miotumida* gp (sinistral)	*Globoconella miotumida* gp (dextral)	Dextral *G. miotumida* gp (%)
					303.2		8.257																													
32X	1	100	105	288.70	303.50		8.264	0.02	late Tt										?	X	X	6									45	55	45	115	0	0.0
32X	2	0	5	289.20	304.00		8.276	0.04	late Tt										X	X	X	7									62	38	62	115	4	3.4
32X	2	50	55	289.70	304.50		8.288	0.07	late Tt										X	X	X	6							10		56	44	56	78	0	0.0
32X	2	100	105	290.20	305.00		8.300	0.10	late Tt										X	X	X	6							3		57	43	57	54	1	1.8
32X	3	0	5	290.70	305.50		8.312	0.12	late Tt										X		X	7							57		33	67	33	52	0	0.0
32X	3	50	55	291.20	306.00		8.324	0.15	late Tt										X	X	X	7							30		54	46	54	115	1	0.9
32X	3	100	105	291.70	306.50		8.336	0.18	late Tt										X		X	4							6		22	78	22	32	1	3.0
32X	4	0	5	292.20	307.00		8.348	0.21	late Tt										X		X	6							43		28	72	28	56	0	0.0
32X	4	50	55	292.70	307.50		8.360	0.23	late Tt										X		X	5									49	51	49	115	1	0.9
32X	4	100	105	293.20	308.00		8.372	0.26	late Tt										X		X	7							14		51	49	51	115	4	3.4
32X	5	0	5	293.70	308.50		8.384	0.29	late Tt										X	?	X	9							8		25	75	25	78	1	1.3
32X	5	50	55	294.20	309.00		8.396	0.31	late Tt										X	X		7							60		28	72	28	76	0	0.0
32X	5	100	105	294.70	309.50		8.408	0.34	late Tt										X		X	8							50		33	67	33	70	0	0.0
32X	6	0	5	295.20	310.00		8.419	0.37	late Tt	X									X	X	X	7							3		43	57	43	86	1	1.1
32X	6	50	55	295.70	310.50		8.431	0.39	late Tt	X									X	X	X	11							2		80	20	80	115	1	0.9
33X	1	10	15	297.40	312.20		8.472	0.49	late Tt	X									X	X	X	9									67	33	67	115	1	0.9
33X	1	50	55	297.80	312.60		8.482	0.51	late Tt										X	X	X	11									58	42	58	115	1	0.9
33X	1	100	105	298.30	313.10		8.494	0.54	late Tt										X	X	X	8									56	44	56	115	2	1.7
33X	2	0	5	298.80	313.60		8.505	0.56	late Tt	X					?				X	X	X	7									62	38	62	115	3	2.5
33X	2	50	55	299.30	314.10		8.517	0.59	late Tt	X									X	X	X	11									76	24	76	115	2	1.7
33X	2	100	105	299.80	314.60		8.529	0.62	late Tt										?		X	8									80	20	80	115	3	2.5
33X	3	0	5	300.30	315.10		8.541	0.64	late Tt										X	X	X	10									54	46	54	115	4	3.4
33X	3	50	55	300.80	315.60		8.553	0.67	late Tt	X									X	X	X	12									68	32	68	115	2	1.7
33X	3	100	105	301.30	316.10		8.565	0.70	late Tt	X									?		X	10									36	64	36	68	2	2.9
33X	4	0	5	301.80	316.60		8.577	0.72	late Tt											X	X	6									83	17	83	115	0	0.0
33X	4	50	55	302.30	317.10		8.589	0.75	late Tt										X		X	7									44	56	44	86	1	1.1
33X	4	100	105	302.80	317.60		8.601	0.78	late Tt										X	X	X	10									52	48	52	115	0	0.0
33X	5	0	5	303.30	318.10		8.613	0.81	late Tt										X	X	X	6									27	73	27	18	0	0.0
33X	5	50	55	303.80	318.60		8.625	0.83	late Tt										X		X	5									37	63	37	115	3	2.5
33X	5	100	105	304.30	319.10		8.637	0.86	late Tt										X	X	X	8									48	52	48	115	1	0.9
33X	6	0	5	304.80	319.60		8.649	0.89	late Tt											X	X	9									50	50	50	115	0	0.0
33X	6	50	55	305.30	320.10		8.661	0.91	late Tt	?									X		X	9									34	66	34	48	1	2.0
33X	6	100	105	305.80	320.60		8.673	0.94	late Tt										X	X	X	8									44	56	44	115	0	0.0
33X	7	0	5	306.30	321.10		8.685	0.97	late Tt										?	X	X	7									30	70	30	115	0	0.0
					321.7		8.699																													
34X	1	10	15	307.00	321.80	■	8.703	0.01	late Tt	X										X	X	8									71	29	71	115	4	3.4
34X	1	50	55	307.40	322.20	■	8.717	0.05	late Tt	X										?	X	9									50	50	50	121	2	1.6
34X	1	100	105	307.90	322.70	■	8.734	0.11	late Tt	X									X	X	X	9									72	28	72	115	0	0.0
34X	2	0	5	308.40	323.20	■	8.752	0.16	late Tt										X	X	X	7									55	45	55	115	0	0.0
34X	2	50	55	308.90	323.70	■	8.769	0.22	late Tt										X	X	X	9									69	31	69	93	1	1.1
34X	2	100	105	309.40	324.20	■	8.787	0.27	late Tt										X	X	X	8						1			69	31	69	115	2	1.7
34X	3	0	5	309.90	324.70	■	8.804	0.32	late Tt	X									X	X	X	9						1			79	21	79	115	0	0.0
34X	3	50	55	310.40	325.20	■	8.822	0.38	late Tt	X									X		X	8									68	32	68	104	2	1.9
34X	3	100	105	310.90	325.70	■	8.839	0.43	late Tt	X									X	X	X	11						4			60	40	60	76	0	0.0
34X	4	0	5	311.40	326.20	■	8.857	0.48	late Tt										X	X	X	7									66	34	66	115	0	0.0
34X	4	50	53	311.90	326.70	■	8.874	0.54	late Tt										X	X	X	8						1			75	25	75	32	4	11.1
34X	4	100	105	312.40	327.20	■	8.892	0.59	early Tt	?									X	X	X	10						1			83	17	83	115	2	1.7
34X	5	0	5	312.90	327.70	■	8.909	0.65	early Tt										X	X	X	10									80	20	80	115	3	2.5
34X	5	50	55	313.40	328.20	■	8.927	0.70	early Tt	X									X	X	X	12									90	10	90	115	3	2.5
34X	5	100	105	313.90	328.70	■	8.944	0.75	early Tt										X	•	X	7						3			58	42	58	115	2	1.7
34X	6	0	5	314.40	329.20	■	8.962	0.81	early Tt	X									X		X	9						2			67	33	67	115	2	1.7
34X	6	50	55	314.90	329.70	■	8.979	0.86	early Tt												X	3						9			78	22	78	115	3	2.5
34X	6	100	105	315.40	330.20	■	8.997	0.91	early Tt										X		X	8						14			30	70	30	18	1	5.3
34X	7	0	5	315.90	330.70	■	9.014	0.97	early Tt										X		X	6									25	75	25	11	0	0.0
					331.0		9.025																													
35X	1	10	15	316.60	331.40		9.040	0.07	early Tt										X		X	8									52	48	52	98	1	1.0
35X	1	50	55	317.00	331.80		9.054	0.14	early Tt										X		X	8									55	45	55	95	0	0.0
35X	1	100	105	317.50	332.30		9.073	0.23	early Tt	X									X	X	X	8									49	51	49	30	0	0.0
35X	2	0	5	318.00	332.80		9.091	0.32	early Tt										X		X	8									24	76	24	28	1	3.4
35X	2	50	55	318.50	333.30		9.109	0.41	early Tt										X	?	X	10									43	57	43	13	0	0.0
35X	2	100	105	319.00	333.80		9.128	0.50	early Tt										X	X	X	8									41	59	41	34	0	0.0
35X	3	0	5	319.50	334.30		9.146	0.59	early Tt										X		X	8									29	71	29	51	0	0.0
35X	3	50	55	320.00	334.80		9.164	0.68	early Tt										X		X	8									25	75	25	34	1	2.9
35X	3	100	105	320.50	335.30		9.182	0.77	early Tt										?		X	7									31	69	31	64	2	3.0
35X	4	0	5	321.00	335.80		9.201	0.86	early Tt										X		X	8									43	57	43	98	4	3.9
35X	4	50	55	321.50	336.30		9.219	0.95	early Tt										X	X	X	6									26	74	26	18	1	5.3
					336.6		9.230																													
35X	4	100	105	322.00	336.80	■	9.234	0.05	early Tt												X	4									17	83	17	28	1	3.4
35X	5	0	5	322.50	337.30	■	9.243	0.17	early Tt										X		X	6									22	78	22	18	1	5.3
35X	5	50	55	323.00	337.80	■	9.253	0.29	early Tt										X	X		7									18	82	18	18	1	5.3
35X	5	101	106	323.51	338.31	■	9.263	0.42	early Tt										X		X	6									33	67	33	77	1	1.3
35X	6	0	5	324.00	338.80	■	9.272	0.54	early Tt										X	X	X	7									45	55	45	118	1	0.8
35X	6	50	55	324.50	339.30	■	9.281	0.66	early Tt										X	X	X	8									14	86	14	29	0	0.0
35X	6	100	105	325.00	339.80	■	9.291	0.78	early Tt										X	X	X	9									48	52	48	60	2	3.2
35X	7	0	5	325.50	340.30	■	9.300	0.90	early Tt										X	X	X	10									36	64	36	78	1	1.3
					340.7		9.308																													
36X	1	10	14	326.00	340.80		9.316	0.03	early Tt											X	X	5									22	78	22	16	1	5.9

| SAMPLES HOLE 1123B | | |

| SAMPLES HOLE 1123B | | |

Study 6

A refined biochronology for New Zealand late Miocene planktic foraminifers and bolboforms based on robust biostratigraphically constrained age models for DSDP Site 593

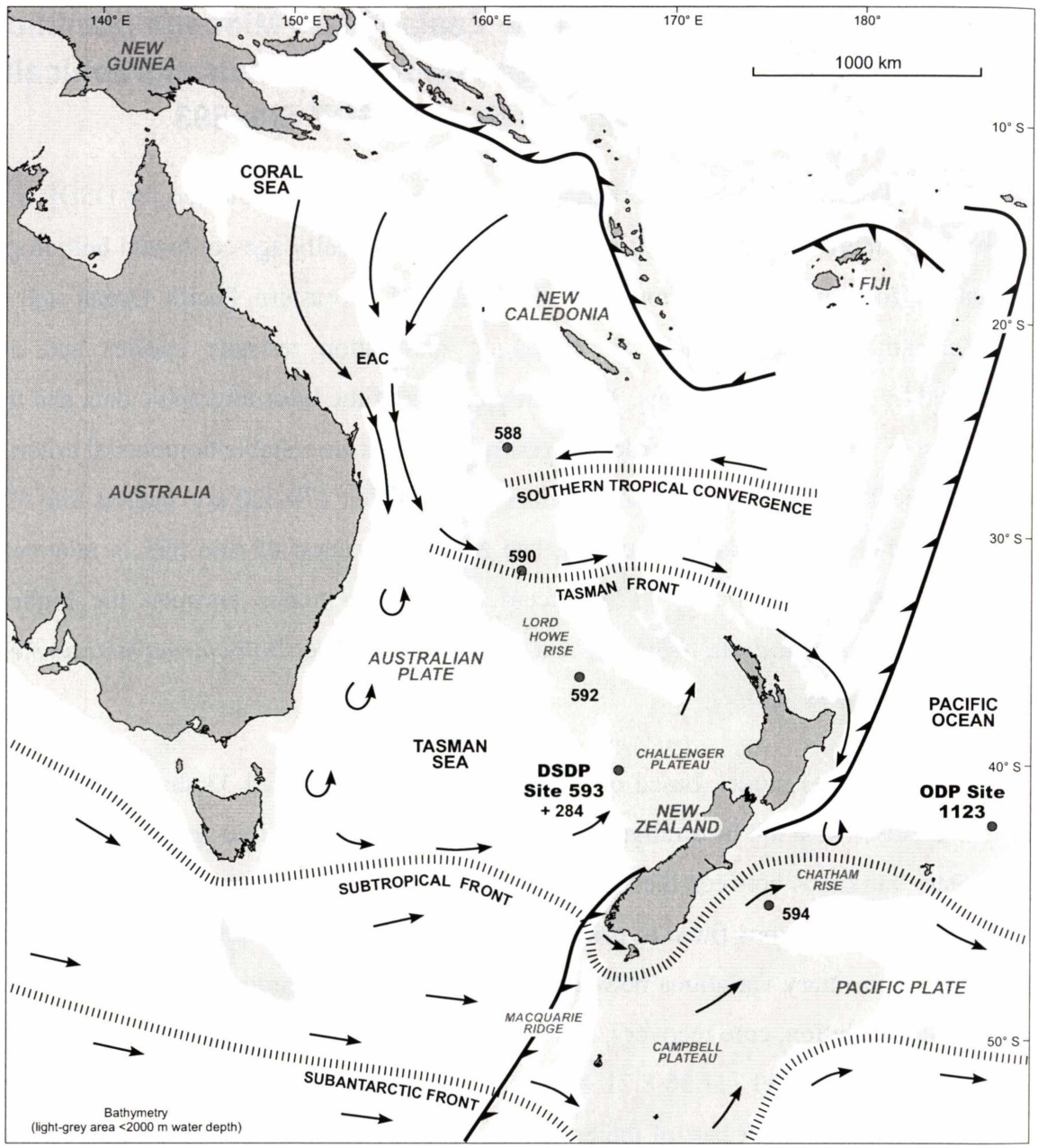
A refined biochronology for New Zealand late Miocene planktic foraminifers and bolboforms based on robust biostratigraphically constrained age models for DSDP Site 593

ABSTRACT: Well-founded late Miocene age models have been established for DSDP Site 593 in the southern Tasman Sea, using magnetostratigraphically age-calibrated bolboform and planktic foraminiferal data from ODP Site 1123, off the eastern, Pacific Ocean side of New Zealand. The age models are based on dissolution resistant species and are constrained by 33-shared bioevents. The tight grouping of the biostratigraphic data and the consistency of their stratigraphic order suggest most events are reliable homotaxial criteria, except for the Tukemokihi Coiling Zone which occurs about 170-320 k.y. later at Site 593 than at Site 1123. They also suggest the late Miocene section of Site 593 is relatively complete with respect to Site 1123, except for a short hiatus between the highest occurrence of *Globoquadrina dehiscens* and the top of the upper *Bolboforma metzmacheri* subzone (c. 8.87-8.78 Ma).

A linear age (L-Age) model, based on a regression line fitted to all 33-shared bioevents, provides a close fit to the biostratigraphic data, but does not take into account short-term sedimentary variations between the sections. An alternative segmented age (S-Age) model, based on linear regressions fitted to pairs of shared bioevents, accommodates hiatuses and short-term sedimentary variations between the sections, and biostratigraphic error derived from sample resolution, core recovery, and fossil preservation and identification. The older part of the S-Age model (11.56-8.21 Ma) is constrained by 22-pairs of closely-spaced bioevents, and the younger part of the S-Age model (8.21-3.58 Ma) is constrained by two widely-spaced chronostratigraphic tie-points – the highest occurrence of *Bolboforma praeintermedia* and the base of Chron C2An.3n.

The new biochronostratigraphic framework for Site 593 has enabled interpolated ages to be assigned to 36 bioevents that are poorly defined or missing at Site 1123, and have not been reliably dated before. This effectively doubles the number of late Miocene bioevents from the greater New Zealand region that have been correlated either directly or indirectly with the geomagnetic polarity time scale (GPTS-95).

Keywords: bolboforms; planktic foraminifers; biostratigraphy; age model; DSDP Site 593; ODP Site 1123; time scale; late Miocene, New Zealand.



Modern oceanic fronts and surface water masses after Cooke (2002)	Abbreviation	Neogene biogeography Kennett & Srinivasan (1983)		Late Miocene biogeography (THIS STUDY)	Example
		Subtropical		Subtropical	Site 588
SOUTHERN TROPICAL CONVERGENCE	**- STC -**	**- STC -**	┐	**- STC -**	**- STC -**
Warm Subtropical Water	WSTW	Transitional	Cool		Site 590
TASMAN FRONT	**- TF -**	**- TF -**	subtropical	Temperate	**- TF -**
Cool Subtropical Water	CSTW	Temperate	assemblage		Sites 592, 593, 1123
SUBTROPICAL FRONT	**- STF -**	**- STF -**	┘	**- STF -**	**- STF -**
Subantarctic Surface Water	SASW				Site 594
SUBANTARCTIC FRONT	**- SAF -**	Subantarctic		Subantarctic	**- SAF -**
Circumpolar Surface Water	CSW				Site 278 (56°33.7'S; 160°04.5'E)

Figure 6.1 – Location map of Sites 593 and 1123. Modern bathymetry, oceanic fronts, and general circulation of surface water in the Southwest Pacific region, after Heath (1985). EAC = East Australian Current. The relationships between modern oceanic fronts and surface water masses, and the biogeography of planktic foraminifers, are given in the table beneath the location map.

INTRODUCTION

DSDP Site 593 was drilled as a reoccupation of Site 284 during Leg 90 of the Deep Sea Drilling Project. It is a relatively shallow oceanic site (1068 m) on the western margin of Challenger Plateau, in the southern Tasman Sea (Figure 6.1). The site includes a very well preserved record of Neogene cool subtropical (temperate) calcareous microfossil assemblages, and it is an important Neogene biostratigraphic and paleoceanographic reference section for southern mid-latitudes (Kennett et al. 1986). Dating of the Neogene section is very poor, however, particularly in the late Miocene where there are no magnetostratigraphic data (Barton & Bloemendal 1986) or other well constrained independent age data (e.g. tephra horizons). Chronologies in this part of the section are generally based on a small number of tenuous biostratigraphic and stable isotope correlations with dated horizons or interpolated horizons in onland New Zealand (e.g. Head & Nelson 1994; Schneider & Kennett 1996) and biochronostratigraphic data from outside the greater New Zealand region (Lazarus et al. 1995; Spencer-Cervato 1999).

The Neogene biostratigraphy of Site 593 has been very well documented. Jenkins & Srinivasan (1986), Hoskins 1990, and Scott (1992; 1995) reported the planktic foraminiferal biostratigraphy, Lohmann (1986) reported the calcareous nannofossils biostratigraphy, and Grützmacher (1993) reported the bolboform biostratigraphy. Schneider & Kennett (1996) have also studied interspecies habitat differences within the planktic foraminiferal clade *Globoconella,* and high-resolution studies of late Miocene planktic foraminifers and bolboforms have been reported here for the first time, in Studies 2 and 3. The site is also an important Neogene oxygen and carbon isotope reference section (Head & Nelson 1994; Cooke 2002) and strontium isotope reference section (Hess et al. 1986; McArthur et al. 2001) for southern mid-latitudes. Cooke (2002) has also reported on aspects of Neogene paleoceanography.

Despite the intensive study of Site 593, the poorly constrained chronology has hampered the correlation of late Miocene faunal and stable isotope data with similar data from outside the greater New Zealand region. Integration of such data on a precise temporal scale is important if we are to gain a reliable southern mid-latitude perspective of paleoceanographic changes, including planktic biogeographic development, rates of organic evolution, and the history of biogenic productivity in the period leading up to and including the Mediterranean Salinity Crisis. To improve the correlation of such data, an age/depth model has been constructed for Site 593 using magnetostratigraphically age-

calibrated bolboform and planktic foraminiferal data from Site 1123 (Study 5) based on dissolution-resistant taxa. The new age model enables interpolated ages to be assigned to bioevents from Site 593 that are poorly defined or missing at Site 1123 due to dissolution, including bioevents that have not been reliably dated before.

Biostratigraphic data

The biostratigraphy of Site 593 is based on data reported in Studies 2 and 3. These include a total of 69 planktic foraminiferal and bolboform bioevents that are potentially useful for correlation (Appendix 6.1). All depths for the site are given in metres below sea floor (mbsf). Biostratigraphic data from the dissolution affected late Miocene section at Site 1123 (Study 5) include 33 bolboform and planktic foraminiferal events that have been integrated with the site's magnetostratigraphic record and age-calibrated with respect to the geomagnetic polarity time scale (GPTS-95: Berggren et al. 1995b; Cande & Kent 1992, 1995). These same events are shared by Site 593. All depths for Site 1123 relate to the emended composite section and are given in revised metres composite depth (r-mcd) (Wilson pers. comm. June 2002).

The biostratigraphic construct is based on the mid-points between the depths of samples that define bioevents and the depths of samples that precede or proceed bioevents, depending upon whether these are a first or last occurrence (Appendix 6.1). Where abundance spikes are used, the average depth of samples adjacent to the species maximum abundance is used rather than the actual depth of the bioevent (e.g. the abundance spike at Site 593 which is associated with the lower *Bolboforma metzmacheri* s.s. subzone).

Paleoceanographic setting

Sites 593 and 1123 are located at similar latitudes, but more than 1500 km apart, off opposite sides of New Zealand (Figure 6.1). Both sites lie north of the modern Subtropical Front, although Site 593 (1068 m) is much shallower than Site 1123 (3290 m) and they are affected by different water masses. Site 593 is overlain by Cool Subtropical Water, Subantarctic Mode Water, and the seafloor is bathed by Antarctic Intermediate Water (Wyrtki 1962; Stanton 1969; Heath 1985). Site 1123 is overlain by a more complex system of water masses comprising surface waters that are a variable mix of Warm and Cool Subtropical Waters, Subantarctic Mode Water, Antarctic Intermediate Water, and corrosive bottom waters of the Deep Western Boundary Current (Shipboard Scientific Party 1999a).

Despite seafloor spreading between Australia and Antarctic shifting the western side of the New Zealand continental landmass (including Site 593) northwards by as much as 5° of latitude since the beginning of the late Miocene (Weissel et al. 1977; Sutherland 1995), and there being substantial Neogene deformation of the New Zealand continent, along the Alpine Fault (Sutherland 1995), a broadly similar paleoceanographic regime to that of the present-day has operated throughout the late Neogene (Edwards 1975; Nelson & Cooke 2001).

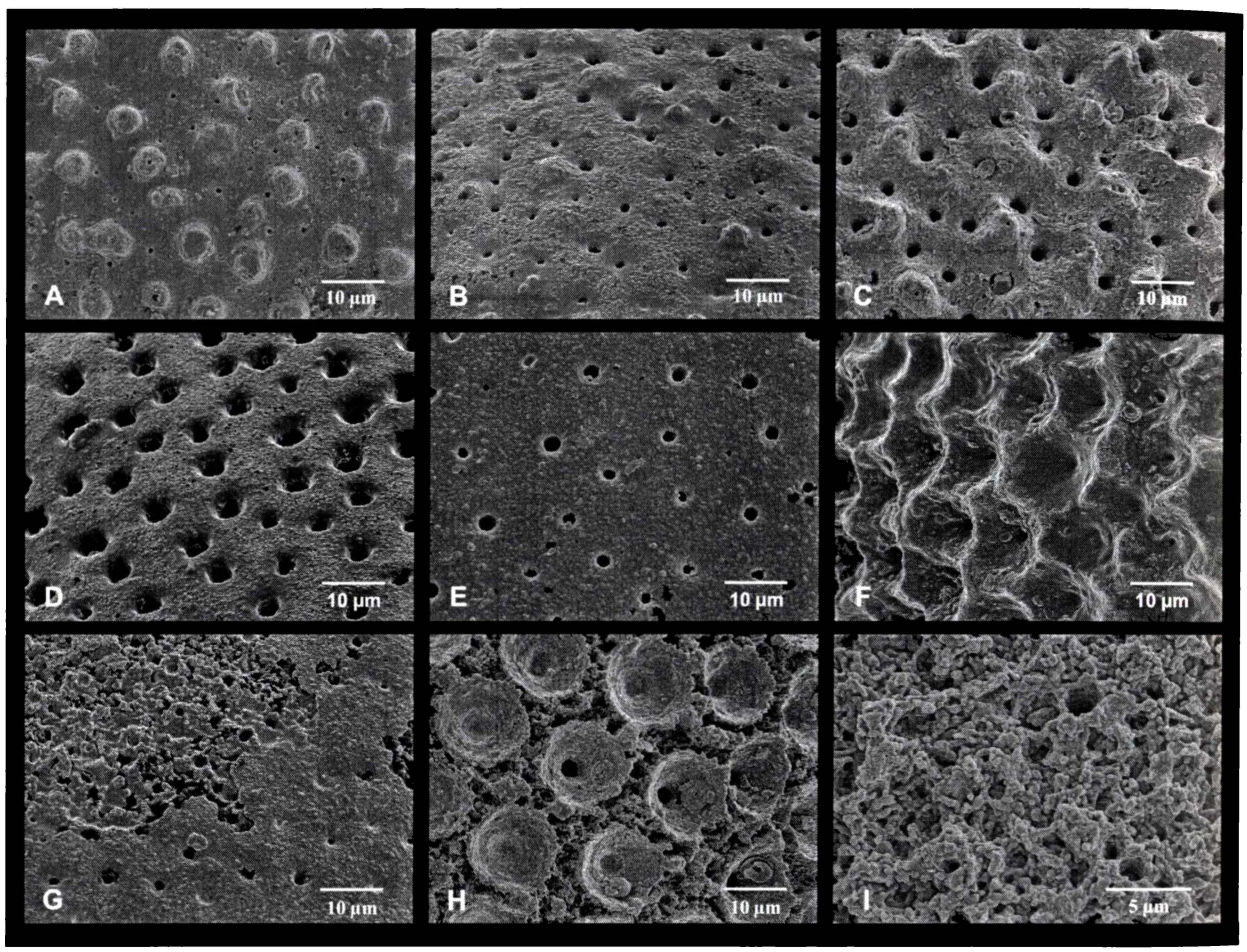
Lithostratigraphy and microfossil preservation

The thick section of Neogene sediments at Site 593 comprises largely undifferentiated nannofossil ooze or foraminifer-bearing nannofossil ooze (>95% calcium carbonate) (Nelson 1986). Late Miocene planktic foraminifers and bolboforms are very well preserved, and the wall surfaces of most planktic foraminifers, even those that are prone to dissolution, show no evidence of etching or recrystallization (Figure 6.2, A–F), except in older parts of the late Miocene section where the wall surfaces of some planktic foraminiferal tests are slightly etched (Figure 6.2, G–I). It is uncertain if these dissolution effects occurred prior to the onset of burial lithification or not, but they are relatively minor and they do not appear to affect the composition of assemblages (Study 1). Calcareous nannofossils in the same samples, including discoasters and sphenoliths that are more prone to dissolution and recrystallization, have secondary calcite overgrowths but not to the extent of older Miocene samples from deeper in the section (Nelson 1986).

The thick Neogene section at Site 1123 is largely composed of clay-rich nannofossil oozes and chalks (Shipboard Scientific Party 1999b). The lithology of the late Miocene section is fairly uniform, although carbonate percentages varying rhythmically between 50-60% (Shipboard Scientific Party 1999b). Calcareous microfossil assemblages have been severely affected by calcite dissolution, although preservation is variable (Study 5). Taxa that are prone to dissolution are very poorly represented and in some samples even taxa that have a high-resistance to dissolution are poorly represented.

Biogeography

Modern planktic foraminifers that surround New Zealand (including Sites 593 and 1123) are associated with the Transitional Province and are characterized by *Globoconella inflata*, the only species indigenous to the province, and a diverse fauna of mixed subtropical and subantarctic species (Bé 1977; Hayward 1983). Similar Transitional



A *Globigerina bulloides* 120.30 mbsf
B *Truncorotalia juanai* 191.52 mbsf
C *Globigerinopsis obesa* 221.66 mbsf
D *Globoconella miotumida* 221.66 mbsf
E *Globoconella miotumida* 221.66 mbsf
F *Neogloboquadrina pachyderma* 154.54 mbsf
G *Hirsutella panda* 315.13 mbsf
H *Globorotaloides hexagonus* 306.86 mbsf
I *Hirsutella scitula* 306.86 mbsf

Figure 6.2 – Late Miocene planktic foraminifers from Site 593. Images A–F show specimens with well preserved wall surfaces, and Images G–I show specimens with etched wall surfaces that have been affected by carbonate dissolution. Specimens with etched wall surfaces are relatively rare and largely occur in the older part of the late Miocene section.

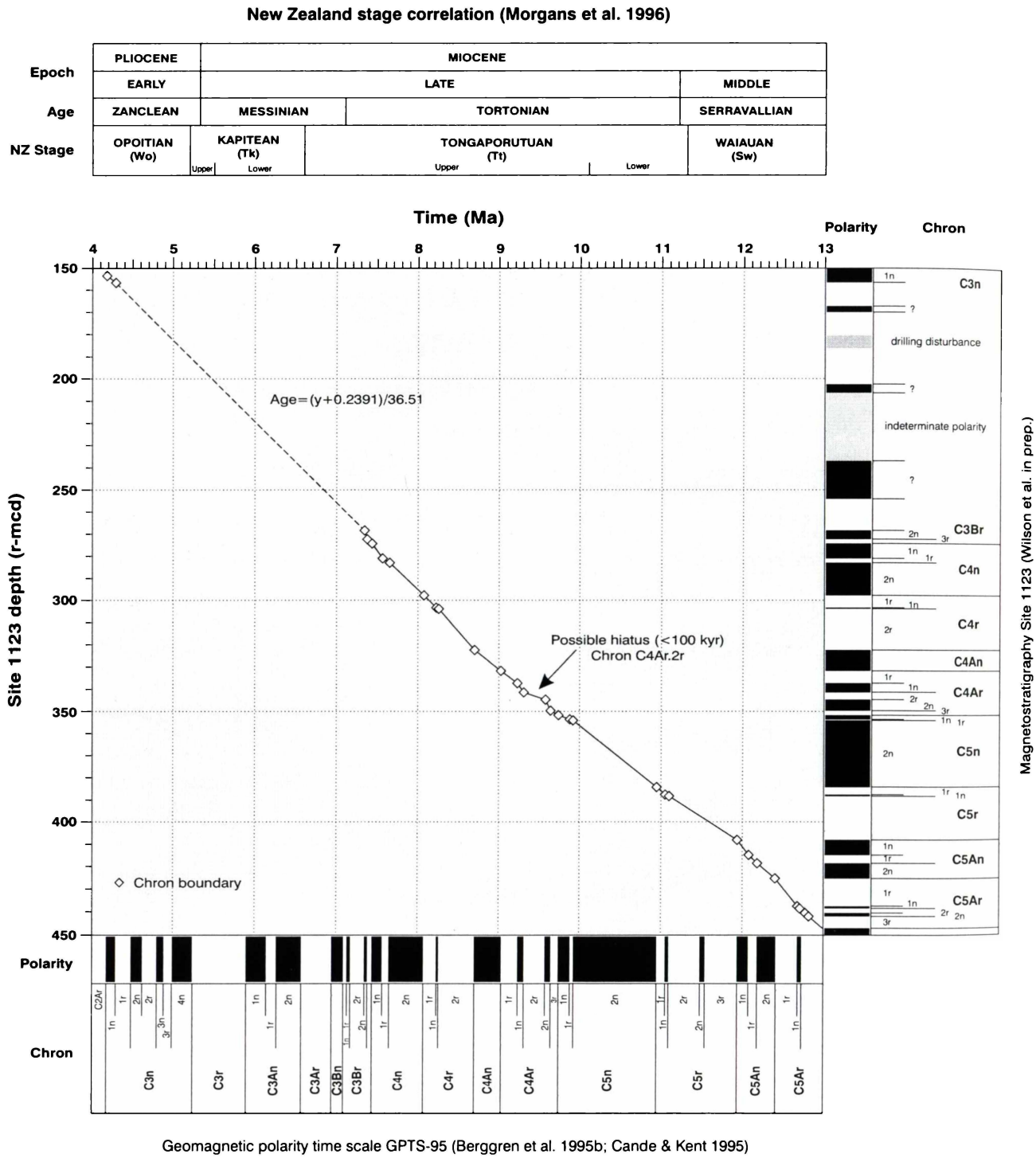
assemblages with common *Globoconella inflata* extend back to the early Pliocene (Jenkins 1992). Miocene counterparts of these assemblages that predate the appearance of the *Globoconella inflata* are included in the Temperate Province (Table in Figure 6.1). Such assemblages generally have common *Globoconella* and a diverse fauna of mixed subtropical and subantarctic species.

Magnetostratigraphic record Site 1123

The Neogene magnetostratigraphic record of Site 1123, which provides the basis for the new late Miocene age model for Site 593, was noted in the Initial Reports of Leg 181 to have a virtually complete Neogene magnetostratigraphic record that extends back to Chron C6r – c. 20 Ma (Shipboard Scientific Party 1999b). However, a subsequent review of the magnetostratigraphy (Wilson pers. comm. June 2002) has identified an interval in the younger part of the late Miocene between Chron C3Br.2n to C3n.1n (7.34-4.29 Ma) where the polarity record is ambiguous (Figure 6.3). Consequently, the interpolated ages of bioevents that occur in this interval may not be as reliable as those that occur in the older part of the late Miocene section, between Chron C5An.1r to C3Br.2n (12.18-7.34 Ma), where there is a virtually complete magnetostratigraphic sequence with only one suspected break of less than 100 k.y. in Chron C4Ar.2r (Figure 6.3).

BIOSTRATIGRAPHIC CORRELATION

A comparison of high-resolution bolboform and planktic foraminiferal distribution data from the late Miocene sections of Site 593 (Studies 2 and 3) and Site 1123 (Study 5) identifies 33 bioevents that are shared by both sites (Table 6.1). This provides a very well constrained biostratigraphic correlation between the two sections. Twenty-five shared bioevents occur in the older part of the late Miocene section between the lowest occurrence of *Bolboforma subfragoris* s.l. and the highest occurrence of *Bolboforma praeintermedia.* Of these, 20 bioevents are associated with very short ranges of bolboforms – calcareous microfossils that are highly resistant to dissolution (Rögl & Hochuli 1976) – and 4 bioevents are associated with short dextral excursions in the preferred coiling direction of *Globoconella miotumida* – a robust and very common planktic foraminiferal species. The paucity of bioevents in the younger part of the late Miocene section, above highest occurrence of *Bolboforma praeintermedia,* is a general characteristic of world-wide planktic zonations in the lead up to the Mediterranean Salinity Crisis (Study 5) and is not entirely due to the poor preservation at Site 1123.



Geomagnetic polarity time scale GPTS-95 (Berggren et al. 1995b; Cande & Kent 1995)

Figure 6.3 – ODP Site 1123 magnetostratigraphic record. Cross-plot of magnetostratigraphic data from Site 1123 and the geomagnetic polarity time scale (GPTS-95), the basis of the sites chronology. The lower part of the magnetostratigraphic sequence is virtually complete, but there is the possibility of a short hiatus within Chron C4Ar.2r. The younger part of the magnetostratigraphic sequence from the top of Chron C3Br.2r to the base of C3n.1n is poorly constrained. All ages for this interval have been interpolated (dashed line).

Table 6.1 – Relative rates of sediment accumulation between pairs of shared bioevents at Sites 593 and 1123 (source Studies 2, 3, and 5) – expressed as a proportion (bioevent spacing: Site 593 / Site 1123). Reference numbers 1–33 relate to the stratigraphic order of bioevents at Site 1123. CB = Base Chron C2An.3n (3.580 Ma), data from Barton & Bloemendal (1986) and Wilson (pers. comm. June 2002). Data relating to the determination of midpoints are given in Appendix 6.1. Depths: mbsf (metres below seafloor); r-mcd (revised metres composite depth). Datums: LO = lowest occurrence; HO = highest occurrence.

Ref.	Datums shared by Sites 593 and 1123 (coiling zones, acmes, highest and lowest occurrences)	Site 593 Mid-point (mbsf)	Site 1123 Mid-point (r-mcd)	Site 1123 age (Ma)	Relative rates of sediment accumulation Site 593 / Site 1123		
CB	Base Chron C2An.3n	153.30	187.65	3.58	0 - CB	0.39	Slower
1	LO *Truncorotalia crassaformis*	129.30	187.65	5.15	CB - 1	2.03	Faster
2	LO *Globoconella puncticulata* s.s. (<5% weakly carinate) **Wo/Tk proxy**	123.01	192.66	5.28	1 - 2	-6.05	Transposed
3	LO *Globoconella pliozea*	132.54	196.65	5.39	2 - 3	2.39	Faster
4	LO *Globoconella sphericomiozea* s.s. **upper-lower Tk proxy**	143.69	201.59	5.53	3 - 4	2.26	Faster
5	LO *Globoconella mons*	145.72	208.49	5.72	4 - 5	0.29	Slower
6	Top *Truncorotalia juanai* acme zone (middle zone Site 593)	184.90	227.15	6.23	5 - 6	2.10	Faster
7	LO *Globoconella conomiozea* **Tk/Tt proxy**	167.25	249.99	6.87	6 - 7	-0.77	Transposed
8	Base *Truncorotalia juanai* acme zone (middle zone Site 593)	193.71	263.90	7.23	7 - 8	1.90	Faster
9	HO *Bolboforma praeintermedia*	236.42	301.65	8.21	8 - 9	1.13	Faster
10	LO *Bolboforma praeintermedia*	240.42	303.25	8.25	9 - 10	2.50	Faster
11	HO *Bolboforma metzmacheri ornata*	240.82	304.25	8.28	10 - 11	0.40	Slower
12	LO *Bolboforma metzmacheri ornata*	246.17	311.35	8.45	11 - 12	0.75	Slower
13	HO *Bolboforma metzmacheri* s.s. (upper subzone)	254.19	323.95	8.78	12 - 13	0.64	Slower
14	HO *Globoquadrina dehiscens* **upper-lower Tt proxy**	254.30	326.95	8.88	13 - 14	0.04	Slower
15	LO *Bolboforma metzmacheri* s.s. (upper subzone)	259.17	330.45	9.01	14 - 15	1.39	Faster
16	HO *Bolboforma metzmacheri* s.s. (lower subzone)	271.83	341.05	9.34	15 - 16	1.19	Faster
17	Top Tukemokihi coiling zone (TCZ) >20% Dex	269.07	342.05	9.42	16 - 17	-2.76	Transposed
18	*Bolboforma metzmacheri* s.s. abundance spike (lower subzone)	274.70	342.30	9.44	17 - 18	22.52	Faster
19	LO *Bolboforma metzmacheri* s.s. (lower subzone)	276.82	343.55	9.54	18 - 19	1.70	Faster
20	HO *Bolboforma gracilireticulata* s.l.	278.61	346.55	9.61	19 - 20	0.60	Slower
21	Base Tukemokihi coiling zone (TCZ) >20% Dex	270.82	347.55	9.62	20 - 21	-7.79	Transposed
22	LO *Bolboforma gracilireticulata* s.l.	284.62	351.05	9.75	21 - 22	3.94	Faster
23	HO *Bolboforma pentaspinosa* (excludes Site 1123 outlier)	287.18	358.05	10.08	22 - 23	0.37	Slower
24	HO *Bolboforma capsula*	289.62	359.65	10.13	23 - 24	1.52	Faster
25	LO *Bolboforma pentaspinosa*	290.42	360.20	10.15	24 - 25	1.46	Faster
26	LO *Bolboforma capsula*	293.61	361.65	10.20	25 - 26	2.20	Faster
27	HO *Bolboforma gruetzmacheri*	295.01	364.65	10.31	26 - 27	0.47	Slower
28	LO *Bolboforma gruetzmacheri*	299.02	369.20	10.46	27 - 28	0.88	Slower
29	HO *Bolboforma subfragoris* s.l. (top subzone 1123-D)	304.57	370.25	10.50	28 - 29	5.28	Faster
30	*Bolboforma subfragoris* s.l. abundance spike (subzone 1123-D)	306.83	374.50	10.61	29 - 30	0.53	Slower
31	Top Kaiti Coiling Zone (KCZ) >20% Dex	309.05	379.50	10.82	30 - 31	0.44	Slower
32	Base Kaiti Coiling Zone (KCZ) >20% Dex **Tt/Sw proxy**	315.25	382.95	10.93	31 - 32	1.80	Faster
33	LO *Bolboforma subfragoris* s.l. (base subzone 1123-A)	334.62	398.44	11.56	32 - 33	1.25	Faster

In Table 6.1 pairs of shared bioevents with proportions >0 maintain homotaxial order, and pairs of shared bioevents with proportions <0 do not maintain homotaxial order. When proportions are >1, sedimentation rates are higher at Site 593 than at Site 1123, and when they are between 1 and 0, sedimentation rates are lower at Site 593 than at Site 1123.

A scatter-plot based on the 33-shared bioevents from Sites 593 and 1123 establishes a basis for a line of correlation (LOC) between the sections (Figure 6.4). The approximately linear scatter of the data, the consistency of their stratigraphic order, and the fact that they are highly correlated (r^2=0.9934), point to a close approximation to a true line of correlation (Shaw 1964; Dowsett 1989). The close fit of the biostratigraphic data to a linear regression also indicates the late Miocene section of Site 593 is relatively complete with respect to

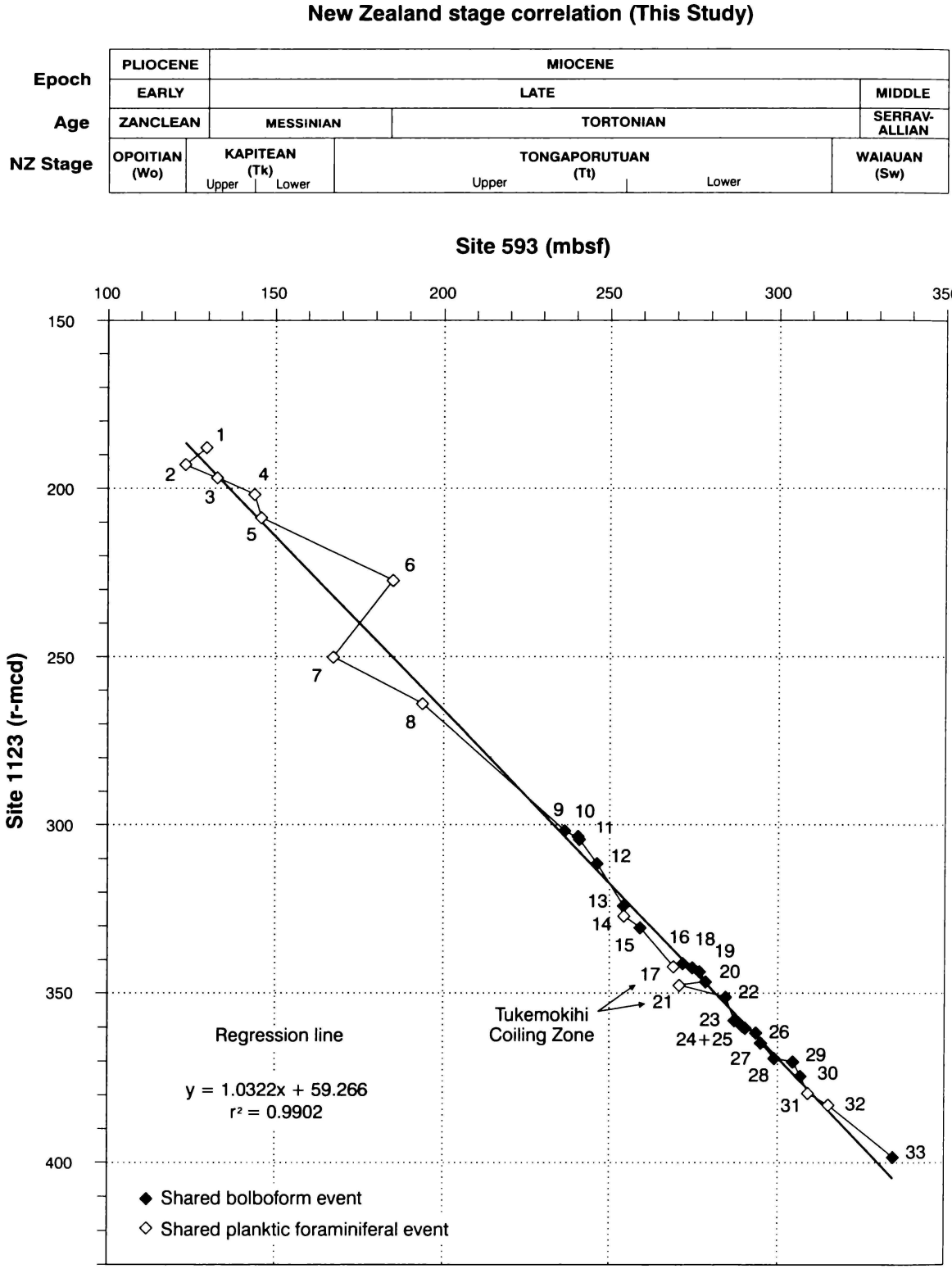


Figure 6.4 – Scatter-plot based on late Miocene biostratigraphic data shared between Sites 593 and 1123 (Studies 2, 3, and 5). Numbered bioevents and relative rates of sediment accumulation are given in Table 6.1. Stratigraphic error bars are not shown for the biostratigraphic data because the sample resolution is too high for the data to be shown in this manner. All bioevents were used in fitting the linear regression.

Site 1123, except for a short hiatus between the highest occurrence of *Globoquadrina dehiscens* and the top of the upper *Bolboforma metzmacheri* subzone (c. 8.87-8.78 Ma). Most bioevents maintain consistent stratigraphic order and plot close to the LOC between Site 593 and 1123, although there are several bioevents that do not maintain homotaxial order and are potentially diachronous:

- The lowest occurrence of *Truncorotalia crassaformis* (bioevent 1) occurs above the lowest occurrence of *Globoconella puncticulata* (bioevent 2) at Site 1123, but the order of these same bioevents is transposed at 593 (Table 6.1). Significantly, in New Zealand onland sections that have good planktic representations, the lowest occurrence of *Globoconella puncticulata* occurs above the lowest occurrence of *Truncorotalia crassaformis* (Scott et al. 1990). This suggests the transposition of these bioevents at Sites 593 and 1123 may be caused by the lowest occurrence of *Truncorotalia crassaformis* being located too high in the section at Site 1123. The difficulty in reliably locating the lowest occurrence of *Truncorotalia crassaformis* in sequences where the morphological transformation between *Tr. neojuanai – Tr. crassaformis* is poorly represented – as at Site 1123 – places a cautionary caveat on its use for correlation. It also suggests the age of 5.15 Ma that has been assigned to the lowest occurrence of *Truncorotalia crassaformis* at Site 1123 (Study 5) may be too young.

- The top of the middle *Truncorotalia juanai* acme zone (bioevent 6) and the lowest occurrence of *Globoconella conomiozea* (bioevent 7) are also transposed and they plot some distance away from the LOC (Figure 6.4). Both bioevents are reliably located in the section at Site 593 (Study 2), but at Site 1123 specimens of *Truncorotalia juanai* are relatively rare and the morphological transformation between *Gc. miotumida* and *Gc. conomiozea* occurs in a part of the section where specimens are heavily crusted and distinguishing morphological features are obscured. This places a cautionary caveat on the reliability of both bioevents at Site 1123. It also casts doubt over their possible diachroneity.

- At Site 1123, bioevents 17 and 21 that are associated with the Tukemokihi Coiling Zone (TCZ), overlap with bioevent 20, the highest occurrence of *Bolboforma gracilireticulata* s.l., and bioevents 18 and 19, that are associated with the lower *Bolboforma metzmacheri* s.s. subzone. At Site 593, however, the TCZ occurs above these same bioevents. All of the bioevents appear to be reliably located in both

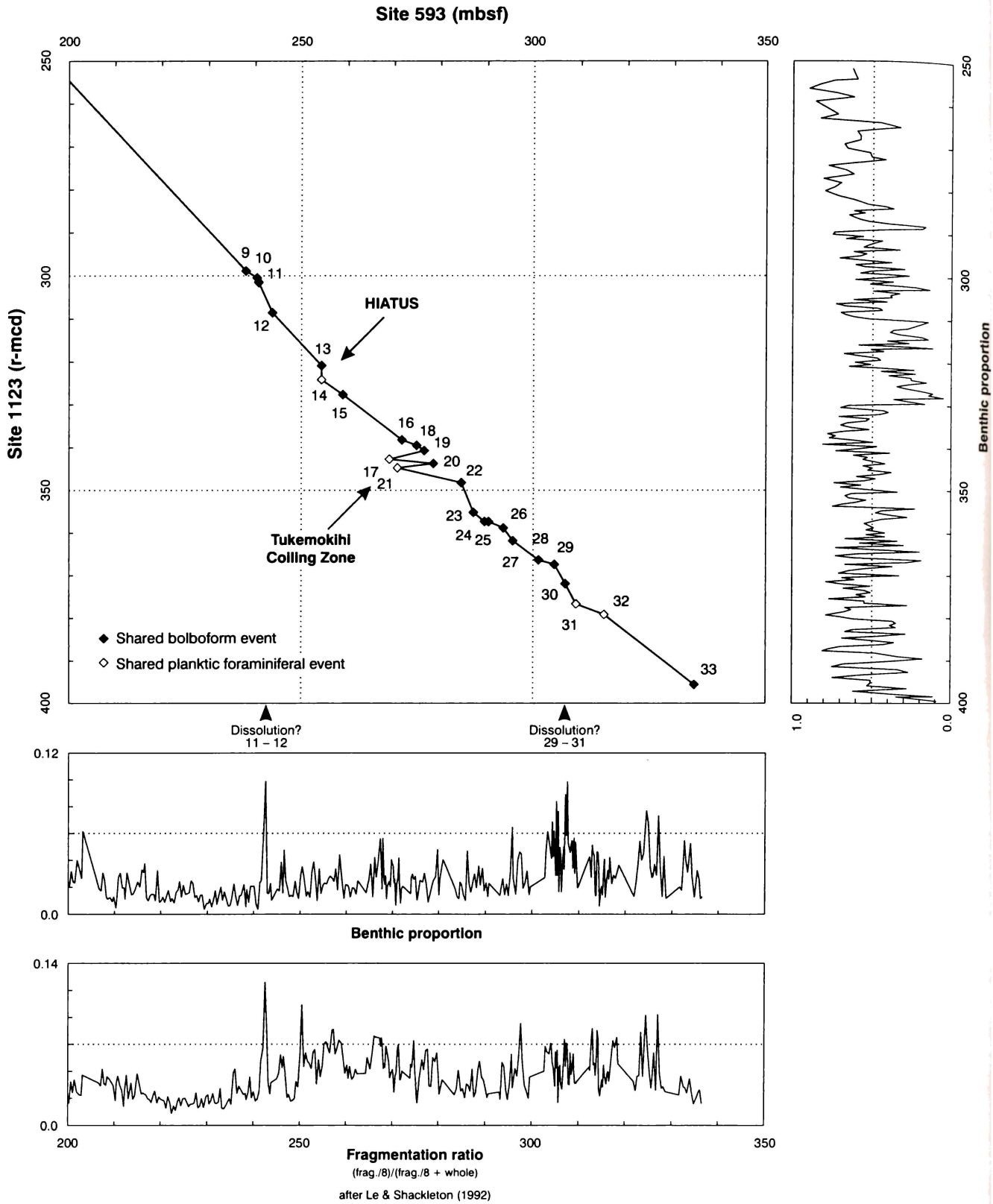


Figure 6.5 – Detail of the older part of the late Miocene biostratigraphic cross-plot shown in Figure 6.4. Most events maintain homotaxial order, except for the Tukemokihi Coiling Zone (bioevents 21 and 17), which is offset (left) from other bioevents that occur in the vicinity. This suggests the Tukemokihi Coiling Zone is diachronous. The vertical offset between bioevents 14 and 13 points to a hiatus in the Site 593 section - the section is otherwise complete with respect to Site 1123. Numbered bioevents are listed in Table 6.1. Dissolution proxies: benthic foraminiferal proportion and fragmentation index are shown for comparison with the sedimentary data. Higher benthic proportions and fragmentation indices point to increased dissolution.

sections, although the TCZ plots separately from the tight linear scatter of most other data and it does not maintain a consistent homotaxial position (Figure 6.5). This suggests the TCZ is slightly diachronous.

Sedimentation

The LOC between sections at Sites 593 and 1123 serves as a proxy for relative sediment accumulation (Figure 6.4). The slope of the LOC (1.0322) suggests that in the late Miocene, at least, rates of sediment accumulation were very similar at both sections, even though they were on opposite sides of New Zealand, and they were associated with different water masses. This contrasts with the Plio-Pleistocene interval when the average rate of sediment accumulation at Site 1123 was 50% higher than at Site 593.

The LOC provides a close fit to the linear scatter of the data, although it does not take into account sedimentary variations caused by paleoceanographic differences between the sections, nor biostratigraphic error derived from sample resolution, core recovery, and fossil preservation and identification. Changes in carbonate dissolution, winnowing and erosion, biogenic productivity, and non-biogenic sedimentary influx, or any combination of these oceanic processes, are manifest in perturbations in the relative rates of sediment accumulation between closely spaced bioevents (Table 6.1). Biostratigraphic error also contributes to some short-term perturbations between the sections.

Dissolution curves for Sites 593 and 1123 (Figure 6.5) based on the proportion of benthic foraminifers (Parker & Berger 1971; Hooper et al. 1991) and the fragmentation ratio of planktic foraminifers (Le & Shackleton 1992), show variations in dissolution at both sites in the late Miocene. However, only traces of dissolution have been noted in the late Miocene section at Site 593 (see earlier) and it is unlikely that they would overshadow the affects that dissolution at Site 1123 would have had on the relative sediment accumulation curve for Sites 593 and 1123. Dissolution at Site 1123 undoubtedly contributes to some of short-term perturbations in the relative sediment accumulation curve, but there are some cases at least where this does not appear to be so. For example, the interval between bioevents 23 and 22 where the sediment thickness at Site 1123 is more than twice that of Site 593 (Table 6.1), corresponds to an interval of relatively high dissolution at Site 1123 (Figure 6.5).

Because there is no composite section for Site 593, and stretching-functions have not been used on cores where there is <100% of core recovery (Kennett & von der Borch 1986), some perturbations in the relative sediment accumulation curve may be due to core deformation from the coring and retrieval operation, and they may not be related to changes in paleoceanography (e.g. between bioevents 32 and 31). Even though such errors are relatively minor, they should at least be taken into consideration in the construct of a high-precision age model for Site 593.

Existing chronology Site 593

Chronostratigraphic data from the Neogene section of Site 593 that are independent of biostratigraphic inference are limited and are too poorly constrained in most instances to provide a reliable chronology. Good magnetostratigraphic data only extend back to the base of the Gauss (Chron C2An.3n) at 59.60 ±0.25 mbsf (Barton & Bloemendal 1986), although the 3.580 Ma age for the chron boundary (Berggern et al. 1995a; Cande & Kent 1995) provides a robust tie point for Miocene biostratigraphy. Sparse strontium isotope data for Site 593 (Hess et al. 1986) have also been translated to a temporal scale using linear equations based on the orbitally-tuned Sr chemostratigraphic reference section of ODP Site 926, in the equatorial Atlantic (Martin et al. 1999). However, the resulting data plot erratically and show at least three age reversals (Figure 6.6-A). Even though the linear equations given by Martin et al. (1999) are an approximation of the seventh-order polynomial fit to the seawater strontium curve, the maximum difference in age estimates of 0.3 Ma between the polynomial and linear fits does not account for the incongruous behaviour of the data. This suggests the strontium data from Site 593 are unreliable and as such they have not been used in the biostratigraphic construct.

Kennett & Vella (1975), Malmgren & Kennett (1981, 1982), Edwards (1985, 1987), Wei (1987), and Wei & Kennett (1988) have employed chronologies for the late Neogene section Site 284 based on biochronostratigraphic data from New Zealand onland sections, although the only New Zealand based chronologies for Site 593 have been developed by Head & Nelson (1994) and Schneider & Kennett (1996). The chronology employed by Head & Nelson (1994) extends back to the base of calcareous nannofossil zone NN11b, or c. 7.2 Ma (Berggren et al. 1995b). For the Miocene part of their chronology they made use of biostratigraphic data from Hoskins (1990) and incorporated biochronostratigraphic data from Edwards (1987) based on integrated biostratigraphic, magnetostratigraphic, and oxygen isotope stratigraphic data from onland New Zealand. Schneider & Kennett (1996)

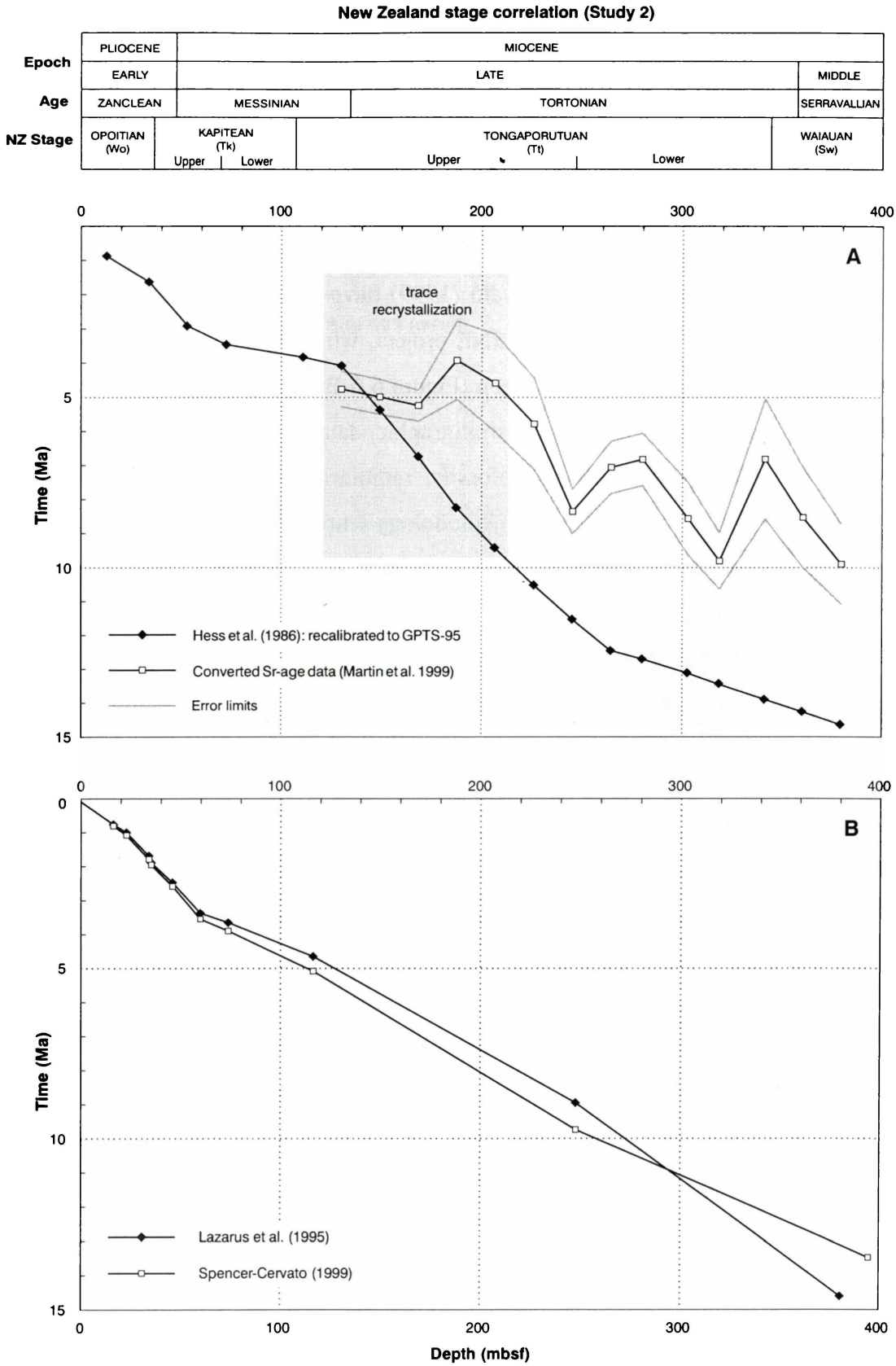


Figure 6.6 – Existing late Neogene age models for Site 593: A) Converted strontium age data from Hess et al. (1986) recalibrated to GPTS-95 (Berggren et al. 1995b; Cande & Kent 1995). The same Sr-data have been converted to age using equations derived from the orbitally-tuned Sr isotope chemostratigraphic reference section of ODP Site 926 (Martin et al. 1999). B) Age models based on stratigraphic event ages used to standardize the chronologic scales for DSDP and ODP Holes from the World Ocean (Lazarus et al. 1995; Spencer-Cervato 1999).

base their late Neogene chronology (2.87-6.06 Ma) on the age model of Hornibrook (1990), however, Hornibrook only provides an overview of New Zealand regional events and makes no specific mention of Site 593 biostratigraphic correlations with onland New Zealand. Although they may have used the Site 284 age model of Edwards (1987), the age of at least one key datum that they cite, the first occurrence *Globoconella puncticulata* (appendix, p. 303), differs from Edwards, age model.

Lazarus et al. (1995) and Spencer-Cervato (1999) have also developed chronologies for Site 593 as part of the NEPTUNE-ONLINE project, which reviewed the chronologies of DSDP and ODP Holes in the World Ocean (Figure 6.6-B). The chronologies were derived from a relational database of magnetostratigraphic data and microfossil occurrences – planktic foraminifers, calcareous nannofossils, radiolarians, and diatoms – reported in DSDP and ODP samples. Although the methodology employed in the construct of the age-depth models is well founded, the paucity of reliable DSDP and ODP biochronostratigraphic data from the New Zealand region – prior to Leg 181 – means the models are biased by fossil distributions from outside the New Zealand region. This makes biostratigraphic event ages prone to diachroneity, as demonstrated by Jenkins (1992) and Spencer-Cervato et al. (1994).

Cooke (2002) has more recently employed a Neogene chronology for Site 593 (0-19 Ma) based on an eclectic selection of radiocarbon, magnetostratigraphic, calcareous nannofossil, and planktic foraminiferal events. Stratigraphic tie points employed by Cooke (2002) for the late Miocene part of this chronology are largely based on data from Study 5.

NEW LATE MIOCENE AGE MODEL FOR SITE 593

By taking the biostratigraphic construct for Sites 593 and 1123 a step further and plotting biostratigraphic data from Site 593 against magnetobiochronologic data from Site 1123, a reliable basis is developed for an age model at Site 593 (Figure 6.7). Because the data from Site 1123 are plotted as time on one of the axes, the sedimentary signal from Site 1123 is effectively removed and changes in the slope of the age-depth curve are confined to sedimentary variations and sources of biostratigraphic error at Site 593.

Biochronostratigraphic data in the older part of the late Miocene section is very well constrained and it allows a precise age model to be constructed (Figure 6.7). Of the 25-shared bioevents in the lower part of the section, only bioevents 21 and 17 that are

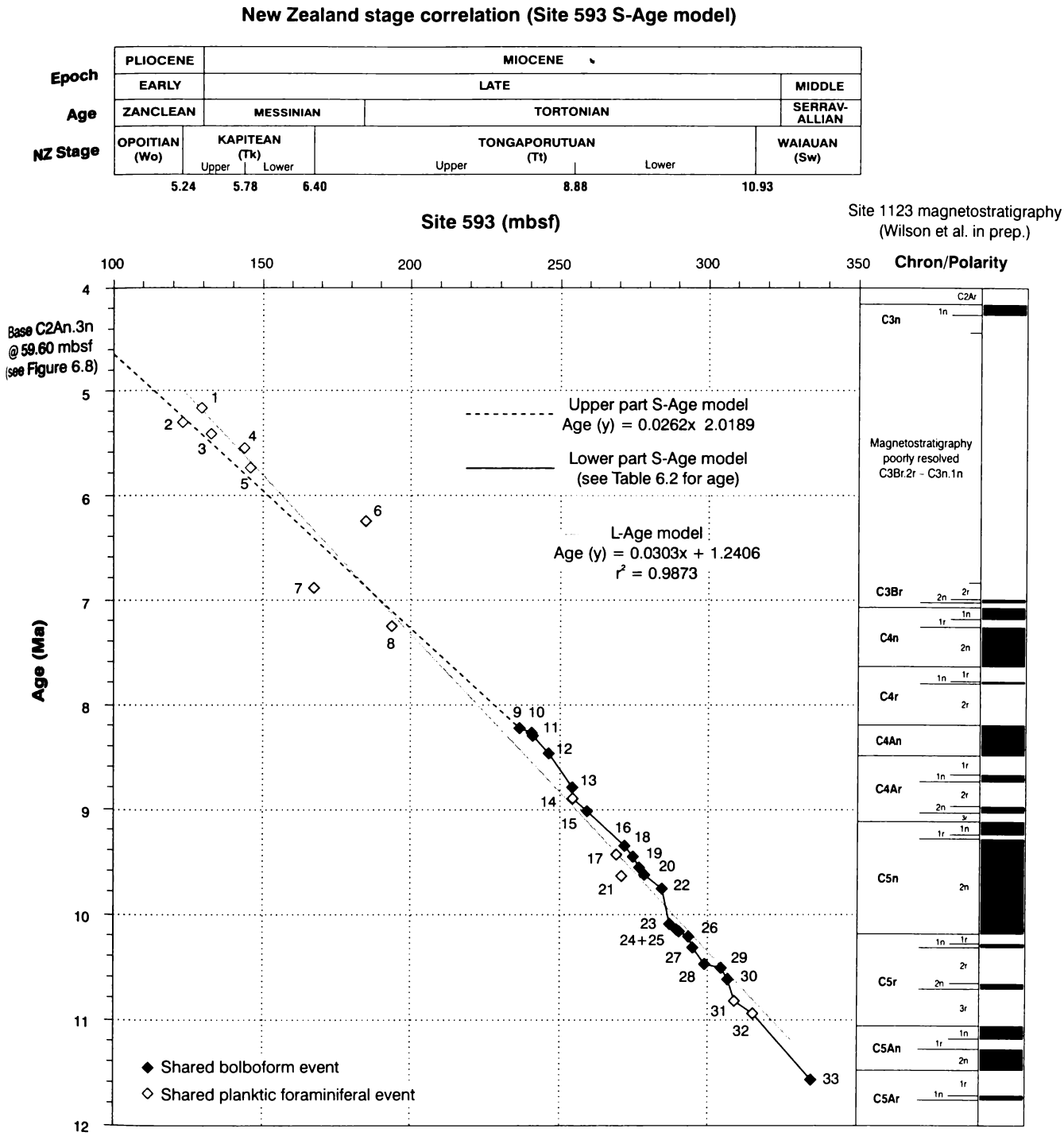


Figure 6.7 – New late Miocene age models for Site 593. Linear (L-Age) model, based on computed regression through all biostratigraphic data shared between Sites 593 and 1123 (bioevents 1–33). The older part of the segmented (S-Age) model, is based on computed regression between pairs of shared bioevents (excluding bioevents 21 and 17). The younger part of the S-Age model is based on a regression line between bioevent 9 and the base of Chron C2An.3n (excluding bioevents 1–8). A comparison of the L-Age and S-Age models is given in Table 6.3. Numbered bioevents, biostratigraphic, and magnetochronologic data are given in Table 6.1. Data sourced from Studies 2, 3 and 5.

associated with the Tukemokihi Coiling Zone have not been included in the segmented age model (S-Age), as it has been shown earlier that the coiling zone does not maintain a constant homotaxial position with respect to the other bioevents.

Because biostratigraphic data in the younger part of the late Miocene section are poorly constrained compared to those in the older part of the same section, and there is uncertainty concerning the reliability of magnetobiochronologic data from Site 1123, a regression line is fitted between the two nearest well constrained chronostratigraphic tie-points at Site 593, bioevent 9 (the highest occurrence of *Bolboforma praeintermedia*) and the base of Chron C2An.3n at 59.60 mbsf (Barton & Bloemendal 1986).

Equations for the S-Age model, based on the computed regression for selected pairs of shared bioevents (chronostratigraphic tie-points), are given in Table 6.2.

Table 6.2 – Linear equations for the late Miocene segmented (S-Age) model for Site 593, which is based on interpolations between 22 pairs of bioevents, and an extended interpolation between bioevent 9 and CB, the base of Chron C2An.3n (Barton & Bloemendal 1986). An explanation of numbered bioevents is given in Table 6.1.

Bioevent ref. no.	Top (mbsf)	(Ma)	Bottom (mbsf)	(Ma)	Age equation
CB - 9	59.60	3.58	236.52	8.21	Age (Ma) = (0.0262 x mbsf) + 2.0203
9 - 10	236.52	8.21	240.32	8.25	Age (Ma) = (0.0105 x mbsf) + 5.7203
10 - 11	240.32	8.25	240.92	8.28	Age (Ma) = (0.05 x mbsf) - 3.766
11 - 12	240.92	8.28	246.06	8.45	Age (Ma) = (0.0331 x mbsf) + 0.3118
12 - 13	246.06	8.45	254.27	8.78	Age (Ma) = (0.0402 x mbsf) - 1.4404
13 - 14	254.27	8.78	254.49	8.88	Age (Ma) = (0.4545 x mbsf) - 106.8
14 - 15	254.49	8.88	259.07	9.01	Age (Ma) = (0.0284 x mbsf) + 1.6565
15 - 16	259.07	9.01	271.94	9.34	Age (Ma) = (0.0256 x mbsf) + 2.3672
16 - 18	271.94	9.34	274.72	9.44	Age (Ma) = (0.036 x mbsf) - 0.442
18 - 19	274.72	9.44	276.73	9.54	Age (Ma) = (0.0498 x mbsf) - 4.2277
19 - 20	276.73	9.54	278.72	9.61	Age (Ma) = (0.0352 x mbsf) - 0.1942
20 - 22	278.72	9.61	284.55	9.75	Age (Ma) = (0.024 x mbsf) + 2.9169
22 - 23	284.55	9.75	287.32	10.08	Age (Ma) = (0.1191 x mbsf) - 24.149
23 - 24	287.32	10.08	289.73	10.13	Age (Ma) = (0.0207 x mbsf) + 4.119
24 - 25	289.73	10.13	290.33	10.15	Age (Ma) = (0.0333 x mbsf) + 0.4723
25 - 26	290.33	10.15	293.51	10.20	Age (Ma) = (0.0157 x mbsf) + 5.5851
26 - 27	293.51	10.20	295.12	10.31	Age (Ma) = (0.0683 x mbsf) - 9.8535
27 - 28	295.12	10.31	298.93	10.46	Age (Ma) = (0.0394 x mbsf) - 1.3089
28 - 29	298.93	10.46	304.66	10.50	Age (Ma) = (0.007 x mbsf) + 8.3732
29 - 30	304.66	10.50	306.86	10.61	Age (Ma) = (0.05 x mbsf) - 4.733
30 - 31	306.86	10.61	309.11	10.82	Age (Ma) = (0.0933 x mbsf) - 18.03
31 - 32	309.11	10.82	315.19	10.93	Age (Ma) = (0.0181 x mbsf) + 5.2275
32 - 33	315.19	10.93	334.36	11.56	Age (Ma) = (0.0329 x mbsf) + 0.5716

For some applications, a linear regression fitted to all of the biostratigraphic data, which is referred to here as the L-Age model, offers an alternative method for determining late Miocene ages at Site 593. Although the L-Age model is slightly less precise, the maximum age difference between the S-Age and L-Age models is only 270 k.y. (Table 6.3).

L-Age model: Age (5-12 Ma) = (0.0303 x depth mbsf) + 1.2406 $r^2 = 0.9873$

The well-founded S-Age and L-Age models for Site 593 have enabled interpolated ages to be assigned to planktic foraminiferal and bolboform events that are very poorly represented or missing in the dissolution-affected late Miocene section at Site 1123 (Table 6.4). This extends the biochronologic framework of Site 1123, and effectively doubles the number of late Miocene bioevents from the greater New Zealand region that have been correlated either directly or indirectly with the geomagnetic polarity time scale (GPTS-95).

Table 6.3 – Comparison of magnetobiochronologic data from Site 1123 and the ages of shared bioevents at Site 593, based on the S-Age and L-Age models.

Ref.	Coiling zones, acmes, highest and lowest occurrences	Site 1123 (Ma)	S-Age (Ma)	Diff. 1123 Age (S-Age)	L-Age (Ma)	Diff. 1123 Age (L-Age)	Diff. S-Age (L-Age)
1	LO *Truncorotalia crassaformis*	5.15	5.41	-0.26	5.16	-0.01	0.25
2	LO *Globoconella puncticulata* s.s. (<5% weakly carinate) Wo/Tk proxy	5.28	5.24	0.04	4.97	0.31	0.27
3	LO *Globoconella pliozea*	5.39	5.49	-0.10	5.26	0.13	0.23
4	LO *Globoconella sphericomiozea* s.s. upper-lower Tk proxy	5.53	5.78	-0.25	5.59	-0.06	0.19
5	LO *Globoconella mons*	5.72	5.84	-0.12	5.66	0.06	0.18
6	Top *Truncorotalia juanai* acme zone (middle zone Site 593)	6.23	6.86	-0.63	6.84	-0.61	0.02
7	LO *Globoconella conomiozea*	6.87	6.40	0.47	6.31	0.56	0.09
8	Base *Truncorotalia juanai* acme zone (middle zone Site 593)	7.23	7.09	0.14	7.11	0.12	-0.02
9	HO *Bolboforma praeintermedia*	8.21	8.21	0.00	8.40	-0.19	-0.19
10	LO *Bolboforma praeintermedia*	8.25	8.25	0.00	8.53	-0.28	-0.28
11	HO *Bolboforma metzmacheri ornata*	8.28	8.28	0.00	8.54	-0.26	-0.26
12	LO *Bolboforma metzmacheri ornata*	8.45	8.45	0.00	8.70	-0.25	-0.25
13	HO *Bolboforma metzmacheri* s.s. (upper subzone)	8.78	8.78	0.00	8.94	-0.16	-0.16
14	HO *Globoquadrina dehiscens* upper-lower Tt proxy	8.88	8.88	0.00	8.95	-0.07	-0.07
15	LO *Bolboforma metzmacheri* s.s. (upper subzone)	9.01	9.01	0.00	9.09	-0.08	-0.08
16	HO *Bolboforma metzmacheri* s.s. (lower subzone)	9.34	9.34	0.00	9.48	-0.14	-0.14
17	Top Tukemokihi coiling zone (TCZ) >20% Dex	9.42	9.27	0.15	9.39	0.03	-0.12
18	*Bolboforma metzmacheri* s.s. abundance spike (lower subzone)	9.44	9.44	0.00	9.56	-0.12	-0.12
19	LO *Bolboforma metzmacheri* s.s. (lower subzone)	9.54	9.54	0.00	9.63	-0.09	-0.09
20	HO *Bolboforma gracilireticulata* s.l.	9.61	9.61	0.00	9.68	-0.07	-0.07
21	Base Tukemokihi coiling zone (TCZ) >20% Dex	9.62	9.31	0.31	9.45	0.17	-0.14
22	LO *Bolboforma gracilireticulata* s.l.	9.75	9.75	0.00	9.86	-0.11	-0.11
23	HO *Bolboforma pentaspinosa* (excludes Site 1123 outlier)	10.08	10.08	0.00	9.94	0.14	0.14
24	HO *Bolboforma capsula*	10.13	10.13	0.00	10.02	0.11	0.11
25	LO *Bolboforma pentaspinosa*	10.15	10.15	0.00	10.04	0.11	0.11
26	LO *Bolboforma capsula*	10.20	10.20	0.00	10.14	0.06	0.06
27	HO *Bolboforma gruetzmacheri*	10.31	10.31	0.00	10.18	0.13	0.13
28	LO *Bolboforma gruetzmacheri*	10.46	10.46	0.00	10.30	0.16	0.16
29	HO *Bolboforma subfragoris* s.l. (top subzone 1123-D)	10.50	10.50	0.00	10.47	0.03	0.03
30	*Bolboforma subfragoris* s.l. abundance spike (subzone 1123-D)	10.61	10.61	0.00	10.54	0.07	0.07
31	Top Kaiti Coiling Zone (KCZ) >20% Dex	10.82	10.82	0.00	10.60	0.22	0.22
32	Base Kaiti Coiling Zone (KCZ) >20% Dex **Tt/Sw proxy**	10.93	10.93	0.00	10.79	0.14	0.14
33	LO *Bolboforma subfragoris* s.l. (base subzone 1123-A)	11.56	11.56	0.00	11.38	0.18	0.18

Because it is important in the development of a high-precision age model for Site 593 to take into account perturbations in the biostratigraphic construct between Sites 593 and 1123, the segmented (S-Age) model is preferred over the linear (L-Age) model, as it accommodates hiatuses and short-term sedimentary variations, and it is more likely to accommodate various sources of biostratigraphic error.

Table 6.4 – Age calibrated bolboform and planktic foraminiferal events from DSDP Site 593. *Site 1123 magnetobiochronologic tie-points used in the S-Age model for Site 593, all other bioevents have interpolated ages (Study 6). New Zealand stages and international correlation emended after M-96 (Morgans et al. 1996), and the bolboform zonation is based on Study 3.

Ref.	Bolboform and planktic foraminiferal events	Mid-point (mbsf)	S-Age (Ma)	L-Age (Ma)	M-96 (Ma)	NZ Stage (This Study)	Bolboform zonation	Age/Epoch	
	Top upper *Truncorotalia juanai* acme	122.82	5.24	4.96		lower Opoitian (lWo)	unzoned	ZANCLEAN	EARLY PLIOCENE
	Top Challenger Coiling Zone (CCZ) = top *Nq* -593/B	122.82	5.24	4.96					
2	LO *Gc. puncticulata* s.s. (<5% weakly carinate) **Wo/Tk proxy**	123.01	5.24	4.97	5.2	5.24			
1	LO *Truncorotalia crassaformis*	129.30	5.41	5.16		upper Kapitean (uTk)			
	Base Challenger Coiling Zone (CCZ)	131.71	5.47	5.23					
3	LO *Globoconella pliozea*	132.54	5.49	5.26					
	LO *Truncorotalia* aff. *crassaconica*	135.40	5.57	5.34					
4	LO *Gc. sphericomiozea* s.s. **upper-lower Tk proxy**	143.69	5.78	5.59	5.5	5.78			
	LO *Truncorotalia neojuanai*	145.72	5.84	5.66		lower Kapitean (lTk)		MESSINIAN	LATE MIOCENE
5	LO *Globoconella mons*	145.72	5.84	5.66					
	Base upper *Truncorotalia juanai* acme	148.50	5.91	5.74					
	Top Palliser Coiling Zone (PCZ) = top subzone *Gc* -593/D3	153.82	6.05	5.90					
	Palliser Coiling Zone (Base subzone *Gc* -593/D3)	154.22	6.06	5.91					
	Palliser Coiling Zone (Top subzone *Gc* -593/D2)	155.17	6.08	5.94					
	Palliser Coiling Zone (Base subzone *Gc* -593/D2)	156.03	6.11	5.97					
	Palliser Coiling Zone (Top subzone *Gc* -593/D1)	157.85	6.15	6.02					
	Base Palliser Coiling Zone (PCZ) = base subzone *Gc* -593/D1	158.18	6.16	6.03					
7	LO *Globoconella conomiozea* **Tk/Tt proxy**	167.25	6.40	6.31	6.6	6.40			
6	Top middle *Truncorotalia juanai* acme	184.90	6.86	6.84		upper Tongaporutuan (uTt)	B. intermedia (BBi)	TORTONIAN	
8	Base middle *Truncorotalia juanai* acme	193.71	7.09	7.11					
9	HO *Bolboforma praeintermedia*	236.42	8.21*	8.40					
	HO *Hirsutella* cf. *ichinosekiensis* (non-carinate)	239.12	8.24	8.49					
10	LO *Bolboforma praeintermedia*	240.42	8.25*	8.53					
11	HO *Bolboforma metzmacheri ornata*	240.82	8.28*	8.54			B. metzmacheri (BBm)		
12	LO *Bolboforma metzmacheri ornata*	246.17	8.45*	8.70					
13	HO *Bolboforma metzmacheri* s.s. (upper subzone)	254.19	8.78*	8.94	10.1	8.88			
14	HO *Globoquadrina dehiscens* **upper-lower Tt proxy**	254.30	8.88*	8.95		lower Tongaporutuan (lTt)			
	HO *Hirsutella* cf. *ichinosekiensis* (weakly carinate)	255.10	8.90	8.97					
15	LO *Bolboforma metzmacheri* s.s. (upper subzone)	259.17	9.01*	9.09					
17	Top Tukemokihi Coiling Zone (TCZ)	269.07	9.27	9.39					
	Top subzone BBm-593/B (small smooth-walled phases)	269.81	9.29	9.42					
	Base subzone BBm-593/B (small smooth-walled phases)	270.59	9.31	9.44					
21	Base Tukemokihi Coiling Zone (TCZ)	270.82	9.31	9.45					
16	HO *Bolboforma metzmacheri* s.s. (lower subzone)	271.83	9.34*	9.48					
18	*B. metzmacheri* s.s. abundance spike (lower subzone)	274.70	9.44*	9.56					
19	LO *Bolboforma metzmacheri* s.s. (lower subzone)	276.82	9.54*	9.63					
20	HO *Bolboforma gracilireticulata* s.l.	278.61	9.61*	9.68			B. capsula (BBc)		
22	LO *Bolboforma gracilireticulata* s.l.	284.62	9.75*	9.86					
23	HO *Bolboforma pentaspinosa*	287.18	10.08*	9.94					
24	HO *Bolboforma capsula*	289.62	10.13*	10.02					
25	LO *Bolboforma pentaspinosa*	290.42	10.15*	10.04					
26	LO *Bolboforma capsula*	293.61	10.20*	10.14					
	Top Glomar Coiling Zone (GCZ)	294.31	10.25	10.16			B. gruetzmacheri (BBg)		
27	HO *Bolboforma gruetzmacheri*	295.01	10.31*	10.18					
	HO *Hirsutella panda* (strongly keeled morphotypes)	297.89	10.42	10.27					
28	LO *Bolboforma gruetzmacheri*	299.02	10.46*	10.30					
	LO *Neogloboquadrina pachyderma* s.l.	301.19	10.48	10.37					
	HO *Neogloboquadrina mayeri* s.l.	301.19	10.48	10.37					
	Top lower *Truncorotalia juanai* acme	303.95	10.50	10.45					
29	HO *Bolboforma subfragoris* s.l.	304.57	10.50*	10.47			B. subfragoris (BBs)		
	Top *Hirsutella panda* acme (>10%)	305.82	10.56	10.51					
	Top Mapiri Coiling Zone (MCZ)	306.02	10.57	10.51					
	Base Mapiri Coiling Zone (MCZ)	306.65	10.60	10.53					
30	*B. subfragoris* s.l. abundance spike (subzone BBs-593/E)	306.83	10.61*	10.54					
	Base *Bolboforma subfragoris* s.l. subzone BBs-593/E	307.82	10.70	10.57					
	Top *Bolboforma subfragoris* s.l. subzone BBs-593/D	308.85	10.80	10.60					
	LO *Truncorotalia juanai* (base lower *Tr. juanai* acme)*	309.05	10.82	10.61					
	Base Glomar Coiling Zone (GCZ)	309.05	10.82	10.61					
31	Top Kaiti Coiling Zone (KCZ)	309.05	10.82*	10.60					
	Base *Hirsutella panda* acme (>10%)	309.20	10.82	10.61					
	HCO *Neogloboquadrina mayeri* s.l. (>5%)	312.60	10.88	10.71					
32	Base Kaiti Coiling Zone (KCZ) **Tt/Sw proxy**	315.25	10.93*	10.79	11.3	10.93			
	Base *Bolboforma subfragoris* s.l. subzone BBs-593/D	316.38	10.97	10.83		Waiauan (Sw)		SERRAVALLIAN	MIDDLE MIOCENE
	Top *Bolboforma subfragoris* s.l. subzone BBs-593/C	322.63	11.17	11.02					
	Base *Bolboforma subfragoris* s.l. subzone BBs-593/C	324.40	11.23	11.07					
	Top *Bolboforma subfragoris* s.l. subzone BBs-593/B	326.39	11.29	11.13					
	Base *Bolboforma subfragoris* s.l. subzone BBs-593/B	331.80	11.47	11.29					
	Top *Bolboforma subfragoris* s.l. subzone BBs-593/A	332.74	11.50	11.32					
33	FO *Bolboforma subfragoris* s.l. = base subzone BBs-593/A	334.62	11.56*	11.38					

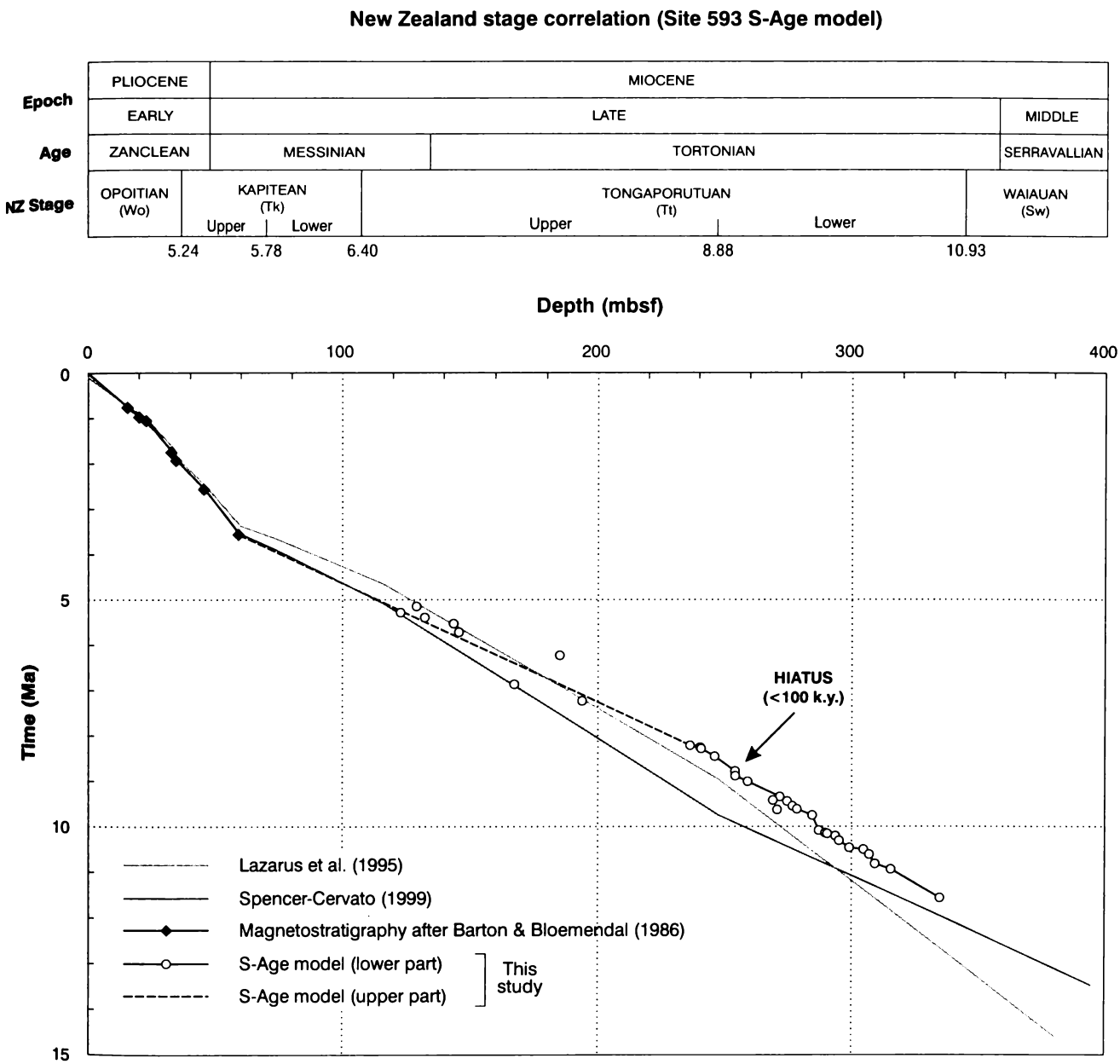


Figure 6.8 – Composite late Neogene age model for Site 593 based on magnetostratigraphic data (Barton & Bloemendal 1986) and S-Age model (this study), compared with LOCs developed by Lazarus et al. (1995) and Spencer-Cervato (1999).

Comparison of biostratigraphic age models

Until now, age models that have been developed as part of the review of DSDP and ODP Holes from the World Ocean (Lazarus et al. 1995; Spencer-Cervato et al. 1999) have provided the only well-founded chronologic scales for the late Miocene section of Site 593 (Figure 6.6). The S-Age model best fits the LOC developed by Lazarus et al. (1995), although the chronology for the Lazarus-LOC is based on Berggren et al. (1985). The S-Age model and LOC of Spencer-Cervato et al. (1999) are both based on the same time scale (GPTS-95), although the S-Age model plots consistently above the Spencer-Cervato LOC (Figure 6.8). The maximum age difference (c. 1.2 m.y.) occurs near the highest occurrence of *Globoquadrina dehiscens,* which has a robust magnetostratigraphically-constrained age of 8.88 Ma at Site 1123. Above this datum, the S-Age model converges on the Spencer-Cervato LOC. This is because they share a common chronostratigraphic tie-point, the base of Chron C2An.3n.

Biochronology

The preferred S-Age model for Site 593 is conservative and preserves the integrity of robust magnetobiochronologic data from the older part of the late Miocene section at Site 1123, except for the Tukemokihi Coiling Zone (TCZ), which has been shown to be diachronous (see earlier). The age model for this part of the section at Site 593 is extremely robust and the interpolated ages that have been assigned to bioevents are very reliable (Table 6.4). Important bioevents that have not been reliably dated in New Zealand before include:

- Subzones associated with short-lived appearances and disappearance of *Bolboforma subfragoris* s.l.: BBs-593/A (11.56-11.50 Ma); BBs-593/B (11.47-11.29 Ma); BBs-593/C (11.23-11.17 Ma); BBs-593/D (10.97-10.80 Ma); and BBs-593/E (10.70-10.61 Ma).

- Highest common occurrence of *Neogloboquadrina mayeri* s.l. (10.88 Ma): At Site 593 this datum occurs in the lowermost part of the Kaiti Coiling Zone. In sequences with poor planktic representations, it may sometimes be mistaken for the highest occurrence of *Nq. mayeri* s.l.

- *Hirsutella panda* acme zone (10.82-10.56 Ma): A narrow, well defined zone where the abundance of *Hr. panda* in planktic foraminiferal assemblages is often >10% and

sometimes exceeds that of *Globoconella miotumida*. *Hirsutella panda* is noted by Scott et al. (1990) to be widespread in lower Tongaporutuan assemblages in eastern North Island, New Zealand, but specimens are seldom as frequent, or as ubiquitous, as those of *Gc. miotumida*. In this respect, the *Hr. panda* acme zone at Site 593, is possibly unique.

- Mapiri Coiling Zone (10.60-10.57 Ma): The MCZ is marked by a very narrow interval with increased contributions of dextrally-coiled *Globoconella miotumida* (>20% dextral). It occurs just above the Kaiti Coiling Zone.

- Glomar Coiling Zone (10.82-10.25 Ma): The GCZ is marked at Site 593 by significant representations of dextrally-coiled shells (>30%), although it occurs in an interval where *Neogloboquadrina* is relatively rare. The lower part of the GCZ (10.82-10.48 Ma) is associated with *Nq. mayeri* s.l., and the upper part (10.48-10.25 Ma) is associated with *Nq. pachyderma*.

- Lower *Truncorotalia juanai* acme zone (10.82-10.50 Ma): A well defined zone that includes small, but persistent populations of *Tr. juanai*, with spiroconical profiles. It corresponds to the oldest of three late Miocene influxes of *Tr. juanai*. The base of the lower acme zone is marked by the lowest occurrence of *Tr. juanai*.

- Highest occurrence of *Neogloboquadrina mayeri* s.l. – excluding expatriates (10.48 Ma): It has been suggested by Berggren et al. (1995b) that the highest occurrence of this important temperate and (sub)tropical zonal species occurs at 11.4 Ma, although Miller et al. (1994) argue that the highest occurrence of *Nq. mayeri* is latitudinally diachronous, persisting to the earliest part of Chron C5n at mid-latitudes in the North Atlantic (e.g. DSDP Site 563). The new age data from Site 593 supports the contention of Miller et al. (1994) that the datum is latitudinally diachronous and that it persists into the early part of Chron C5n.2n in the Southwest Pacific. This has important implications for New Zealand stage correlations, as the highest occurrence of *Nq. mayeri* Zone was used by Jenkins (1967) as a marker species for the Tongaporutuan-Waiauan Stage boundary and the top of the middle Miocene (11.3 Ma). Subsequent workers in New Zealand (e.g. Hornibrook et al. 1989; Scott et al. 1990) have extended the range of *Nq. mayeri* into the lower Tongaporutuan, although the highest occurrence of *Nq. mayeri* is still widely used as a marker for the top of the middle Miocene.

- Lowest occurrence of *Neogloboquadrina pachyderma* (10.48 Ma): This datum immediately follows the highest occurrence of *Nq. mayeri* s.l., although it occurs in an interval at Site 593 where *Neogloboquadrina* is relatively rare.

- Highest occurrence of strongly keeled *Hirsutella panda* (10.42 Ma): In New Zealand the highest occurrence of *Hr. panda* has generally been located just prior to the highest occurrence of *Globoquadrina dehiscens* (Hornibrook et al. 1989; Scott et al. 1990), although Kennett & Srinivasan (1983) give the top of its range as *Globoconella conomiozea* Zone. At Site 593, however, *Hr. panda* is replaced by weakly keeled forms of *Hr.* cf. *ichinosekiensis* in the lower Tongaporutuan, well below the highest occurrence of *Gq. dehiscens*.

- Tukemokihi Coiling Zone (9.31-9.27 Ma): Based on the S-Age model, the TCZ occurs about 170-310 k.y. later at Site 593 than at Site 1123. This places a cautionary caveat on the use of TCZ for correlation.

- A short subzone (BBm-593/B) comprised of small smooth-walled bolboforms (9.31-9.29 Ma): The subzone occurs in the lower part of the *Bolboforma metzmacheri* Zone.

- Highest occurrence of weakly carinate *Hirsutella* cf. *ichinosekiensis* (8.90 Ma): Specimens of *Hirsutella* cf. *ichinosekiensis* are very similar to *Hirsutella panda*, but are distinguished on the basis of their weaker keel development. Weakly keeled specimens of *Hr.* cf. *ichinosekiensis* are poorly represented at Site 593, but they appear to grade up into non-carinate specimens of *Hr.* cf. *ichinosekiensis*. This occurs just prior to the highest occurrence of *Globoquadrina dehiscens*.

- Highest occurrence of non-carinate *Hirsutella* cf. *ichinosekiensis* (8.90 Ma): The datum is very poorly defined at Site 593, even though the site has large, well preserved, planktic foraminiferal assemblages. It is unlikely that the datum would be reliably located in sequences with poor planktic representations.

A number of useful bioevents also occur in the younger part of the late Miocene section at Site 593, where the dating is less robust than in the older part of the section. In the S-Age model, bioevents between the highest occurrence of *Bolboforma praeintermedia* (8.21 Ma) and the base of Chron C2An.3n (3.58 Ma) have been assigned ages based on a simple

linear interpolation between these two well-constrained stratigraphic tie-points. Bioevents in this part of the section that have not been reliably dated before include:

- Middle *Truncorotalia juanai* acme zone (7.09-6.86 Ma): A well defined zone at Site 593 that is associated with spirally-domed specimens of *Tr. juanai.* It corresponds to the second of three late Miocene influxes of *Tr. juanai*, where specimens of *Tr. juanai* form a small but ubiquitous part of planktic foraminiferal assemblages.

- Lowest occurrence of *Globoconella conomiozea* (6.40 Ma): In the shallow water section at Blind River, in Marlborough, the lowest occurrence of *Gc. conomiozea* is noted by Loutit & Kennett (1979) to occur close to a permanent $\delta^{13}C$ shift of 0.5 per mil, from heavy to lighter values. Roberts et al. (1994) correlate this biostratigraphic datum with a horizon near the base of Chron C3An.1r (c. 6.2 Ma). Significantly, this is above the base of the Kapitean Stage at Blind River, as defined by the lowest occurrence of the molluscan species *Sectipecten wollastoni* at Blind River (Kennett & Watkins 1974), which Roberts et al. (1994) correlate with a horizon near the base of Chron C3An.2n (c. 6.6 Ma). This suggests the base of the Kapitean is probably located too high in some oceanic sequences where the lowest occurrence of *Gc. conomiozea* has been used as a proxy for the stage boundary. At Site 593, for example, where the morphological transformation between *Gc. miotumida* and *Gc. conomiozea* is very well defined and the lowest occurrence of *Gc. conomiozea* is located at a horizon where >10% of adult specimens have less than four and one-half chambers in the outer whorl, the planktic datum is estimated on the basis of the S-Age model to have an age of 6.4 Ma.

- Subzones associated with the Palliser Coiling Zone (6.16-6.05 Ma): *Gc*-593/D1 (6.16-6.15 Ma); *Gc*-593/D2 (6.11-6.08 Ma); and *Gc*-593/D3 (6.06-6.05 Ma). Subzones associated with the PCZ are marked by increased representations of dextrally-coiled *Globoconella conomiozea* (>20% dextral). There are at least three such subzones at Site 593, although they are very narrow and there are no reliable faunal criteria that distinguish between them. This limits the potential use of the subzones for correlation. The PCZ, which includes all three subzones, occupies a relatively narrow interval (110 k.y. duration), and is potentially more useful as a stratigraphic marker.

- Upper *Truncorotalia juanai* acme zone (5.91-5.24 Ma): At Site 593, the acme corresponds to the youngest of three late Miocene influxes of *Tr. juanai.* It is distinguished from the older acmes in being associated with the early part of a morphological transformation in Kapitean truncorotalid populations – a transformation that leads to the appearances of *Tr. neojuanai, Tr. crassaformis,* and *Tr.* aff. *crassaconica.*

- Lowest occurrence of *Globoconella mons* (5.84 Ma): *Globoconella mons* evolves from *Gc. conomiozea* at Site 593 in the lower Kapitean, although early specimens are extremely rare and this affects the reliability of the datum and its interpolated age.

- Lowest occurrence of *Truncorotalia neojuanai* (5.84 Ma): The lowest occurrence of *Truncorotalia neojuanai* is defined in terms of a rapid morphological transformation between ventrally-inflated specimens of *Tr. juanai* and *Tr. crassaformis.* The datum is located at the level where the ratio between axial height and the maximum spiral diameter first exceeds 0.6. This is moderately well defined at Site 593, although it is unlikely that the datum would be reliably located in sequences with poor planktic representations.

- Lowest occurrence of *Globoconella sphericomiozea* (5.78 Ma): The lowest occurrence of *Gc. sphericomiozea*, where at least 5% of adult specimens lack a keel, is associated with the morphological transformation between *Gc. conomiozea* and *Gc. sphericomiozea.* The datum is reliably located in the section at Site 593, although its stratigraphic position at Site 1123, where the datum has an interpolated age of 5.53 Ma, is less reliable, and is probably too old. The lowest occurrence of *Gc. sphericomiozea* is correlated by Roberts et al. (1994) with Chron C3r at Blind River (c. 5.5 Ma). Although the data from New Zealand concerning the precise age of the lowest occurrence of *Gc. sphericomiozea* are somewhat equivocal, there is general agreement that the datum occurs within the mid to lower part of Chron C3r.

- Lowest occurrence of *Truncorotalia* aff. *crassaconica* (5.57 Ma): Specimens of *Tr.* aff. *crassaconica* with angular chamber outlines first appear at Site 593 in truncorotalid populations near the Miocene/Pliocene boundary. Early specimens of *Truncorotalia* aff. *crassaconica* are very rare and this places a caveat on the reliability of the datum and its interpolated age.

- Lowest occurrence of *Globoconella pliozea* (5.49 Ma): *Globoconella pliozea* forms part of a divergent group of compactly coiled globoconellids that evolves from *Gc. conomiozea* in the upper Kapitean. Early specimens of *Gc. pliozea* are relatively rare at Site 593 and this adversely affects the reliability of the datum and its interpolated age.

- Challenger Coiling Zone (5.47-5.24 Ma): The CCZ is marked by increased contributions of dextrally-coiled *Neogloboquadrina pachyderma* (>30% dextral) in the vicinity of the Miocene/Pliocene boundary. At Site 593, it is a well defined zone that represents the first significant increase in late Miocene contributions of dextrally-coiled *Nq. pachyderma,* following the Glomar Coiling Zone.

- Lowest occurrence of *Truncorotalia crassaformis* (5.41 Ma): The lowest occurrence of *Tr. crassaformis* is defined in terms of a morphological transformation between *Tr. neojuanai* and *Tr. crassaformis.* The transformation is moderately well defined at Site 593, although early specimens of *Tr. crassaformis* are relatively rare and this places a caveat on the reliability of the datum.

- Lowest occurrence of *Globoconella puncticulata* (5.24 Ma): The lowest occurrence of *Gc. puncticulata,* where at least 95% of adult specimens lack a keel, is reliably located at Site 593. It occurs in a part of the section where there is a rapid morphological transformation and evolutionary radiation in globoconellid populations. Significantly, the lowest occurrence of *Gc. puncticulata* is noted by Dowsett (1989) to occur at the base of Chron C3n.4n (5.23 Ma) at subtropical South Pacific and South Atlantic DSDP Sites. This suggests the interpolated age for the datum at Site 593 is probably reliable, and that the datum is potentially isochronous over a wide southern mid-latitude region.

CONCLUSIONS

The well-founded segmented (S-Age) model for Site 593, which is based on magnetobiochronologic data from Site 1123, provides a robust chronology and time scale for the older part of the late Miocene section (11.56-8.21 Ma). The S-Age model takes into account hiatuses and short-term sedimentary variations, and it is more likely to accommodate various sources of biostratigraphic error than the alternative linear age (L-Age) model. Interpolated ages that have been assigned to bioevents in this part of the section at Site 593 are very reliable and they extend the number of late Miocene bioevents in the New Zealand region that have been calibrated either directly or indirectly with the

geomagnetic polarity time scale (GPTS-95). The chronology of the younger part of the late Miocene and early Pliocene section at Site 593 (8.21-3.58 Ma) is based on a simple linear interpolation between two reliable stratigraphic tie-points, the highest occurrence of *Bolboforma praeintermedia* and the base of Chron C2An.3n. This part of the S-Age model is less robust than the older part, although it provides a good basis for assigning ages to bioevents that have not been reliably dated before.

The S-Age model that has been developed for Site 593 represents a major advance in biostratigraphic correlation in New Zealand, and it effectively doubles the number of late Miocene bioevents that have been correlated either directly or indirectly with the geomagnetic polarity time scale (GPTS-95). The older part of the robust late Miocene biostratigraphic framework is very important for petroleum exploration in New Zealand, as it refines the correlation of reservoir sequences associated with the Mt Messenger Formation – a productive and economically important source of hydrocarbons in North Taranaki (King & Thrasher 1996).

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Appendix

Appendix 6.1 – Data used in the determination of midpoints for bioevents at Sites 593 and 1123 (source: Studies 2, 3, and 5). See general explanation Table 6.1. Numbering of cores follows the standard practices of the Ocean Drilling Program (Carter et al. 1999). Closest = closest constraining sample to a datum. Chron/subchron correlations give the proportional position from its younger end.

Site 593								Site 1123 (Hole B)									Bioevents	
Core	Sect.	Upp. (cm)	Low. (cm)	Depth (mbsf)	Closest (m)	Mid-point (mbsf)	S-Age (Ma)	Core	Sect	Upp (cm)	Low (cm)	Depth (mbsf)	Depth (r-mcd)	Closest (m)	Midpoint (r-mcd)	Chron/ Subchron	Age (Ma)	Ref	Coiling zones, acmes, highest and lowest occurrences
14X	2	112	115	122 92	-0 19	122 82	5.24												Top upper *Truncorotalia* acme zone
14X	2	112	115	122 92	-0 19	122 82	5.24												Top Challenger Coiling Zone (CCZ) = top *Nq* -593/B (>30% Dex)
14X	2	112	115	122 92	0 18	123 01	5.24	20X	4	50	55	177 36	192 16	1.00	192 66	reversed	5.28	2	LO *Globoconella puncticulata* s s (<5% weakly cannate) Wo/Tk proxy
14X	6	130	133	129 10	0 40	129 30	5.41	20X	1	10	14	172 40	187 20	0.90	187 65	reversed	5.15	1	LO *Truncorotalia crassaformis*
15X	2	11	14	131 54	0 40	131 71	5.47												Base Challenger Coiling Zone (CCZ) = base *Nq* -593/B (>30% Dex)
15X	2	93	96	132 33	0 41	132 54	5.49	20X	7	0	5	181 40	196.20	0.90	196.65	reversed	5.39	3	LO *Globoconella pliozea*
15X	4	90	93	135 30	0 20	135 40	5 57												LO *Truncorotalia* aff *crassaconica*
16X	3	103	106	143 53	0 31	143 69	5.78	21X	3	140	145	186 30	201 10	0.98	201 59	reversed	5 53	4	LO *Globoconella sphericomiozea* s s upper-lower Tk proxy
16X	5	0	3	145 50	0 43	145 72	5.84												LO *Truncorotalia neojuanai*
16X	5	0	3	145 50	0 43	145 72	5.84	22X	1	140	145	193.00	207 80	1 37	208 49	indeterminate	5.72	5	LO *Globoconella mons*
16X	6	133	136	148 33	0 34	148 50	5.91												Base upper *Truncorotalia juanai* acme zone
17X	4	37	39	153 97	-0 31	153 82	6.05												Top Palliser Coiling Zone (PCZ) = Top subzone *Gc* -593/D3 (>20% Dex)
17X	4	53	56	154 13	0 19	154 22	6.06												Palliser Coiling Zone (Base subzone *Gc* -593/D3)
17X	5	14	17	155 24	-0 14	155 17	6.09												Palliser Coiling Zone (Top subzone *Gc* -593/D2)
17X	5	84	87	155 94	0 19	156 03	6 11												Palliser Coiling Zone (Base subzone *Gc* -593/D2)
17X	6	133	136	157 93	-0 17	157 85	6.16												Palliser Coiling Zone (Top subzone *Gc* -593/D1)
17X	7	0	3	158 10	0 17	158 18	6.16												Base Palliser Coiling Zone (PCZ) = Base subzone *Gc* -593/D1 (>20% Dex)
18X	6	86	89	167 06	0 38	167 25	6.40	26X	2	30	35	231 80	249 24	1 50	249 99	indeterminate	6 87	7	LO *Globoconella conomiozea*
20X	5	117	119	185 07	-0 35	184 90	6.86	24X	2	50	55	212 80	227 60	-0 90	227 15	indeterminate	6.23	6	Top middle *Truncorotalia juanai* acme zone
21X	5	0	2	193 50	0 42	193 71	7 10	27X	7	0	5	248 80	263 40	1.00	263 90	C3Br 2r	7.23	8	Base middle *Truncorotalia juanai* acme zone
26X	1	102	104	236 52	-0 20	236 42	8 21	31X	7	0	5	287 10	301 90	-0 50	301 65	C4r 1r(0 81)	8 21	9	HO *Bolboforma praeintermedia*
26X	3	82	84	239 32	-0 39	239 12	8 23												HO *Hirsutella* cf. *ichnosekensis* (non-carinate)
26X	4	32	34	240 32	0 20	240 42	8.25	32X	1	50	55	288 20	303 00	0 50	303 25	base C4n 1n	8.25	10	LO *Bolboforma praeintermedia*
26X	4	92	94	240 92	-0 20	240 82	8.28	32X	2	50	55	289.70	304 50	-0 50	304 25	C4r 2r(0 06)	8.28	11	HO *Bolboforma metzmacheri ornata*
27X	1	96	98	246 06	0 21	246 17	8.45	32X	6	50	55	295 70	310 50	1 70	311 35	C4r 2r(0 44)	8.45	12	LO *Bolboforma metzmacheri ornata*
27X	7	17	19	254 27	-0 17	254 19	8.78	34X	2	100	105	309 40	324 20	-0 50	323 95	C4An(0 25)	8.78	13	HO *Bolboforma metzmacheri* s s (upper subzone)
27X	CC	10	12	254 49	-0 39	254 30	8.88	34X	4	100	105	312 40	327 20	-0 50	326 95	C4An(0 57)	8.88	14	HO *Globoquadrina dehiscens* upper-lower Tt proxy
28X	1	58	60	255 28	-0 35	255 10	8 90												HO *Hirsutella* cf. *ichnosekensis* (weakly carinate)
28X	3	137	139	259 07	0 19	259 17	9 01	34X	6	100	105	315 40	330 20	0 50	330 45	C4An(0 94)	9 01	15	LO *Bolboforma metzmacheri* s s. (upper subzone) BBm-593/C
29X	4	48	50	269 28	-0 42	269 07	9.26	36X	2	10	14	327 50	342 30	-0 50	342 05	C4Ar 2r(0 41)	9.42	17	Top Tukemokihi coiling zone (TCZ) >20% Dex
29X	4	107	109	269 87	-0 12	269 81	9.27												Top subzone BBm-593/B (small smooth-walled phases)
29X	5	15	17	270 45	0 27	270 59	9.29												Base subzone BBm-593/B (small smooth-walled phases)
29X	5	42	44	270 72	0 19	270 82	9.30	36X	5	60	64	332 50	347 30	0 50	347 55	C4Ar 2n(0 71)	9.62	21	Base Tukemokihi coiling zone (TCZ) >20% Dex
29X	6	14	16	271 94	-0 22	271 83	9.34	36X	1	60	64	326 50	341 30	-0 50	341 05	C4Ar 2r(0 11)	9.34	16	HO *Bolboforma metzmacheri* s s. (lower subzone) BBm-593/A
30X	1	82	84	274 72	-0 24/0 21	274 70	9 44	36X	2	10	14	327 50	342 30	±0 50	342 30	C4Ar 2r(0 48)	9.44	18	*Bolboforma metzmacheri* s s abundance spike (lower subzone)
30X	2	133	135	276 73	0 18	276 82	9.54	36X	2	110	114	328 50	343 30	0 50	343 55	C4Ar 2r(0 86)	9.54	19	LO *Bolboforma metzmacheri* s s. (lower subzone) BBm-593/A
30X	4	32	34	278 72	-0 23	278 61	9.61	36X	5	10	14	332 00	346 80	-0 50	346 55	C4Ar 2n(0 51)	9.61	20	HO *Bolboforma gracilireticulata* s l
31X	1	105	107	284 55	0 13	284 62	9.75	37X	1	50	54	336 00	350 80	0 50	351 05	base C4Ar 3r	9.75	22	LO *Bolboforma gracilireticulata* s l.
31X	3	82	84	287 32	-0 28	287 18	10 08	37X	6	50	54	343 50	358 30	-0 50	358 05	C5n 2n(0 16)	10 08	23	HO *Bolboforma pentaspinosa* (excludes Site 1123 outlier)
31X	5	23	25	289 73	-0 23	289 62	10 13	38X	1	10	14	345 20	360 00	-0 70	359 85	C5n 2n(0 21)	10.13	24	HO *Bolboforma capsula*
31X	5	83	85	290 33	0 18	290 42	10.15	38X	1	10	14	345 20	360 00	0 40	360 20	C5n 2n(0 22)	10.15	25	LO *Bolboforma pentaspinosa*
32X	1	41	43	293 51	0 20	293 61	10.20	38X	2	0	4	346 60	361 40	0 50	361 65	C5n 2n(0 27)	10.20	26	LO *Bolboforma capsula*
32X	1	141	143	294 51	-0 39	294 31	10.25												Top Glomar Coiling Zone (GCZ) >30% Dex
32X	2	52	54	295 12	-0 22	295 01	10.31	38X	4	50	54	350 10	364 90	-0 50	364 65	C5n 2n(0 38)	10.31	27	HO *Bolboforma gruetzmacheri*
32X	4	48	50	298 08	-0 38	297 89	10.43												HO *Hirsutella panda* (strongly keeled morphotypes)
32X	4	133	135	298 93	0 18	299 02	10.46	38X	7	0	4	354 10	368 90	0 60	369 20	C5n 2n(0 53)	10 46	28	LO *Bolboforma gruetzmacheri*
32X	CC	2	4	299 67	3 04	301 19	10 46												LO *Neogloboquadrina pachyderma* s l
33X	1	1	3	302 71	-3 04	301 19	10.46												HO *Neogloboquadrina mayeri* s l
33x	1	143	145	304 13	-0 36	303 95	10.50												Top lower *Truncorotalia juanai* acme zone
33X	2	46	48	304 66	-0 19	304 57	10.50	39X	1	100	104	355 70	370 50	-0 50	370 25	C5n 2n(0 56)	10.50	29	HO *Bolboforma subtragora* s l (top subzone BBs-593/E = BBs-1123/D)
33X	3	23	25	305 93	-0 22	305 82	10.56												Top *Hirsutella panda* acme (>10%)
33X	3	41	43	306 11	-0 18	306 02	10.57												Top Mapin Coiling Zone (MCZ) >20% Dex
33X	3	84	86	306 54	0 21	306 65	10 60												Base Mapin Coiling Zone (MCZ) >20% Dex
33X	3	116	118	306 86	-0 11/0 06	306 83	10.61	39X	4	50	53	359 70	374 50	±0 50	374 50	C5n 2n(0 71)	10 61	30	*Bolboforma subtragora* s l abundance spike (BBs-593/E = BBs-1123/D)
33X	4	50	52	307 70	0 23	307 82	10.69												Base *Bolboforma subtragora* s l subzone BBs-593/E
33X	5	29	31	308 99	-0 28	308 85	10.79												Top *Bolboforma subtragora* s l subzone BBs-593/D
33X	5	29	31	308 99	0 12	309 05	10.80												LO *Truncorotalia juanai* (base lower *Tr juanai* acme)
33X	5	29	31	308 99	0 12	309 05	10.80												Base Glomar Coiling Zone (GCZ) >30% Dex
33X	5	41	43	309 11	-0 12	309 05	10.82	40X	1	50	53	364 90	379 70	-0 40	379 50	C5n 2n(0 87)	10.82	31	Top Karti Coiling Zone (KCZ) >20% Dex
33X	5	41	43	309 11	0 17	309 20	10 82												Base *Hirsutella panda* acme (>10%)
34X	1	37	39	312 67	-0 13	312 60	10.89												HCO *Neogloboquadrina mayeri* s l (>5%)
34X	2	139	142	315 19	0 11	315 25	10.93	40X	3	50	53	367 90	382 70	0 50	382 95	C5n 2n(0 98)	10.93	32	Base Karti Coiling Zone (KCZ) >20% Dex Tt/Sw proxy
34X	3	97	99	316 27	0 21	316 38	10.98												Base *Bolboforma subtragora* s l subzone BBs-593/D
35X	1	82	84	322 72	-0 18	322 63	11.19												Top *Bolboforma subtragora* s l subzone BBs-593/C
35X	2	90	92	324 30	0 20	324 40	11.24												Base *Bolboforma subtragora* s l subzone BBs-593/C
35X	4	10	12	326 50	-0 22	326 39	11.31												Top *Bolboforma subtragora* s l subzone BBs-593/B
36X	1	19	21	331 69	0 21	331 80	11 49												Base *Bolboforma subtragora* s l subzone BBs-593/B
36X	1	130		332 80	-0 12	332 74	11 52												Top *Bolboforma subtragora* s l subzone BBs-593/A
36X	2	136	138	334 36	0 51	334 62	11 56	41X	6	0	5	381 60	398 42	0 04	398 44	C5r 2r(0 55)	11 56	33	LO *Bolboforma subtragora* s l (base subzone BBs-593/A = BBs-1123/A)

Study 7

Reassessment of faunal criteria used for the operational recognition and correlation of the lower Tongaporutuan Stage (late Miocene, New Zealand)

Reassessment of faunal criteria used for the operational recognition and correlation of the lower Tongaporutuan Stage (late Miocene, New Zealand)

ABSTRACT: The Waiauan-Tongaporutuan Stage boundary cannot be resolved in many oceanic sequences and some neritic sequences because of the absence of the defining faunal criterion, the lowest occurrence of the *Bolivinita quadrilatera* group. *Bolivinita* is a benthic foraminiferal species that is largely found in slope environments (water depths c. 300-1500 m). A review of planktic foraminiferal events in the vicinity of the boundary at oceanic Sites 593 and 1123 and uplifted marine sequences in New Zealand identifies intervals of dextrally-coiled *Globoconella miotumida* that are potentially useful for biostratigraphic subdivision and correlation of the Tongaporutuan Stage. From oldest to youngest they include the Kaiti Coiling Zone (KCZ) and the newly named Mapiri (MCZ) and Tukemokihi (TCZ) Coiling Zones. To date, no onland section has been found with all three coiling zones, but they have been reliably identified and correlated on the basis of a robust biostratigraphic framework of planktic foraminiferal and bolboform events that has been developed for Site 593 (Studies 2 and 3).

The Kaiti Coiling Zone occurs in the upper part of the *Bolboforma subfragoris* s.l. Zone and is associated with the highest common occurrence of *Neogloboquadrina mayeri* s.l. (>5% planktic abundance). It is found in eastern North Island sequences (e.g. Kaiti Beach, Gisborne) near some of the earliest known New Zealand occurrences of the *B. quadrilatera* group. The Mapiri Coiling Zone also occurs in the upper part of the *Bolboforma subfragoris* s.l. Zone, above the Kaiti Coiling Zone, and between distinctive acmes of *Hirsutella panda* where this typically rare planktic foraminiferal species is more common than *Globoconella miotumida.* It is also closely associated with the entry of the *B. quadrilatera* group in at least one sequence, Tukemokihi Stream, in northern Hawkes Bay. The Tukemokihi Coiling Zone occurs in the lower part of the *Bolboforma metzmacheri* Zone near the highest occurrence of *Globoquadrina dehiscens,* substantially above the Kaiti and Mapiri Coiling Zones. Significantly, it occurs just above the entry of the *B. quadrilatera* group at the Tongaporutuan stratotype in the northern Taranaki, but substantially above the entry of the *B. quadrilatera* group in eastern North Island sequences (e.g. Tukemokihi Stream). These relationships suggest the entry of the *B. quadrilatera* group does not maintain consistent position and that it is the least reliable of

the boundary criteria examined. Consequently, it is proposed that the lower Tongaporutuan Stage boundary should be redefined (primarily) by the base of the Kaiti Coiling Zone and (secondarily) the highest common occurrence of *Neogloboquadrina mayeri* s.l. The entry of the *B. quadrilatera* group is potentially diachronous, but remains useful as a low-resolution proxy for the base of the stage in suitable facies – water depths of 300-1500 m.

The redefinition of the Tongaporutuan Stage resolves a long-standing enigma of Tongaporutuan biostratigraphy, namely the anomalous absence of *Neogloboquadrina mayeri* s.l. near the base of the Tongaporutuan stratotype, and it locates the Waiauan-Tongaporutuan Stage boundary near the base of Chron C5n.2n (10.93 Ma). A new reference section for the stage boundary has yet to be nominated, but a sequence where the entry of the *B. quadrilatera* group can be unambiguously related to the proposed planktic foraminiferal stage criteria is most likely to be found in eastern North Island.

Keywords: stage correlation; faunal definition; Tongaporutuan; Kaiti, Mapiri, Tukemokihi Coiling Zones; late Miocene; New Zealand

INTRODUCTION

The New Zealand Cenozoic stage classification of Finlay & Marwick (1940, 1947) was based on an eclectic selection of molluscan and benthic and planktic foraminiferal events (Table 7.3). As originally proposed, it was suitable for clastic sequences deposited in landward basins, and was only partially applicable to offshore sequences deposited under oceanic water. Micropaleontological studies of cored oceanic sequences at Deep Sea Drilling Project (DSDP) Site 284 (Hornibrook 1982) and Site 593 (Hoskins 1990; Scott 1992) have extended the application of Miocene (Altonian) to Pleistocene stages to offshore sequences (Figure 7.1). As a consequence, most Neogene stage boundaries can now be related to planktic foraminiferal events distributed in latitudinally extensive water masses. These events allow the New Zealand Neogene stage classification to be applied over a wide region of the cool subtropical (temperate) Southwest Pacific and they provide a robust framework for regional syntheses (Figure 7.2).

Improvements to our understanding of planktic foraminiferal taxonomy and phylogeny (e.g. Jenkins 1971; Kennett & Srinivasan 1983; Cifelli & Scott 1986; Scott et al. 1990) and the stratigraphic and geographic distributions of planktic species (e.g. Hornibrook 1981; 1982, Jenkins & Srinivasan 1986) have warranted ongoing revisions of planktic events and

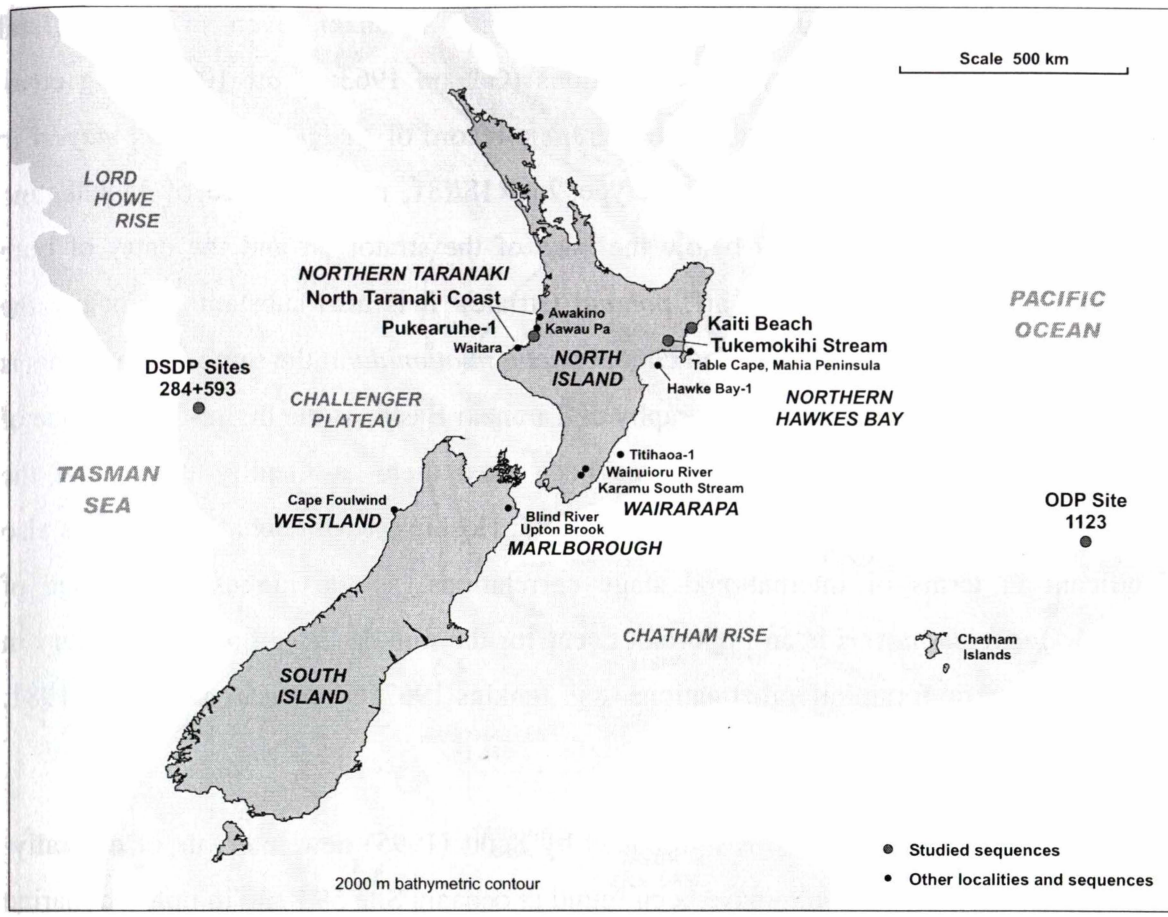


Figure 7.1 – Locality map of New Zealand region showing important late Miocene sequences, onshore and offshore. Detail of the northern Taranaki coastal region is shown in Figure 7.9.

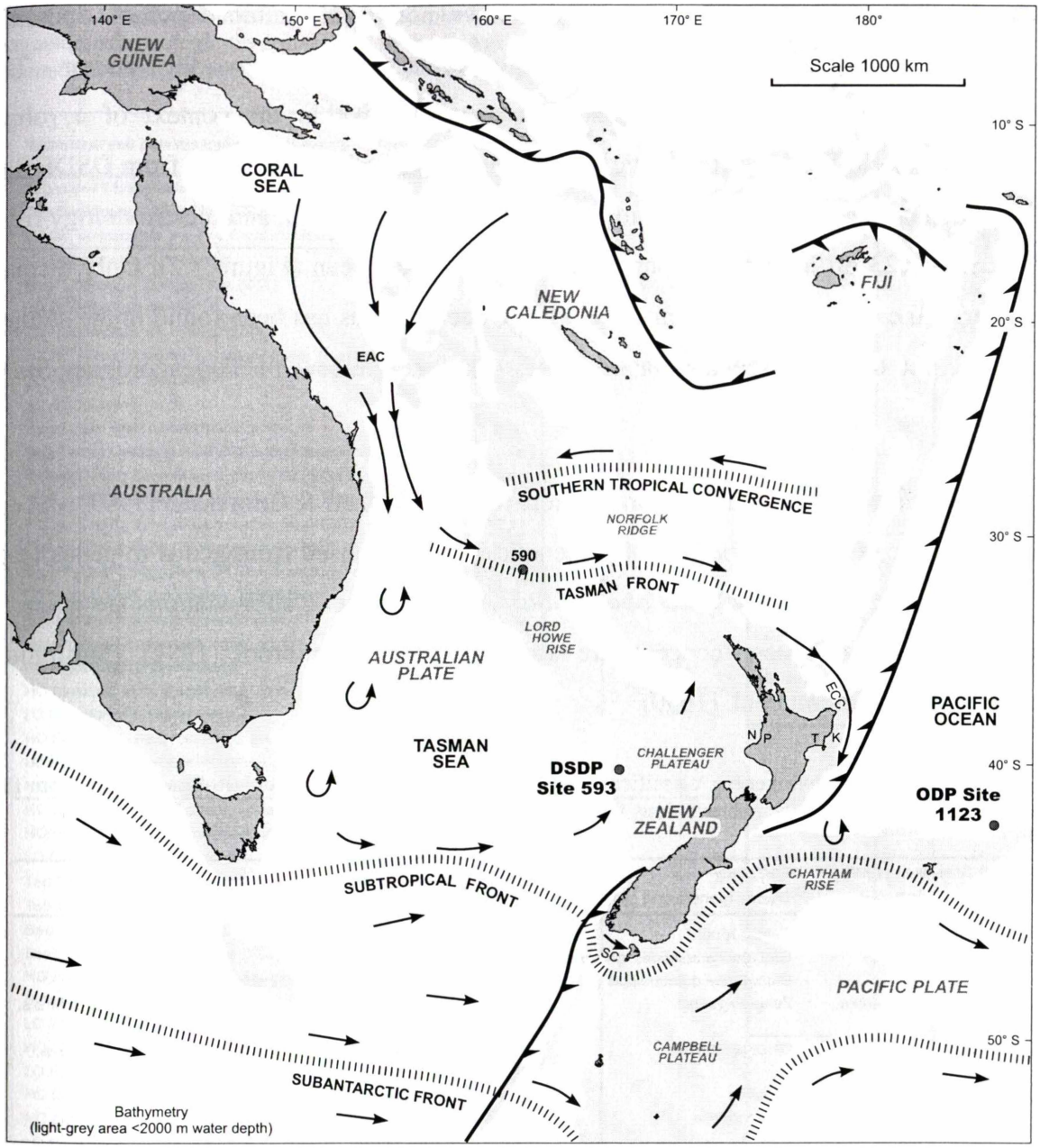
their correlation with New Zealand stages. Scott (1992) advanced Miocene (Altonian to Tongaporutuan) stage correlations by correlating biostratigraphic data from Site 593 with uplifted marine sections in New Zealand. Significantly, a pronounced increase in dextrally-coiled *Globoconella miotumida* was noted at Site 593, near the base of the late Miocene, and similar events were noted immediately above the base of the Tongaporutuan Stage (as identified by the entry of *Bolivinita pohana*) in two onshore sequences, Kaiti Beach and North Taranaki Coast. Scott (1995) subsequently named this event the Kaiti Coiling Zone (KCZ). When the KCZ was established it was considered to be a unique event, at least on a scale not repeated in the history of *Globoconella miotumida*, and it was thought to maintain a consistent, but slightly higher stratigraphic position than the entry of *Bolivinita pohana.* At the same time, the highest occurrence of *Neogloboquadrina mayeri* was judged to be a poor chronostratigraphic estimator for the base of the Tongaporutuan Stage because it did not maintain a constant homotaxial position with respect to these events. It disappears close to the defining faunal criterion for the base of the lower Tongaporutuan Stage – the entry of the *B. quadrilatera* group – at Kaiti Beach, but it is anomalously absent adjacent to

the base of the Tongaporutuan stratotype in North Taranaki, even in foraminiferal assemblages with large planktic representations (Gibson 1963; Scott 1992; King et al. 1993). Scott (1992) noted the highest stratigraphic record of *Neogloboquadrina mayeri* in the vicinity of the Tongaporutuan stratotype, in R18/f81, near the base of Mohakatino Formation. This is substantially below the base of the stratotype and the entry of both *Bolivinita pohana* and *Bolivinita* aff. *pohana* (striate). It is also substantially below the base of the interval of dextrally-coiled *Globoconella miotumida* in the same section. This is significant in the subsurface biostratigraphy of Taranaki Basin, as the highest occurrence of *Neogloboquadrina mayeri* has sometimes been used there to identify the top of the Waiauan Stage (e.g. Scott 1986; Strong et al. 1988; Hoskins & Mildenhall 1989). It is also significant in terms of international stage correlations, as the highest occurrence of *Neogloboquadrina mayeri* is an important event for the middle-late Miocene boundary in temperate planktic foraminiferal zonations (e.g. Jenkins 1967; Srinivasan & Kennett 1981; Jenkins & Srinivasan 1986).

Since the Kaiti Coiling Zone was introduced by Scott (1995) new intervals of dextrally-coiled *Globoconella miotumida* have been found at oceanic Site 593 and in uplifted marine sections in eastern North Island, New Zealand, that are potentially useful for subdivision of the Tongaporutuan Stage (Crundwell et al. 1997; Crundwell 1998). They occur on a scale similar to the Kaiti Coiling Zone and can be reliably located using a simple two-state feature in planktic populations, although they cannot be reliably correlated without distinguishing biostratigraphic criteria, except where all known intervals of dextrally-coiled *Globoconella miotumida* occur in a single succession (e.g. Site 593). In view of the increasing use of the Kaiti Coiling Zone in Tongaporutuan biostratigraphy, it is important to review stage correlations, especially the relationships between known intervals of dextrally-coiled *Globoconella miotumida* and other important stage events, including the entry of the *B. quadrilatera* group and the highest occurrences of *Neogloboquadrina mayeri* s.l. and *Globoquadrina dehiscens*.

Materials and methods

This study examines the biostratigraphy of several important late Miocene sequences in onland New Zealand, including North Taranaki coast and Pukearuhe-1 well sections in western North Island, and Kaiti Beach and Tukemokihi Stream sections in eastern North Island (Figure 7.1). It uses existing microfossil collections held by Geological and Nuclear



Oceanic fronts and surface water masses after Cooke (2002)	Abbreviation	Biogeographic classification after Kennett & Srinivasan (1983)		Example
		Subtropical		Site 588
SOUTHERN TROPICAL CONVERGENCE	**– STC –**	**– STC –**	**– STC –**	**– STC –**
Warm Subtropical Water	WSTW	Transitional	Cool subtropical assemblage	Site 590
TASMAN FRONT	**– TF –**	**– TF –**		**– TF –**
Cool Subtropical Water	CSTW	Temperate		Site 593
SUBTROPICAL FRONT	**– STF –**	**– STF –**	**– STF –**	**– STF –**
Subantarctic Surface Water	SASW			Site 281
SUBANTARCTIC FRONT	**– SAF –**	Subantarctic		**– SAF –**
Circumpolar Surface Water	CSW			Site 278

Figure 7.2 – Modern bathymetry, oceanic fronts and general circulation of surface water in the Tasman Sea region, after Heath (1985). EAC = East Australian Current, ECC = East Cape Current, SC = Southland Current. Locations of cored oceanic Sites 593 and 1123 and important upper Miocene sequences in onland New Zealand: N = North Taranaki Coast, P = Pukearuhe-1, T = Tukemokihi Stream, K = Kaiti Beach. The relationships between oceanic fronts, surface water masses, and planktic foraminiferal biogeography are given in the table beneath the map.

Sciences, Lower Hutt, including some that have not been examined before, and new collections from important stratigraphic intervals collected by the author. The biostratigraphy of the onland sequences is examined within the context of a robust framework of closely spaced planktic foraminiferal and bolboform events from DSDP Site 593 drilled on the Challenger Plateau in the southern Tasman Sea, and biochronology from ODP Site 1123 drilled on Chatham Rise in the Pacific Ocean (Figure 7.2). Only a small number of the pelagic events identified at these oceanic sites has been found in the studied sections, but they provide a reliable framework for a review of Tongaporutuan Stage criteria.

The higher taxonomy of planktic foraminifers follows Kennett & Srinivasan (1983), except the taxonomic status of important phylogenetic groups is raised from genus to genus (e.g. *Globorotalia* (*Globoconella*) = *Globoconella*). Adopted generic abbreviations are given in Table 7.1. Adopted species concepts are largely based on Hornibrook (1982), Hornibrook et al. (1989), and Scott et al. (1990).

Table 7.1 – Adopted phylogenetic classification of important late Miocene planktic foraminifers from the New Zealand region. Generic abbreviations follow Kennett & Srinivasan (1983)

Kennett & Srinivasan (1983) Genera (Subgenera)	This study Clades (genera and groups)	Species and subspecies
Catapsydrax	*Catapsydrax*	*Cs. parvulus*
Globigerina (Globigerina)	*Globigerina bulloides* group	*Gg. bulloides, Gg. falconensis*
	Globigerina quinqueloba group	*Gg. angustiumbilicata, Gg. quinqueloba*
Globigerina (Zeaglobigerina)	*Zeaglobigerina*	*Zg. druryi, Zg. woodi apertura, Zg. woodi decoraperta, Zg. woodi* s.s. *Zg,. nepenthes*
Globigerinoides	*Globigerinoides*	*Gs. obliquus, Gs. quadrilobatus immaturus, Gs. quadrilobatus* s.s., *Gs. quadrilobatus trilobus, Gs. sacculifer*
Orbulina	*Orbulina*	*Or. bilobata, Or. universa*
Globorotalia (Globoconella)	*Globoconella*	*Gc. conomiozea, Gc. explications, Gc. miotumida, Gc. mons, Gc. pliozea, Gc. puncticulata, Gc. sphericomiozea*
Globorotalia (Menaredlla)	*Menardella*	*Mn.* cf. *limbata*
Globorotalia (Hirsutella)	*Hirsutella*	*Hr.* cf. *ichinosekiensis, Hr. margaritae, Hr. panda, Hr. scitula*
Globorotalia (Truncorotalia)	*Truncorotalia*	*Tr.* aff. *crassaconica, Tr. crassaformis, Tr. juanai, Tr. neojuanai* n.sp.
Globorotalia (Globorotalia)	*Globorotalia*	*Gr. lenguaensis*
Globorotalia (Jenkinsella)	– included in *Neogloboquadrina*	
Globoquadrina	*Globoquadrina*	*Gq. dehiscens, Gq. venezuelana*
Neogloboquadrina	*Neogloboquadrina*	*Nq. dutertrei, Nq. mayeri continuosa, Nq. mayeri* s.s., *Nq. mayeri nympha, Nq. pachyderma*
Sphaeroidinllopsis	*Sphaeroidienllopsis*	*Ss. paenedehiscens, Ss. seminulina*
Globorotaloides	*Globorotaloides*	*Gd. hexagona*
Globigerinita	*Globigerinita*	*Gt. glutinata, Gt. uvula*
Globigerinella	*Globigerinella*	*Ge. aequilateralis*
	Globigerinopsis	*Gp. obesa*

Biostratigraphic data and curation

All microfossil collections examined in this study have been searched extensively for planktic foraminiferal and bolboform events that have been found at Sites 593 and 1123 – a list of key events is given in Table 7.2. Proportions of planktic taxa and coiling data were

Table 7.2 – Age calibrated bolboform and planktic foraminiferal events from DSDP Site 593. *Site 1123 magnetobiochronologic tie-points used in the S-Age model for Site 593 (Study 6). New Zealand stages and international correlation emended after M-96 (Morgans et al. 1996); bolboform zonation follows Study 3.

Bolboform and planktic foraminiferal events	S-Age (Ma)	M-96 (Ma)	NZ Stage (This Study)	Bolboform zonation	Age/Epoch	
Top upper *Truncorotalia juanai* acme	5.24		lower Opoitian (lWo)	unzoned	ZANCLEAN	EARLY PLIOCENE
Top Challenger Coiling Zone (CCZ) = top *Nq*-593/B	5.24					
LO *Gc. puncticulata* s.s. (<5% weakly carinate) **Wo/Tk proxy**	5.24	5.2	5.24			
LO *Truncorotalia crassaformis*	5.41		upper Kapitean (uTk)		MESSINIAN	LATE MIOCENE
Base Challenger Coiling Zone (CCZ)	5.47					
LO *Globoconella pliozea*	5.49					
LO *Truncorotalia* aff. *crassaconica*	5.57					
LO *Gc. sphericomiozea* s.s. **upper-lower Tk proxy**	5.78	5.5	5.78			
LO *Truncorotalia neojuanai*	5.84		lower Kapitean (lTk)			
LO *Globoconella mons*	5.84					
Base upper *Truncorotalia juanai* acme	5.91					
Top Palliser Coiling Zone (PCZ) = top subzone *Gc*-593/D3	6.05					
Palliser Coiling Zone (Base subzone *Gc*-593/D3)	6.06					
Palliser Coiling Zone (Top subzone *Gc*-593/D2)	6.08					
Palliser Coiling Zone (Base subzone *Gc*-593/D2)	6.11					
Palliser Coiling Zone (Top subzone *Gc*-593/D1)	6.15					
Base Palliser Coiling Zone (PCZ) = base subzone *Gc*-593/D1	6.16					
LO *Globoconella conomiozea* **Tk/Tt proxy**	6.40	6.6	6.40			
Top middle *Truncorotalia juanai* acme	6.86		upper Tongaporutuan (uTt)	B. intermedia (BBi)	TORTONIAN	
Base middle *Truncorotalia juanai* acme	7.09					
HO *Bolboforma praeintermedia*	8.21*					
HO *Hirsutella* cf. *ichinosekiensis* (non-carinate)	8.24					
LO *Bolboforma praeintermedia*	8.25*					
HO *Bolboforma metzmacheri ornata*	8.28*			B. metzmacheri (BBm)		
LO *Bolboforma metzmacheri ornata*	8.45*					
HO *Bolboforma metzmacheri* s.s. (upper subzone)	8.78*	10.1	8.88			
HO *Globoquadrina dehiscens* **upper-lower Tt proxy**	8.88*		lower Tongaporutuan (lTt)			
HO *Hirsutella* cf. *ichinosekiensis* (weakly carinate)	8.90					
LO *Bolboforma metzmacheri* s.s. (upper subzone)	9.01*					
Top Tukemokihi Coiling Zone (TCZ)	9.27					
Top subzone BBm-593/B (small smooth-walled phases)	9.29					
Base subzone BBm-593/B (small smooth-walled phases)	9.31					
Base Tukemokihi Coiling Zone (TCZ)	9.31					
HO *Bolboforma metzmacheri* s.s. (lower subzone)	9.34*					
B. metzmacheri s.s. abundance spike (lower subzone)	9.44*					
LO *Bolboforma metzmacheri* s.s. (lower subzone)	9.54*					
HO *Bolboforma gracilireticulata* s.l.	9.61*			B. capsula (BBc)		
LO *Bolboforma gracilireticulata* s.l.	9.75*					
HO *Bolboforma pentaspinosa*	10.08*					
HO *Bolboforma capsula*	10.13*					
LO *Bolboforma pentaspinosa*	10.15*					
LO *Bolboforma capsula*	10.20*					
Top Glomar Coiling Zone (GCZ)	10.25			B. gruetzmacheri (BBg)		
HO *Bolboforma gruetzmacheri*	10.31*					
HO *Hirsutella panda* (strongly keeled morphotypes)	10.42					
LO *Bolboforma gruetzmacheri*	10.46*					
LO *Neogloboquadrina pachyderma* s.l.	10.48					
HO *Neogloboquadrina mayeri* s.l.	10.48					
Top lower *Truncorotalia juanai* acme	10.50					
HO *Bolboforma subfragoris* s.l.	10.50*			B. subfragoris (BBs)		
Top *Hirsutella panda* acme (>10%)	10.56					
Top Mapiri Coiling Zone (MCZ)	10.57					
Base Mapiri Coiling Zone (MCZ)	10.60					
B. subfragoris s.l. abundance spike (subzone BBs-593/E)	10.61*					
Base *Bolboforma subfragoris* s.l. subzone BBs-593/E	10.70					
Top *Bolboforma subfragoris* s.l. subzone BBs-593/D	10.80					
LO *Truncorotalia juanai* (base lower *Tr. juanai* acme)*	10.82					
Base Glomar Coiling Zone (GCZ)	10.82					
Top Kaiti Coiling Zone (KCZ)	10.82*					
Base *Hirsutella panda* acme (>10%)	10.82					
HCO *Neogloboquadrina mayeri* s.l. (>5%)	10.88					
Base Kaiti Coiling Zone (KCZ) **Tt/Sw proxy**	10.93*	11.3	10.93			
FO *Bolboforma subfragoris* s.l. = base subzone BBs-593/A	11.56*		Waiauan (Sw)		SERR.	M. Miocene

compiled from counts of specimens in the 150-1000 μm size fraction. All biostratigraphic materials resulting from the study, including washed and unwashed sample portions and faunas mounted on slides, are held at Geological and Nuclear Sciences, Lower Hutt. Collections are registered with New Zealand Fossil Record numbers (e.g. Q18/f125) and GNS (F-series) curation numbers listed in Appendices 7.3-7.8. Important biostratigraphic data for individual collections are also given in the appendices. The ODP classification for sample numbering is adopted for sampled horizons at oceanic sites. This follows the format: Hole number, core, core type, core section, and depth from top of core section (e.g. 593-34X-3, 118-120 cm).

Oceanographic setting

Modern surface water circulation in the New Zealand region and the relationships between oceanic fronts, surface water masses, and planktic foraminiferal biogeography are shown in Figure 7.2. At present, all of the studied sections are located between the Subtropical Front and Tasman Front, in the cool subtropical (temperate) Tasman Sea and Southwest Pacific regions. Sea-floor spreading between Australia and Antarctica has shifted the continental landmass of New Zealand northwards from a position of 45° S latitude at the beginning of the late Miocene to its present position of 40° S (Weissel et al. 1977), but the relative positions of the sites appear to have been similarly located in the early late Miocene (Edwards 1975; Nelson & Cooke 2001).

TONGAPORUTUAN STAGE

Marwick (1924) proposed the name Tongaporutuan early in the development of the New Zealand Cenozoic stage classification when distinctive lithostratigraphic units (e.g. Tongaporutu Series of Grange (1922)) were being nominated as bases for sequential biostratigraphic units that might be recognized throughout New Zealand. Allan (1933) advanced this procedure and formulated stage concepts for intervals of time represented by lithostratigraphic units in stratotypes, noting that late Miocene type localities for the Tongaporutuan and Urenuian (p. 96) "will, no doubt be defined in terms of the coast sections between Kawau, Whitecliffs, and Waitara" (Figure 7.1). The stages were formally defined by Finlay & Marwick (1940), but in a subsequent review of the New Zealand stage classification Finlay & Marwick (1947) abandoned the Urenuian because of uncertainty about the defining faunal criteria and it was included in an expanded Tongaporutuan, the sense in which the stage is presently used (Figure 7.3). In this context, the Tongaporutuan

stratotype is represented by the coast section between Kawau and Waitara, and the base of the stratotype corresponds to the base of the Tongaporutu Series (Formation), which Henderson & Ongley (1923) located at Kawau Pa.

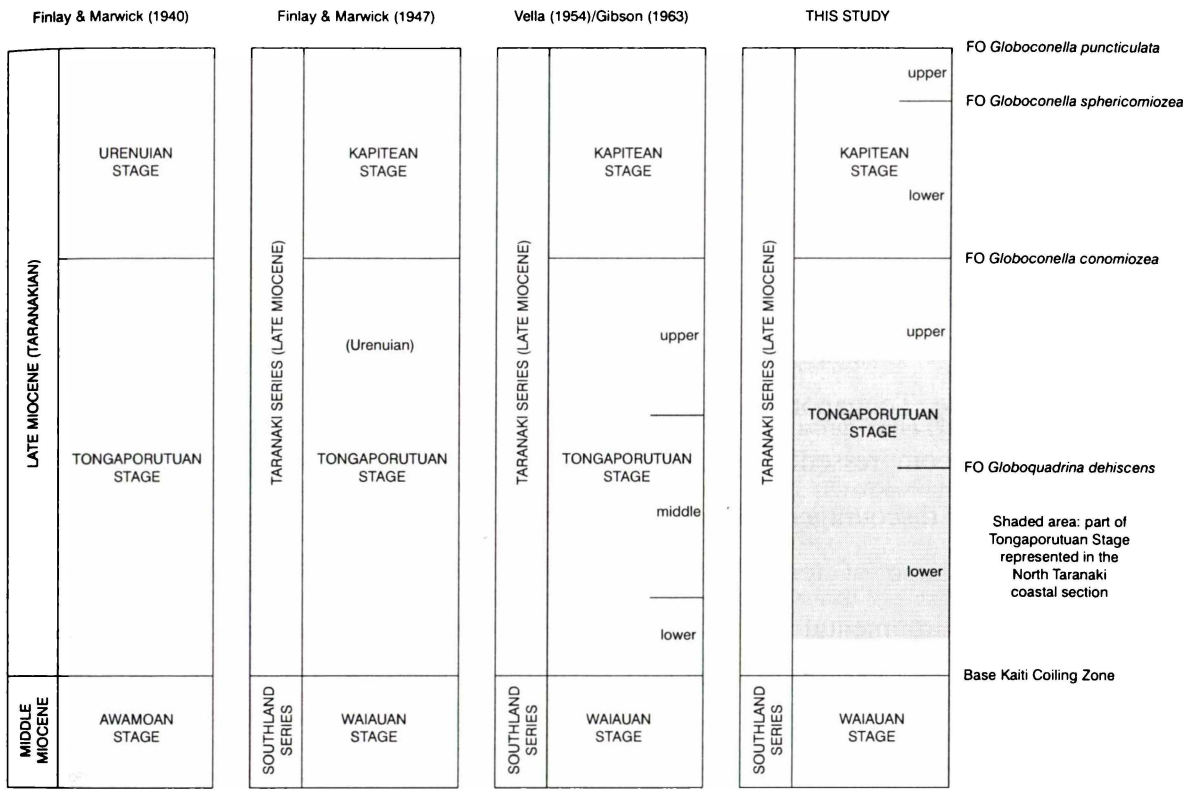


Figure 7.3 – Changes to the classification of New Zealand late Miocene stages. A summary of foraminiferal criteria used by subsequent workers for the recognition and correlation of the Tongaporutuan Stage is given in Table 7.3.

Faunal criteria

Finlay & Marwick (1940) introduced the only formal citation of Tongaporutuan faunal criteria. As was customary at the time, it included an eclectic selection of molluscan and benthic foraminiferal events that were considered to be characteristic of the stage, but not necessarily unique or critical boundary events (Table 7.3). Most are now known to be unreliable, but the lowest occurrence of distinctive benthic foraminifers of the *B. quadrilatera* group remains the primary faunal criterion for the base of the stage (e.g. Hornibrook in Fleming 1959; Gibson 1963; Hornibrook et al. 1989; King et al. 1993).

The *B. quadrilatera* group has played a central role in Tongaporutuan biostratigraphy for more than 60 years, although the order of species appearances at the base of the stage is still poorly understood. Vella (1954) informally subdivided the Tongaporutuan on the basis of the entry of successive species of the *B. quadrilatera* group, noting that the lower

Tongaporutuan was marked by the presence of *Bolivinita quadrilatera*, middle Tongaporutuan by *Bolivinita pohana* without *Bolivinita compressa*, and upper Tongaporutuan by *Bolivinita compressa*. Hornibrook (in Fleming 1959) advanced the concept of a tripartite subdivision of the stage and noted that it held for eastern North Island. Gibson (1963) subsequently applied the tripartite zonation at the Tongaporutuan stratotype and at sections in eastern North Island and at Cape Foulwind, in Westland, South Island.

Subsequent studies of *Bolivinita* (Scott 1978a, b, 1979, and work in progress) cast a more complex view of the phylogeny and entry of the *B. quadrilatera* group than has generally been applied in Tongaporutuan biostratigraphy, and they do not support the tripartite subdivision of the Tongaporutuan Stage based on the successive entry of quadrate, rhomboidal, and compressed species of the *B. quadrilatera* group. The use of such a scheme should be discouraged for anything other than local correlations, as fundamental changes in the shape of tests in benthic organisms are likely to be ecophenotypic adaptations to environmental changes and they are unlikely to maintain consistent order with respect to widely distributed planktic events.

Table 7.3 – Foraminiferal criteria used for the recognition and correlation of the Tongaporutuan Stage and stage equivalents by successive workers.

TONGAPORUTUAN STAGE (Finlay & Marwick 1940)

Restricted: **Haeuslerella morgani, *Siphotextularia subcylindrica, Massilina subaequalis, Plectofrondicularia fyfei, Ehrenbergina fyfei.* [* Taxa found in stratotype].

Lowest occurrences: **Bolivinita* (as *pohana*). **Karreriella cylindrica, Gaudryina kingi, Mucronina sinalata, Vaginulina* cf. *margaritifera, *Plectofrondicularia pohana, *Bulimina elegans, *Zeaflorilus parri, *Anomalina spherica, *Cibicides deliquatus.* [NB. Finlay & Marwick (1947) subsequently listed LO *C. deliquatus* as a marker for base Sw].

Highest occurrences: *Migros* (as *medwayensis*), *Clavulinoides, Planorbulinella. *Textularia miozea, Martinottiella weymouthi, Tritaxia virilis, *Lenticulina loculosus, *Mucroninina subtetragona, *Dentalina legumen, *Bolivina lapsus, Rectobolivina parvula, Euuvigerina mioschwageri* and **miozea, *Rectuvigerina pohana, *Trifarina australis, *Bulimina senta* and *truncanella, Ehrenbergina osbornei, Ceratobulimina kellumi, Nonion maoricum, *Discorotalia tenuissima, *Planulina* aff. *wuellerstorfi, *Anomalinoides vitrinodus, *Cibicides novozelandicus, Planulina catilla, "Discorbis"* aff. *saulcii, Laticarinina deflata, *Globoquadrina dehiscens, *Hirsutella scitula.*

URENUIAN STAGE (Finlay & Marwick 1940)

Restricted: *Bolivinita compressa, Rectobolivina hangaroana, Bulimina mapiria,* undescribed species of *Bolivina* and *Loxostomum.*

Lowest occurrences: *Rectobolivina striatula, *Sphaeroidinella dehiscens.*

Highest occurrences: Included in list of Tongaporutuan taxa.

KAPITEAN STAGE (Finlay & Marwick 1947)
Included Urenuian in Tongaporutuan Stage and established a late Miocene Kapitean Stage. Base Kapitean defined on mollusca (lowest occurrence *Sectipecten wollastoni*)

TONGAPORUTUAN STAGE (Hornibrook in Fleming 1959)

Base Tt: defined by entry of *Bolivinita quadrilatera*

Lowest occurrences: *Gaudryina kingi, Bolivina* aff. *albatrossi, Notorotalia hurupiensis.*

Typical Tt taxa: *Karreriella cylindrica, Haeuslerella morgani, Rectuvigerina pohana, Plectofrondicularia pohana, P. fyfei, Notorotalia taranakia, Menardella* aff. *menardii, Cibicides deliquatus.*

Highest occurrences: *Textularia miozea, Bulimina miolaevis, B. truncanella, B. senta, Bolivina lapsus, Rectobolivina parvula, Planulina catillus, Ciicides novozelandicus, Cassidulina cuneata.*

Restricted: *Massilina subaequalis, Bolivina barnwelli, Rectobolivina hangaroana, Bulimina mapiria*

Tk/Tt boundary: defined on mollusca (lowest occurrence *Sectipecten wollastoni*)

Tt subdivision: applicable to east coast of North Island New Zealand, after Vella (1954)

Tt: Lowest occurrences *Bolivinita compressa, Rectobolivina striatula, Rectobolivina hangaroana,* rare *Bolivinita pohana*

- **middle Tt:** Lowest occurrence *Bolivinita pohana* without *B. compressa*
- **lower Tt:** Lowest occurrence *Bolivinita quadrilatera* sometimes accompanied by *Loxostomum truncatum*

TONGAPORUTUAN STAGE (Gibson 1963, 1966)

Tt subdivision: extended to Tt-stratotype and Cape Foulwind, Westland
- **upper Tt:** Lowest occurrence *Bolivinita compressa*
- **middle Tt:** Lowest occurrence *Bolivinita pohana* without *B. compressa*
- **lower Tt:** Lowest occurrence *Bolivinita quadrilatera*

TONGAPORUTUAN STAGE (Hornibrook et al. 1989)

Restricted benthics: *Bolivinita pohana* s.s.

Sequential appearances: Characteristic *Bolivinita* species: *B. quadrilatera, B. pohana, B. compressa, B. pliozea.*

Lowest occurrences (benthics): *Bulimina mapiria, Cibicides neoperforatus, Haeslerella morgani* (typical), *Mucronina tosta*(?), *Plectofrondicularia pellucida, Rectobolivina striatula, Rectuvigerina pohana* (typical), *Textularia kapitea* (upper Tt), *Euuvigerina peregrina, Haeuslerella pliocenica*(?).

Highest occurrences (benthics): *Amphistegina* (in abundance), *Anomalina aotea, Arenodosaria antipoda* (lower Tt), *Bolivinia zedirecta, Bolivininella lilliei, B. rugosa, Bueningia creeki, Bulimina senta, B. truncanella* (common), *Cancris lateralis, Ceratocancris clifdenensis, Cibicides ihungia, C. novozelandicus, C. thiaracuta, Cribrotalia dorreeni, Globocassidulina arata, Loxostomum truncatum* (basal Tt), *Martinottiella weymouthi* (common), *Melonis doreeni, Mucronina subtetragona, Nodosaria acuminata* (common), *Nonionella novozealandica, Planorbulinella zelandica* (rare in Tk?), *Planulina catilla, P. renzi, Plectofrondicularia pohana* (common), *Rectobolivina maoriella, R. pohana, R. ongleyi, Textularia gladizea* (lower Tt), *T. miozea, Tritaxia virilis, Tritaxalina zealandica, Vulvulina pennatula* (common).

Lowest occurrences (planktics): *Menardella menardii, Neogloboquadrina pachyderma, Truncorotalia juanai, Globoconella* aff. *conomiozea*(4½-5 chambers, upper Tt).

Highest occurrences (planktics): *Fohsella peripheroronda* (basal Tt), typical *Globoconella miotumida* populations in abundance, *Hirsutella panda, Globoquadrina dehiscens* (basal Urenui Formation). [Scott 1991 has susequently redefined the Sl/Sw boundary as the highest occurrence *Fohsella peripheroronda*)

TONGAPORUTUAN STAGE (Scott 1992; King et al. 1993; Scott 1995)

- **upper Tt:** Immediately above highest occurrence *Globoquadrina dehiscens.*
- **lower Tt:** Lowest occurrence *Bolivinita pohana.* Secondary event: base Kaiti Coiling Zone.

TONGAPORUTUAN STAGE (This study)

- **upper Tt:** Immediately above highest occurrence *Globoquadrina dehiscens.*
- **lower Tt:** Base of Kaiti Coiling Zone (KCZ). Secondary events: highest common occurrence *Neogloboquadrina mayeri* s.l., lowest occurrence *Bolivinita* of the *B. quadrilatera* group in suitable slope facies (400-1500 m water depth).

OCEANIC RECORD OF MICROFOSSIL EVENTS

The use of planktic foraminiferal events in Tongaporutuan biostratigraphy has heralded a significant advance in the correlation of pelagic and deep-water clastic sequences without age diagnostic benthic taxa, but to date only a few planktic microfossil events have been routinely used to correlate and subdivide Tongaporutuan sequences. They include the highest occurrence of *Neogloboquadrina mayeri* s.l., intervals of dextrally coiled *Globoconella miotumida,* and the highest occurrence of *Globoquadrina dehiscens* (Scott 1992, 1995). These events provide a valuable framework for regional syntheses, but more biostratigraphic events are needed to refine stage correlations. High-resolution studies of pelagic sequences at Site 593 in the southern Tasman Sea and Site 1123 on Chatham Rise in the Pacific Ocean (Figure 7.2) provide a robust late Miocene framework of closely-spaced magnetostratigraphically-constrained planktic foraminiferal and bolboform events suitable for the study of uplifted marine sequences in onland New Zealand (Table 7.1). An overview of important Tongaporutuan events at these oceanic sites, which have been reviewed in Studies 2, 3, and 5, is given below and in Figures 7.4 and 7.5.

Disappearance of *Neogloboquadrina mayeri* s.l.

Neogloboquadrina mayeri s.l. is poorly represented in the dissolution-affected Miocene section of Site 1123, but in the very well preserved sequence of calcareous microfossils at Site 593 there is an excellent record of *Neogloboquadrina.* A census of planktic foraminifers at this site provides important insights into the regional disappearance of *Neogloboquadrina mayeri* s.l. (Study 2). It is a common and sometimes dominant species in the vicinity of the base of the late Miocene, but near the base of 593-34X-1 there is a very rapid and permanent decrease in the species abundance (Figure 7.4). This corresponds to the highest common occurrence of *Neogloboquadrina mayeri* s.l., as identified by the 5% abundance threshold in planktic foraminiferal assemblages. It also corresponds to the same level where Scott (1992) noted the highest occurrence of typical *Neogloboquadrina*

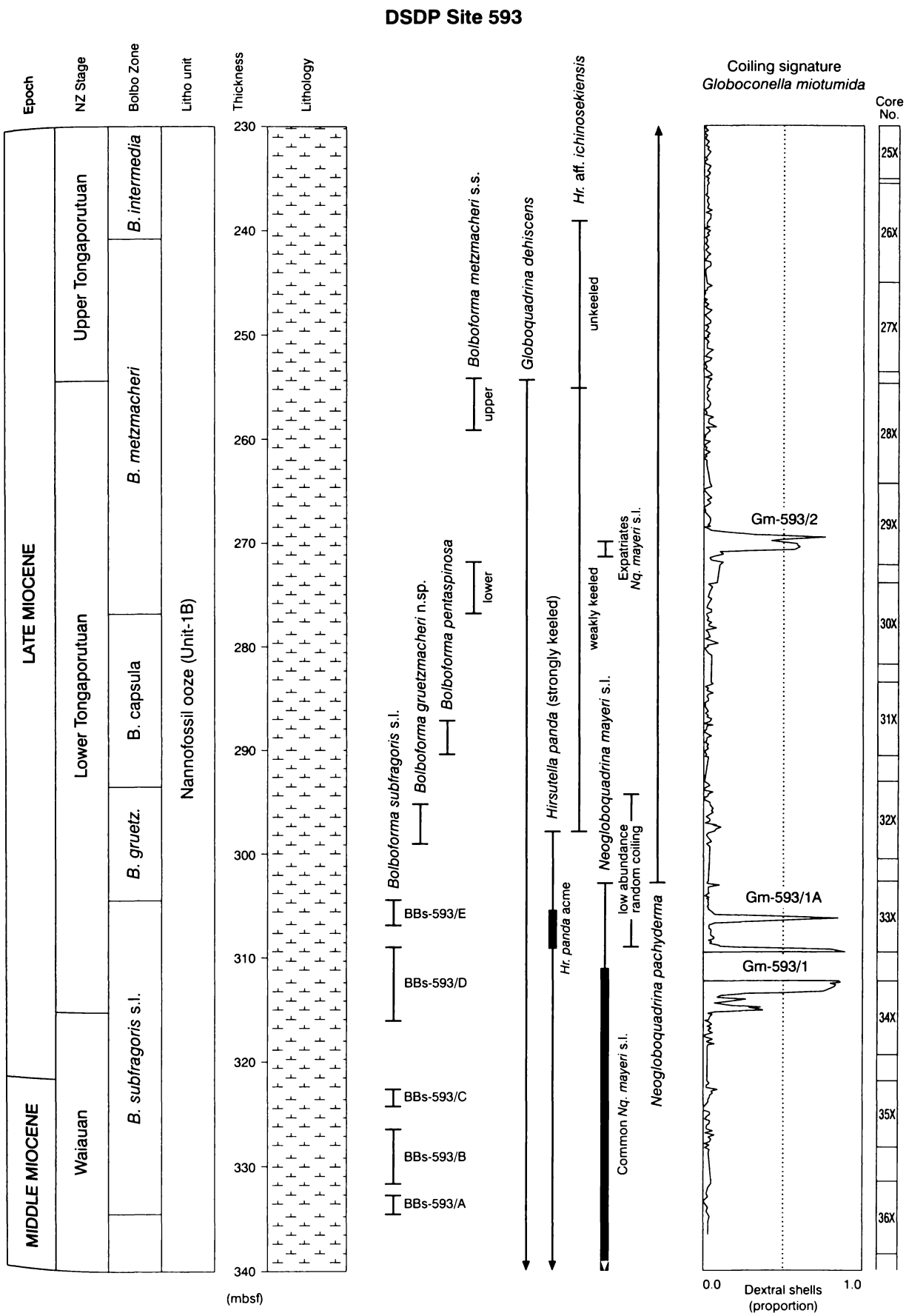


Figure 7.4 – Selected late Miocene planktic foraminiferal and bolboform events, DSDP Site 593, southern Tasman Sea, 470 km west of central New Zealand. Explanations of bioevents are given in Studies 2 and 3.

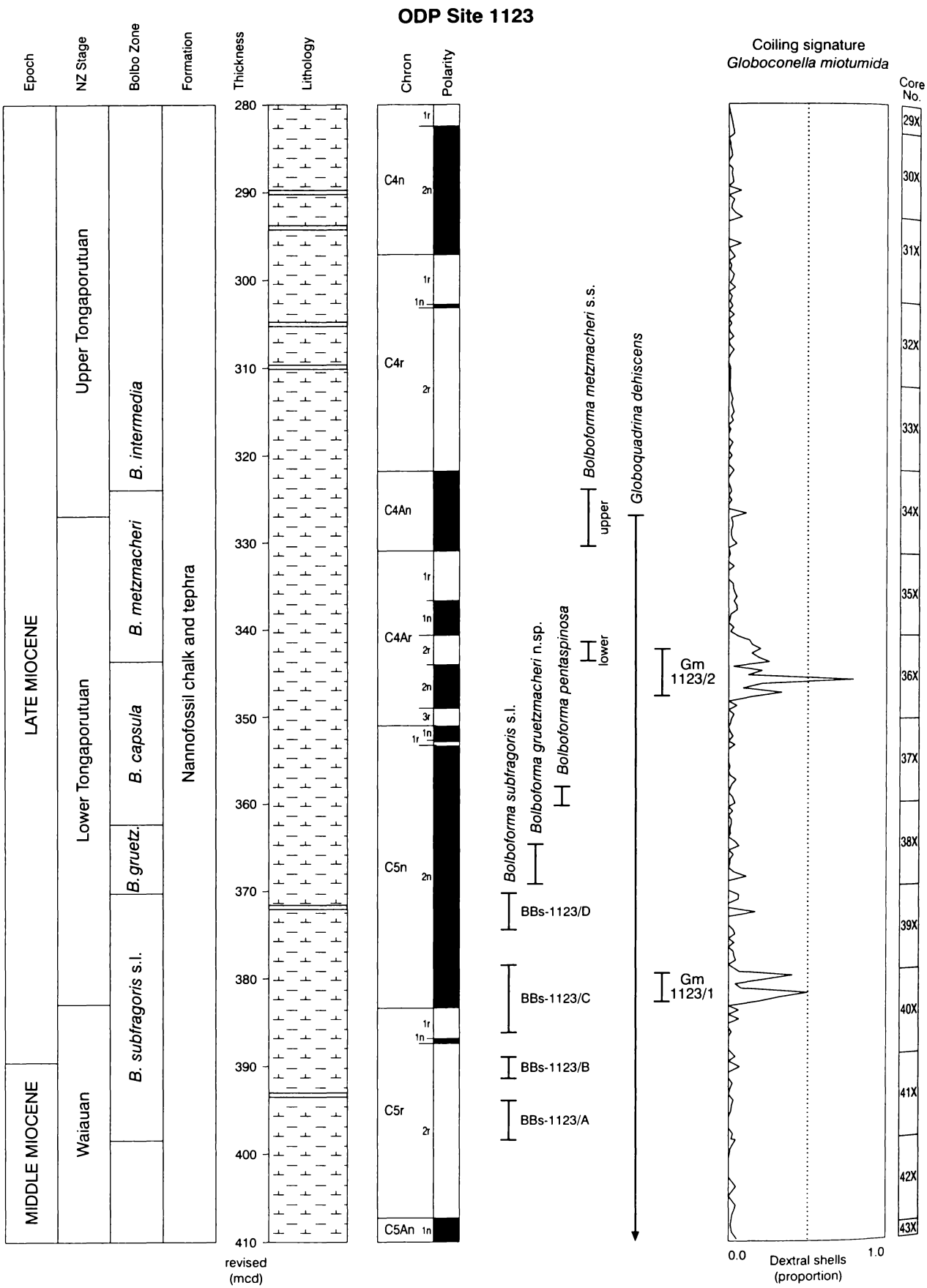


Figure 7.5 – Selected late Miocene planktic foraminiferal and bolboform events, ODP Site 1123, northeast Chatham Rise, 1000 km east of central New Zealand. Magnetostratigraphy (Wilson et al. in prep.). Explanations of bioevents are given in Study 5.

mayeri, and it is above the level of the highest occurrence of *Neogloboquadrina mayeri* noted by Jenkins & Srinivasan (1986) at the base of 593-34X.

A further decrease in the species abundance occurs slightly above the highest common occurrence of *Neogloboquadrina mayeri* s.l. This coincides with a marked increase in the proportion of dextrally-coiled shells in core 593-33X-5 (Figure 7.4). Very small populations of *Neogloboquadrina mayeri* s.l. with highly variable proportions of dextrally-coiled shells persist above this level, up to 593-33X-1. The disappearance of *Neogloboquadrina mayeri* s.l. is followed almost immediately by the entry of *Neogloboquadrina pachyderma* in 593-32CC (Figure 7.4). This occurs slightly above a narrow interval of dextrally-coiled *Globoconella miotumida* (*Gc*-593/B). Substantially above the disappearance of *Neogloboquadrina mayeri* s.l., rare expatriate specimens – mostly four-chambered individuals – appear in the vicinity of another interval of dextrally coiled *Globoconella miotumida* (*Gc*-593/C). The co-occurrence of *Neogloboquadrina mayeri* s.l. with more numerous specimens of *Neogloboquadrina pachyderma* distinguishes the expatriates from earlier occurrences of *Neogloboquadrina mayeri* s.l.

Intervals of dextrally-coiled *Globoconella miotumida*

Globoconella miotumida is a common and sometimes dominant late Miocene species at Sites 593 and 1123. It has a long history of sinistral coiling that is interrupted only occasionally by populations with majorities of dextral shells (Scott 1995). Three well defined intervals of dextrally-coiled *Globoconella miotumida* have been identified in the closely sampled late Miocene sequence at Site 593 (Figure 7.4). The lowest interval, or *Gc*-593/A, extends from the upper part of core 593-34X up into the lower part of core 593-33X (315.21-309.11 mbsf). Assuming no section has been lost from the base of core 593-33X and that the incomplete length of this core is due to biscuiting and compaction during the core recovery operation (Shipboard Scientific Party 1986), the interval of dextrally-coiled *Globoconella miotumida* has a nett thickness of 3.58 m. The base of the *Gc*-593/A interval corresponds to an abrupt, almost four-fold increase in the proportion of dextral shells, from 0.07 to 0.26. This occurs 1.49 m below the highest common occurrence of *Neogloboquadrina mayeri* s.l. The interval is represented by a total of 26 samples and the top is marked by an abrupt decrease in the proportion of dextral shells. As a whole, the interval is informally subdivided on the basis of the proportions of dextral shells into a lower part (315.21-313.54 mbsf), that has variable proportions in the range 0.37 to 0.07,

and an upper part (313.49-309.11 mbsf), that includes dextral majorities in the range 0.50-0.89.

The second interval of dextrally-coiled *Globoconella miotumida,* labelled *Gc*-593/B, occurs in core 593-33X-3 (306.55-306.12 mbsf). It is a very narrow, 0.43 m-thick interval represented by only three samples. The maximum proportion of dextral shells reaches 0.85. The base of the interval occurs 2.74 m above the *Gc*-593/A interval, and the top occurs 3.14 m below the highest occurrence of *Neogloboquadrina mayeri* s.l. Scott (1995) included both *Gc*-593/A and *Gc*-593/B intervals in a single zone, which he correlated with the Kaiti Coiling Zone. However, it is proposed here that the intervals represent discrete events in stratigraphic space and that they should be mapped separately.

The uppermost interval of dextrally-coiled *Globoconella miotumida, Gc*-593/C in core 593-29X (270.73-269.29 mbsf), occurs substantially above the *Gc*-593/A and *Gc*-593/B intervals, and the highest occurrence of *Neogloboquadrina mayeri* s.l. The interval is 1.44 m thick and is represented by a total of eight samples. The proportions of dextral shells are variable, in the range 0.31-0.76. The top of the interval occurs 14.79 m below the highest occurrence of *Globoquadrina dehiscens,* which denotes the top of lower Tongaporutuan (Scott 1992). In terms of stratigraphic space this places the *Gc*-593/C interval near the top of lower Tongaporutuan.

Other important Tongaporutuan events

Changes in the predominant coiling direction of *Neogloboquadrina mayeri* s.l. and *Neogloboquadrina pachyderma,* and a well-defined acme of *Hirsutella panda,* are also noted in the vicinity of the Waiauan-Tongaporutuan Stage boundary at Site 593 (Figure 7.4). Short-ranging monospecific influxes of bolboforms are also noted at Sites 593 and 1123 (Figures 7.4 and 7.5). These events provide a useful stratigraphic context for intervals of dextrally-coiled *Globoconella miotumida* and they help to refine Tongaporutuan Stage correlations and locate events such as the disappearance of *Neogloboquadrina mayeri* s.l.

BIOSTRATIGRAPHY OF ONLAND SECTIONS

Kaiti Beach, Gisborne

Kaiti Beach provides almost complete exposure of a fine-grained clastic sequence of tuffaceous mudstone and siltstone in proximity to the base of the Tongaporutuan Stage (Kaiti Formation) (Figure 7.6). The section is important in Tongaporutuan biostratigraphy

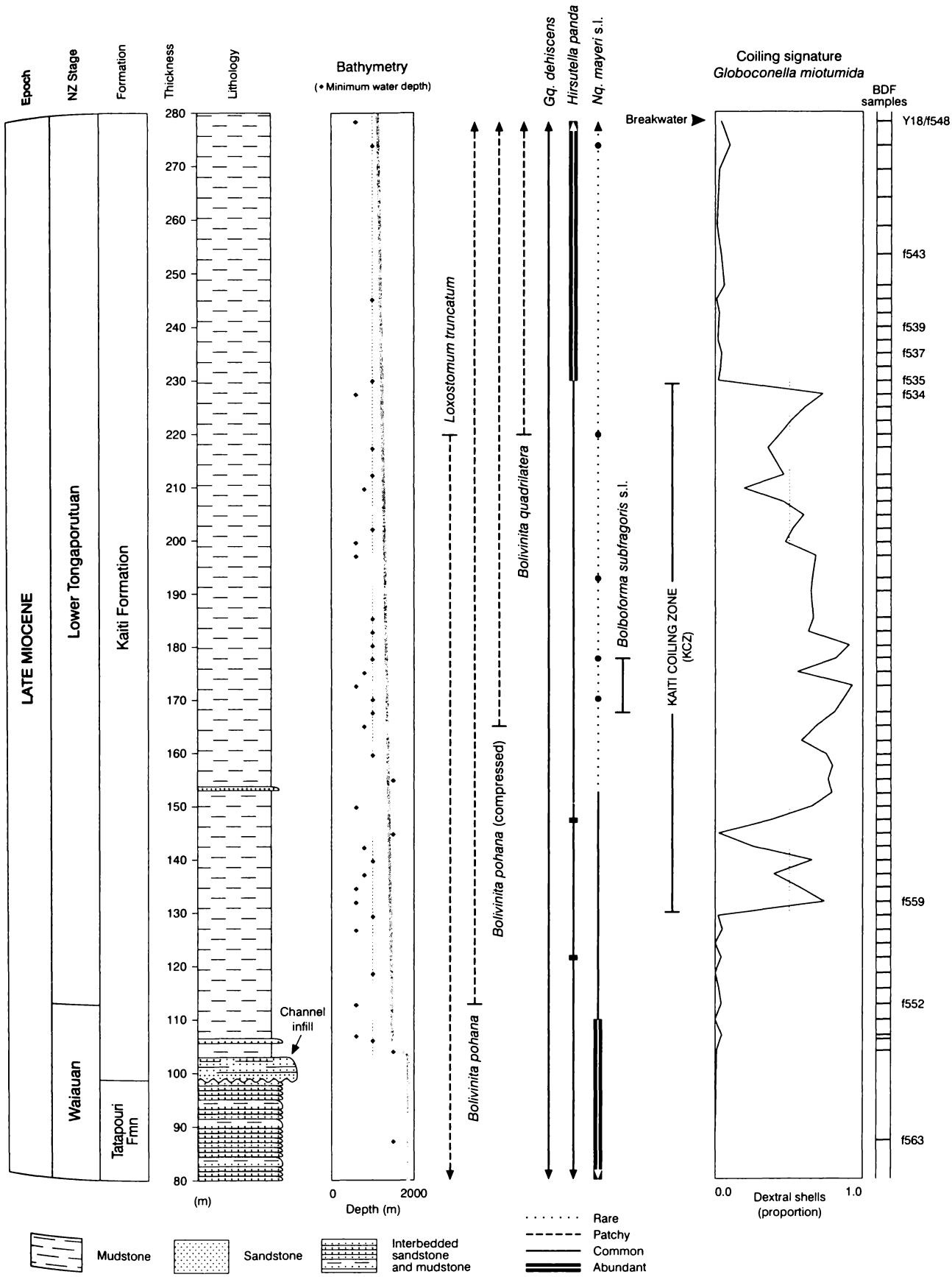


Figure 7.6 – Late Miocene lithostratigraphy and biostratigraphy of Kaiti Beach, Gisborne. Based on the measured section of Brad Field, Geological and Nuclear Scences stratigraphic column file (Y18). Details of individual collections are given in Appendix 7.1. *Gq.* = *Globoquadrina*, *Nq.* = *Neogloboquadrina*, *Cycl.* = '*Cyclammina* bed' of Finlay.

as the name bearer and reference section for the Kaiti Coiling Zone. The microfossil collections examined in this study were collected by Brad Field, who also compiled the stratigraphic section – Geological and Nuclear Sciences stratigraphic column file (X19). The collections include 37 samples that were examined by Scott (1995) and another 24 samples that have not been examined before. The section is 174 m thick and samples have an average stratigraphic spacing of 2.9 m (Appendix 7.1).

The base of the Tongaporutuan, as identified by the entry of *Bolivinita pohana,* occurs near the base of the Kaiti Formation. This is slightly above a reef-forming tuffaceous sandstone, a 5 m-thick channel-infill sequence that has been informally mapped as the "*Cyclammina* bed" (Finlay, unpublished fossil record data). The channel-infill is underlain by a thin-bedded alternating sandstone and mudstone sequence (Tatapouri Formation). The stratigraphic significance of the channel-infill is unclear, but there is no apparent angular discordance between the formations above and below the channel-infill.

An examination of beds associated with the channel-infill sequence shows they contain very distinctive microfossil assemblages with large agglutinated taxa, such as *Bathysiphon, Rhabdammina, Reophax, Ammodiscus, Miliammina, Cyclammina, Trochamminoides, Tritaxalina*, that are typical of lower slope and upper abyssal biofacies, deposited in water depths >1500 m. Assemblages from immediately above the channel-infill sequence lack many of the very deep-water agglutinated taxa that characterize the '*Cyclammina* bed', and they are more characteristic of lower slope biofacies deposited in water depths of 1000-1500 m. This suggests there was a shallowing prior to the deposition of fine-grained clastic sediments of the Kaiti Formation. Collections from higher in the Kaiti Formation represent similar lower slope biofacies deposited in water depths of 1000-1500 m. Rare individuals of very deep-water taxa, like those in the '*Cyclammina* bed', also occur in some collections. They have probably been reworked from middle Miocene rocks. Rare taxa from shallower biofacies, including *Loxostomum truncatum* that is common in shelf and upper slope environments (Hornibrook et al. 1989), also occur in some collections. Because there is no faunal evidence of significant shelf flushing, the specimens of *Loxostomum truncatum* are thought to be from allochthonous upper slope material that has been transported downslope.

Entry of *Bolivinita quadrilatera* group (Kaiti Beach): The base of the Tongaporutuan is marked by the entry of *Bolivinita pohana* in Y18/f552, slightly above the channel-infill

sequence. There are no ancestors in preceding strata and the species is persistent, but rare, in collections up to Y18/f559, where there is a marked increase in the species abundance. The majority of individuals in the vicinity of the species entry have distinctly rhomboidal spiral profiles, but a few individuals have weakly alate spiral profiles resembling those of *Bolivinita compressa.* Similar populations of *Bolivinita* persist through to the top of the exposed section. Only one specimen of *Bolivinita quadrilatera* was noted in the section, in Y18/f531, substantially above the base of the Tongaporutuan section, near the top of the Kaiti Coiling Zone. It occurs with a moderately alate specimen of *Bolivinita pohana.*

Dextrally-coiled *Globoconella miotumida* (Kaiti Beach): Figure 7.6 shows the coiling signature – dextral proportion – of *Globoconella miotumida* at Kaiti Beach. It identifies only one interval with significant contributions of dextrally-coiled shells, between Y18/f559 and Y18/f534, the Kaiti Coiling Zone of Scott (1995). Due to the close stratigraphic spacing of samples, it is unlikely that another coiling zone – even one of very short duration – has been missed. The new biostratigraphic data show that the proportion of dextral shells varies throughout the KCZ, to the extent that some populations have majorities of sinistral shells. This is the same pattern of dextral coiling that Scott (1995) noted when establishing the KCZ and there is no evidence of major interruptions to the coiling zone, at least on a scale comparable to the sinistral populations between the *Gc*-593/A and *Gc*-593/B intervals at Site 593 (Figure 7.4).

***Neogloboquadrina* (Kaiti Beach):** *Neogloboquadrina mayeri* s.l. is a relatively common species in middle Miocene assemblages of the Tatapouri Formation, and in assemblages from the lowermost part of Kaiti Formation, but its abundance declines markedly above Y18/f551. This denotes the highest common occurrence of *Neogloboquadrina mayeri* s.l., 17 m below the entry of *Bolivinita pohana* at the base of the Tongaporutuan. Small populations of *Neogloboquadrina mayeri* s.l. (mostly four-chambered individuals) occur above this level, in some but not all collections, up to the top of the exposed section. Significantly, neither Scott (1995) nor I have found typical *Neogloboquadrina pachyderma* at Kaiti Beach. This is presumably because the exposed section does not extend up to the stratigraphic level of the lowest occurrence of *Neogloboquadrina pachyderma.*

Bolboforms (Kaiti Beach): Small bolboforms with subspherical lagenoid-shaped tests and rudimentary spirospinose ornaments are found in five consecutive samples (Y18/f507-f511) near the middle of the Kaiti Coiling Zone. They are all of the same species,

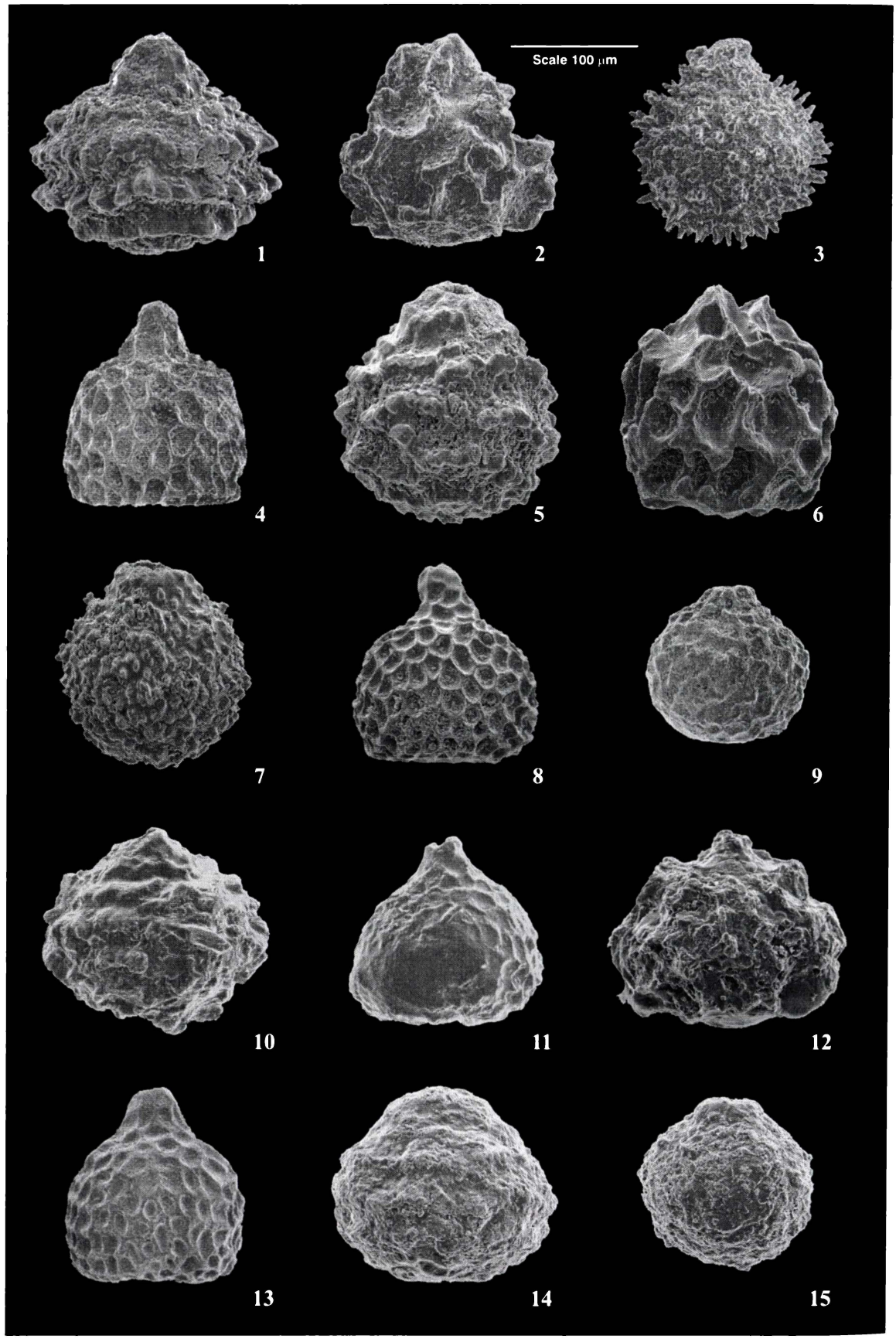


Figure 7.7 – Late Miocene bolboforms from the New Zealand region. [1–4] DSDP Site 593; 1) *Bolboforma subfragoris* s.l., 2) *B. gruetzmacheri*, 3) *B. pentaspinosa*, 4) *B. metzmacheri* s.s. [5–8] ODP Site 1123; 5) *B. subfragoris* s.l., 6) *B. gruetzmacheri*, 7) *B. pentaspinosa*, 8) *B. metzmacheri* s.s. [9] Kaiti Beach; *B. subfragoris* s.l.? [10–11] Tukemokihi Stream; 10) *B. subfragoris* s.l., 11) *B. metzmacheri* s.s. [12–13] North Taranaki coast; 12) *B. subfragoris* s.l., 13) *B. metzmacheri* s.s. [14–15] Pukearuhe-1; 14) *B. subfragoris* s.l., 15) *B. pentaspinosa*

Bolboforma subfragoris s.l. (Figure 7.7), a species that appears and disappears several times in the late middle and early late Miocene (Figure 7.4). At Site 593 its highest occurrence is between the *Gc*-593/B interval and the lowest occurrence of *Neogloboquadrina pachyderma.* This suggests the Kaiti Coiling Zone is a correlative of either the *Gc*-593/A interval or the *Gc*-593/B interval at Site 593.

***Hirsutella panda* (Kaiti Beach):** Major influxes of *Hirsutella panda* are noted immediately above the KCZ and they extend upwards through to the top of the exposed section (Y18/f535-f548). Significantly, in at least three of the collections (Y18/f537, f539, and f543) the abundance of *Hirsutella panda* exceeds that of *Globoconella miotumida.* This is highly unusual, as *Globoconella miotumida* is a very common and sometimes dominant species in late Miocene assemblages at Site 593, and *Hirsutella panda* rarely exceeds abundances of 10%, except for a narrow interval between 593-33X-5 and 593-33X-3. This interval is informally referred to as the *Hirsutella panda* acme (Figure 7.4).

Tukemokihi Stream, northern Hawkes Bay

Tukemokihi Stream is a major tributary of Mangapoike River, 23 km northeast of Wairoa, northern Hawkes Bay. The stream provides excellent exposure of a 2000 m-thick late Miocene sequence (Mapiri Formation), predominantly massive calcareous mudstone, and intervals of thin-bedded alternating mudstone and sandy siltstone, and thin rhyolitic tephra (Gosson 1986) (Figure 7.8). It is an important section for the magnetostratigraphic age calibration of Tongaporutuan bioevents (Wright et al. 1985). The base of the Tongaporutuan as defined by the appearance of *Bolivinita pohana* occurs in the lowermost part of Mapiri Formation, 15 m above Makaretu Sandstone – a 145 m thick sandstone-dominated unit of redeposited alternating sandstone and mudstone (Field et al. 1997).

Wright & Vella (1988) document the late Miocene magnetostratigraphy of Tukemokihi Stream, but they give only a brief overview of the biostratigraphy. Wright's (1986) paleomagnetic core-plugs have been used in this study to refine the biostratigraphy. They include a suite of samples from 340 sites (ICW#1–340) with an average stratigraphic spacing of 6.3 m (Appendix 7.2). The microfossil assemblages from the core-plugs are small, but a reliable biostratigraphic framework of planktic foraminiferal events has been established. New high-resolution sample suites (MC97/2/26–53, MC97/3/4–25, MC97/5/1–15 and 29–50) have also been examined from the vicinity of intervals of

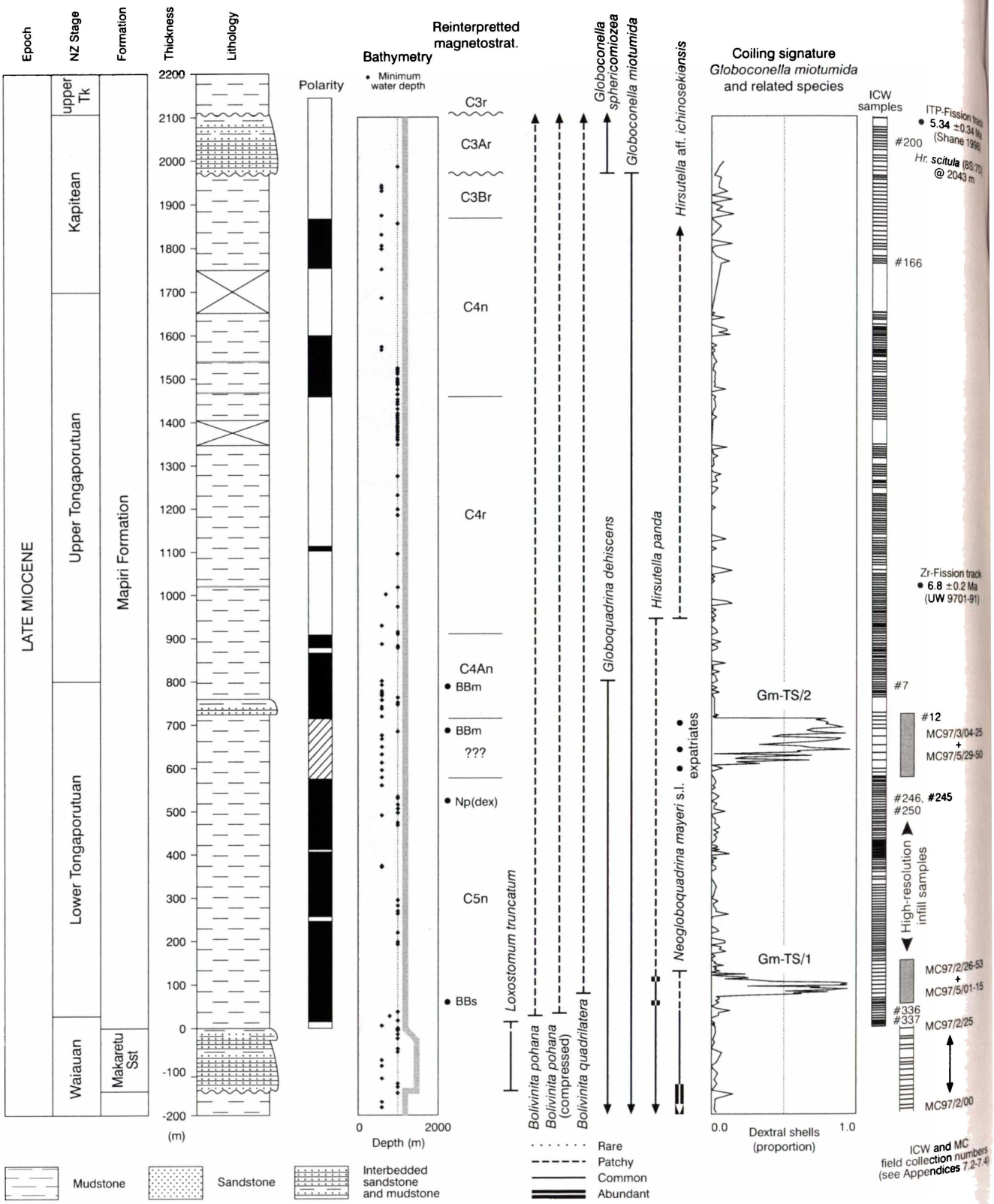


Figure 7.8 – Late Miocene lithostratigraphy and biostratigraphy of Tukemokihi Stream, northern Hawkes Bay. Based on the measured section of Greg Gosson, Geological and Nuclear Sciences stratigraphic column file (X19). Magnetostratigraphy from Wright & Vella (1988). Details of individual collections are given in Appendices 7.2–7.4. BBm = *Bolboforma metzmacheri* s.s., BBs = *Bolboforma subfragoris* s.l., Np(dex) = dextrally-coiled *Neogloboquadrina pachyderma*. Zircon fission track age UW 9701-91 (Peter Kamp pers. comm. 1998). Note the biostratigraphic data do not concur with the radiometric ages and they support a magnetostratigraphic correlation for the upper part of the sequence that is older.

dextrally-coiled *Globoconella miotumida,* from very low in Mapiri Formation (*Gc*-TS/A), and the lower part of Mapiri Formation (*Gc*-TS/B) (Appendices 7.3 and 7.4). In order to reconcile stratigraphic differences, the new biostratigraphic data have been rescaled and spliced to fit the magnetostratigraphic section of Wright & Vella (1988). This allows a direct correlation to be made between the biostratigraphy and magnetostratigraphy of the section.

Benthic foraminiferal assemblages associated with the Mapiri Formation are typical of mid to lower slope biofacies deposited in water depths of 600-1200 m. Biofacies generally shallow up through the formation, but deepen again in the vicinity of the top of the formation. The deepest biofacies – representing lower slope depths of 1000-1500 m – occur at the base of the Mapiri Formation, immediately above Makaretu Sandstone, just prior to the entry of *Bolivinita pohana.* The deep-water assemblages are interbedded with allochthonous outer shelf and upper slope assemblages, similar to those of the Makaretu Sandstone that have been transported downslope.

Entry of *Bolivinita quadrilatera* group (Tukemokihi Stream): The base of the Tongaporutuan is marked by the entry of *Bolivinita pohana* in X19/f99 (ICW#336), in the lowermost part of Mapiri Formation, 15 m above the top of Makaretu Sandstone. There are no ancestors to *Bolivinita pohana* in the preceding strata – the same as at Kaiti Beach (see above). The majority of specimens in the vicinity of the species entry have distinctly rhomboidal spiral profiles, but a few individuals have weakly alate profiles resembling those of *Bolivinita compressa.* Typical *Bolivinita compressa,* with strongly alate spiral profiles, appear much higher in Mapiri Formation, in the vicinity of ICW#166. *Bolivinita elegantissima* occurs with *Bolivinita pohana* at several levels within Mapiri Formation, but it is not found with *Bolivinita compressa.* It is also not found in Waiauan strata, prior to the entry of *Bolivinita pohana*, although it is noted by Hornibrook et al. (1989) to appear before the *B. quadrilatera* group in other sequences.

Bolivinita pliozea first appears in the uppermost part of Mapiri Formation, in ICW#200. It occurs in several samples with *Bolivinita elegantissima* and *Bolivinita pohana.*

Typical specimens of *Bolivinita quadrilatera* have not been found in the Mapiri Formation, but rare quadrate individuals with slightly rhomboidal spiral profiles occur in populations of *Bolivinita pohana,* near the middle of the formation (e.g. ICW#12).

Dextrally-coiled *Globoconella miotumida* (Tukemokihi Stream): The coiling signature – dextral proportion – of *Globoconella miotumida* at Tukemokihi Stream (Figure 7.8) shows only two short intervals in the late Miocene where there are significant contributions of dextral shells. The first of these intervals (*Gc*-TS/A) occurs 72 m above the base of Mapiri Formation. It is a well defined interval that is 51 m thick, extending between MC97/2/30 and MC97/2/52. While most samples in the lower part of the interval, below MC97/2/45, have majorities of dextral shells, dextral proportions in the upper part of the interval are highly variable and they do not exceed 0.5 (Appendix 7.3). The average proportion of dextral shells in the upper part of the interval is only 0.2, but this is about four times the average baseline value for late Miocene populations and it is significant in terms of the overall coiling history of *Globoconella miotumida.*

The second interval of dextrally-coiled *Globoconella miotumida* (*Gc*-TS/B) occurs 606 m above the base of Mapiri Formation. It extends between MC97/3/20.5 and MC97/5/36, and is 107 m thick. The lower part of the interval, below MC97/5/48, has highly variable proportions of dextral shells that only sometimes form majorities (Figure 7.7) (Appendix 7.4). In contrast, the upper part of the interval generally has majorities of dextral shells. This is the opposite pattern to the *Gc*-TS/A interval.

***Neogloboquadrina* (Tukemokihi Stream):** *Neogloboquadrina mayeri* s.l. is relatively common in planktic assemblages below the Makaretu Sandstone and in the lowermost part of Mapiri Formation, but its abundance declines markedly 9 m above the base of Mapiri Formation. Common *Neogloboquadrina mayeri* s.l. is not seen again in Mapiri collections above ICW#337. This corresponds to the highest common occurrence of *Neogloboquadrina mayeri* s.l., 6 m below the entry of *Bolivinita pohana* at the base of the Tongaporutuan.

The highest occurrence of *Neogloboquadrina mayeri* s.l. is noted 129 m above the base of Mapiri Formation (MC97/5/07) and it is succeeded by the entry of *Neogloboquadrina pachyderma,* 497 m above the base of Mapiri Formation (ICW #250). The absence of *Neogloboquadrina* in the interval between the highest occurrence of *Neogloboquadrina mayeri* s.l. and the lowest occurrence of *Neogloboquadrina pachyderma,* where only small core plug samples were examined, places a caveat on the reliability of both bioevents.

Significantly, rare expatriate occurrences of *Neogloboquadrina mayeri* s.l. with typical *Neogloboquadrina pachyderma* occur substantially above the highest occurrence of *Neogloboquadrina mayeri* s.l., in the vicinity of the *Gc*-TS/B interval (MC97/3/22, MC97/3/16, and MC97/3/08). This is similar to Site 593, where expatriates of *Neogloboquadrina mayeri* s.l. occur in the vicinity of the *Gc*-593/B interval.

Middle Miocene populations of *Neogloboquadrina mayeri* s.l. from below the Makaretu Sandstone are dominated by sinistral shells, but the contribution of dextral shells increases in the vicinity of the base of the Tongaporutuan, at about the same time that the abundance of the species decreases. These populations are too small, however, to determine reliable coiling directions.

Late Miocene populations of *Neogloboquadrina pachyderma* are dominated by sinistrally-coiled shells, except for collections ICW#246 and ICW#245, in the vicinity of the lowest occurrence of *Neogloboquadrina pachyderma,* that have significant representations of dextral shells. This very short but distinctive interval of dextrally-coiled *Neogloboquadrina pachyderma* occurs 404-409 m above the top of the *Gc*-TS/A interval. An equally distinctive interval of dextrally-coiled *Neogloboquadrina pachyderma* has been noted at Site 593, 11.4 m above the *Gc*-593/B interval.

Bolboforms (Tukemokihi Stream): Bolboforms are extremely rare in the Tukemokihi section, but small spirospinose specimens of *Bolboforma subfragoris* s.l. (Figure 7.7) have been found in the vicinity of the *Gc*-TS/A interval of dextrally-coiled *Globoconella miotumida* (MC97/5/04, MC97/5/02 and MC97/2/29), and cancellate-ridged specimens of *Bolboforma metzmacheri* s.s. (Figure 7.7) have been found in the vicinity of the *Gc*-TS/B interval (MC97/3/12 and ICW#7). This supports the correlation of the *Gc*-TS/A interval with either the *Gc*-593/A interval or *Gc*-593/B interval at Site 593, and the correlation of the *Gc*-TS/B interval with the *Gc*-593/C interval at Site 593.

***Hirsutella panda* (Tukemokihi Stream):** Strongly keeled specimens of *Hirsutella panda* are generally rare in collections from Tukemokihi Stream, except those in the vicinity of the *Gc*-TS/A interval. Collections immediately above this interval (MC97/5/05 and MC97/5/06) and those immediately below it (MC97/5/02 and MC97/5/01) are especially notable, as *Hirsutella panda* is more common than *Globoconella miotumida.* At Site 593, assemblages where *Hirsutella panda* is more common than *Globoconella miotumida* are

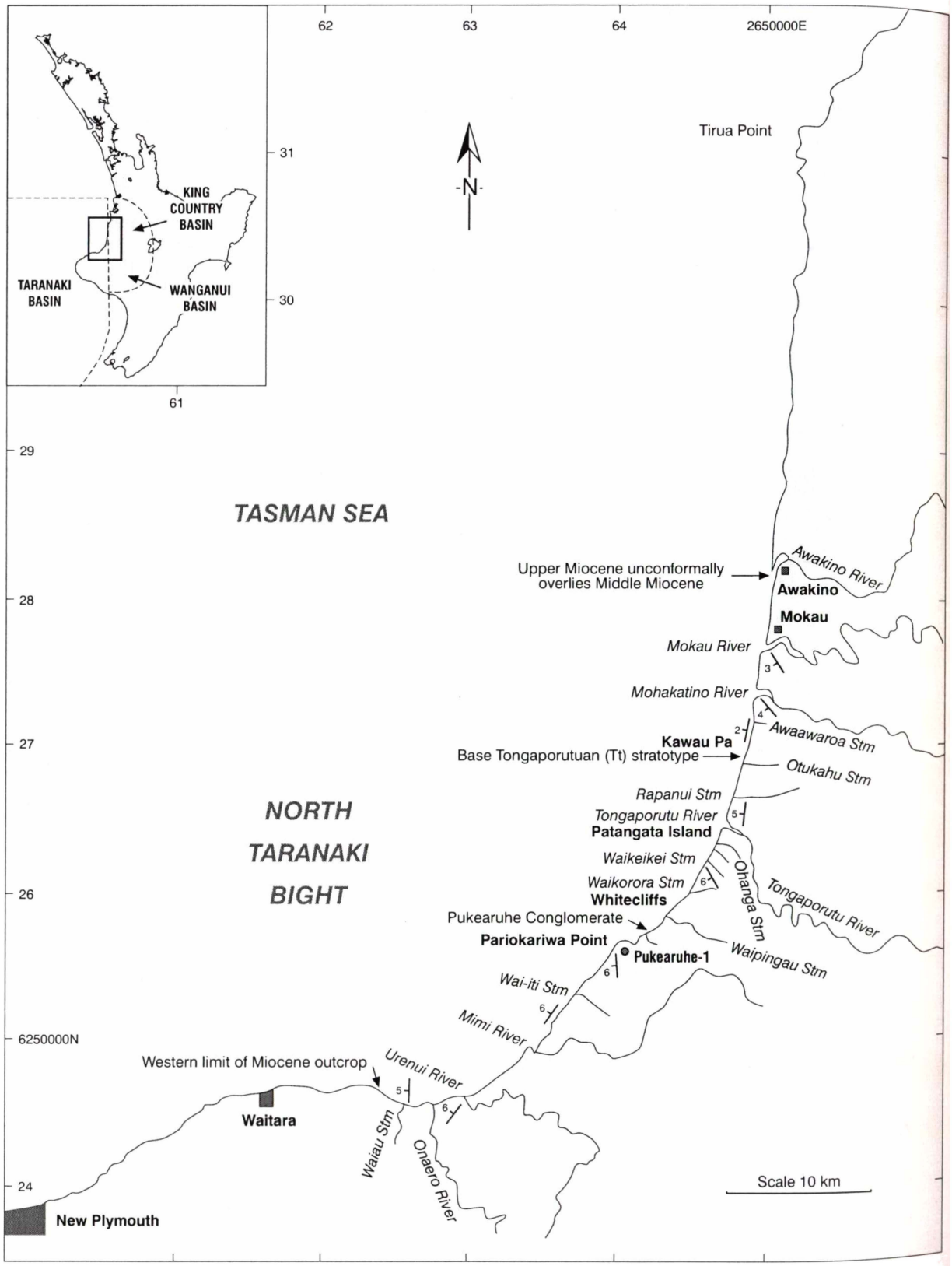


Figure 7.9 – Locality map, northern Taranaki coastal region (NZMS metric grid, 1986).

only found in the vicinity of the top and bottom of the *Gc*-593/B interval, and there is no comparable influx of *Hirsutella panda* at the base of the *Gc*-593/A interval. This supports the correlation of the *Gc*-TS/A and *Gc*-593/B intervals, and it points to the possibility of there being another interval of dextrally-coiled *Globoconella miotumida* lower in the Tukemokihi section. To date, no such interval has been found and this alludes to the possibility of an unconformity between the Makaretu Sandstone and Mapiri Formation?

Other bioevents (Tukemokihi Stream): *Loxostomum truncatum* is an age diagnostic benthic species that is confined to the Waiauan and earliest Tongaporutuan (Hoskins 1978; Hornibrook et al. 1989). Its presence with *Bolivinita pohana* in the lowermost part of Mapiri Formation indicates proximity to the base of the Tongaporutuan Stage. The highest occurrence of *L. truncatum* is noted 152 m above the base of Mapiri Formation (MC97/5/15), 29 m above the top of the *Gc*-TS/A interval.

North Taranaki coast, Awakino to Waitara

The North Taranaki coast between Awakino and Waitara (Figure 7.9) has played a major role in Tongaporutuan biostratigraphy ever since Finlay & Marwick (1940) established the Tongaporutuan Stage (see earlier). Late Miocene rocks are well exposed along the coast, but high sea cliffs and headlands make parts of the sequence difficult to access. The Tongaporutuan stratotype corresponds to the upper part of the Wai-iti Group (King & Thrasher 1996) – a predominantly fine-grained regressive sequence of basin floor and base of slope sandstones (Mt Messenger Formation), basin floor and slope mudstones (Manganui Formation), and slope and shelf siltstones and conglomerates (Urenui Formation). Deep-water volcaniclastic deposits of Mohakatino Formation (Purupuru Tuff) are also present in the lower part of the coastal section, below the Tongaporutuan stratotype, although they have generally been assigned to the Waiauan Stage (King et al. 1993).

The coast between Awakino and Waitara has been sampled extensively for foraminifers for more than 60 years, but the only systematic micropaleontological studies have been by Gibson (1963) and King et al. (1993). The collections that they studied are lodged at the Institute of Geological and Nuclear Sciences in Lower Hutt. Fine-grained calcareous mudstone and siltstone are over-represented in the collections. The sampling bias does not adversely affect biostratigraphic outcomes relating to planktic taxa, but it may reduce the

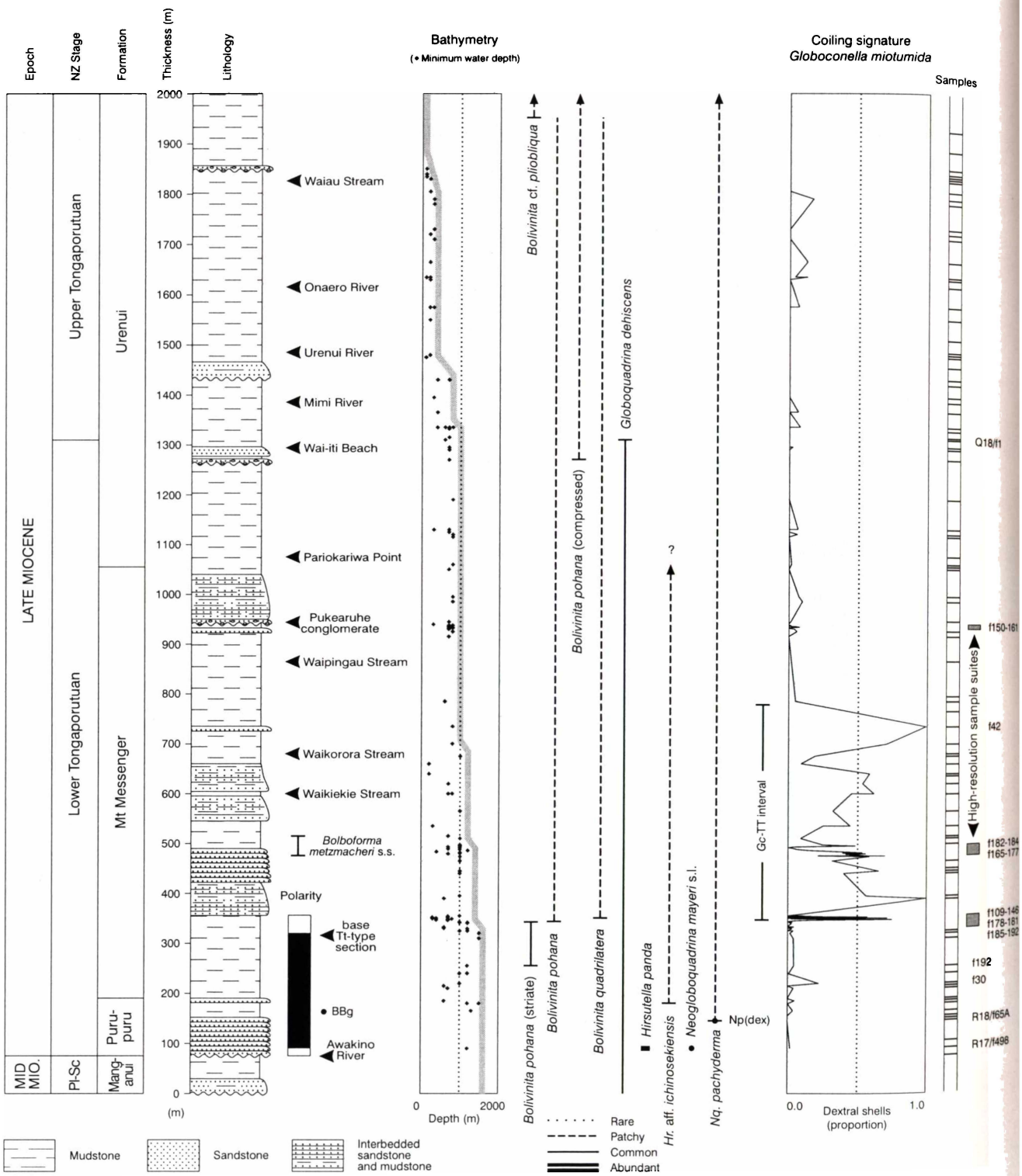


Figure 7.10 – Late Miocene lithostratigraphy and biostratigraphy of North Taranaki coast between Awakino and Waitara. Based on the measured sections of various authors, reproduced in King et al. (1993) – see Figure 7.9 for localities. Magnetostratigraphy modified after Hansen (1996). Details of individual collections are given in Appendix 7.5. BBg = *Bolboforma gruetzmacheri*, *Nq.* = *Neogloboquadrina*, Np(dex) = dextrally-coiled *Nq. pachyderma*.

reliability of some benthic events, particularly those found in the allochthonous component of assemblages.

Figure 7.10 shows a composite section of the North Taranaki coast, based on King et al. (1993). The micropaleontological collections of Gibson (1963) and the paleomagnetic data of Hansen (1996) have been integrated on the basis of locality information. Some samples may be poorly located in stratigraphic space, but the section is highly expanded compared to offshore pelagic sequences and the relative order of events is unlikely to be affected. New collections have also been examined to identify faunal events that may have been missed because of inadequate sampling in difficult to access and disrupted parts of the coastal section. The new collections include a high-resolution suite of samples from the Tongaporutu River estuary that extends to 30 m below the base of the cliff-forming tabular sandstone at Tongaporutu River. This suite of samples corresponds to the upper part of the disrupted coastal sequence between Tongaporutu River and Kawau Pa, but it does not extend down to the base of the Tongaporutuan stratotype. The late Miocene biostratigraphy of the North Taranaki coast is summarized in Figure 7.10 and comments on individual collections are given in Appendix 7.5.

Mohakatino assemblages from Awakino River are very poor, except for collection R17/f498 near the base of Purupuru Tuff, which has a planktic-dominated lower slope assemblage, deposited under an open oceanic watermass, in water depths >1200 m. Nodder et al. (1990) interpret similar siliciclastic-volcaniclastic-carbonate sediments as mass-emplaced seafloor deposits, from active submarine volcanic edifices off the North Taranaki coast.

Lower slope assemblages similar to those of Purupuru Tuff are also found in the lower part of Mount Messenger Formation, but they also include allochthonous material that has been transported downslope. The allochthonous component – mostly upper slope material – increases markedly in slump-folded deposits, in the vicinity of the base of the Tongaporutuan stratotype. Autochthonous deep-water assemblages without allochthonous material are relatively rare, and are generally confined to condensed, highly calcareous mudstones. Assemblages from higher in the Mount Messenger Formation are also characterized by mixed biofacies, but water depths generally shallow from >1200 m at the base of the stratotype, to <200 m at the top of the exposed coastal section (Urenui Formation).

Entry of the *Bolivinita quadrilatera* group (North Taranaki coast): The coastal sequence in the vicinity of the base of the Tongaporutuan stratotype is disrupted by synsedimentary slumping and faulting, and the entry of the *B. quadrilatera* group is poorly resolved (Gibson 1963; King et al. 1993). In the less disrupted sequence at Tongaporutu River, the first species of *Bolivinita* to appear is *Bolivinita* aff. *pohana* (striate) in collections Q18/f192, f185, and f179. Gibson (1963) and King et al. (1993) found the same species below the Tongaporutuan stratotype (Q18/f27) and in disrupted beds above its base (Q18/f23, f21, and f9562). Populations of *Bolivinita pohana* with rhomboidal spiral profiles, and rare individuals with quadrate profiles, appear slightly higher in the Tongaporutu River section, in collections Q18/f146, f143, f139, and f138. King et al. (1993) suggest this may have been the species that Gibson (1963) mistakenly identified as *Bolivinita quadrilatera*. Extensive searches to date, by George Scott (pers. comm.) and the author, have not found typical *Bolivinita quadrilatera* in the vicinity of the base of the Tongaporutuan stratotype.

Significantly, the entry of rhomboidal forms of *Bolivinita pohana* that are reported by King et al. (1993) to mark the base of the Tongaporutuan Stage correspond to a marked faunal change where autochthonous lower slope assemblages are replaced by assemblages with a predominance of allochthonous upper slope taxa. The rhomboidal and striate species of *Bolivinita* are only found together in collections Q18/f138 and f143, that have autochthonous and allochthonous faunal components. It appears from these data that the striate species may have had a preference for lower slope biofacies and that the rhomboidal species may be part of the allochthonous biofacies component that has been transported from a shallower biofacies. This suggests the entry of the *B. quadrilatera* group near the base of the Tongaporutuan stratotype may depend on the presence of suitable facies.

Dextrally-coiled *Globoconella miotumida* (North Taranaki coast): A review of available samples from the North Taranaki coast between Awakino and Waitara confirms the observation of Scott (1992) that a well defined interval of dextrally-coiled *Globoconella miotumida* occurs near the base of the Tongaporutuan stratotype (*Gc*-TT) (Figure 7.10).

The first representation of dextral *Globoconella miotumida* occurs 2.7 m above the entry of rhomboidal specimens of *Bolivinita pohana,* in Q18/f143, at least 24 m above the base of the Tongaporutuan stratotype. The interval of dextrally-coiled *Globoconella miotumida*

extends upwards to collection Q18/f42, and it is 390 m thick. The proportion of dextrally-coiled shells is highly variable throughout the interval and there are at least two distinctive short-lived returns to sinistral majorities, one in the lower part of the interval and the other in the upper part (Figure 7.10). Assemblages from the *Gc*-TT interval are characterized by mixed biofacies – mostly allochthonous – and this may have contributed to the complexity of the coiling signature. At the very least, it places a cautionary caveat on the use of the coiling signature for subzonal correlation.

At the top of the *Gc*-TT interval there is an abrupt return to populations of *Globoconella miotumida* with large majorities of sinistral shells that persist through to the top of the exposed coastal section (Urenui Formation). Below the Tongaporutuan stratotype, sinistral populations of *Globoconella miotumida* extend down to the base of Purupuru Tuff and there are no other intervals with significant contributions of dextrally-coiled *Globoconella miotumida* in the coastal section, at least not on a scale comparable to the intervals at Site 593 (Figure 7.4). A slight increase is noted in the contribution of dextral shells in Q18/f30 (7S:2D), but the population is too small to be significant.

***Neogloboquadrina* (North Taranaki coast):** The absence of *Neogloboquadrina mayeri* from the vicinity of the base of the Tongaporutuan stratotype has been a long-standing enigma of Tongaporutuan biostratigraphy (Gibson 1963; Scott 1992; King et al. 1993).

Neogloboquadrina pachyderma, the first appearance of which follows the disappearance of *Neogloboquadrina mayeri s.l.* at Site 593, has been found at various levels within the coastal section. It is relatively common in the Urenui Formation, but its abundance decreases down-section and it is rare in the vicinity of the base of the Tongaporutuan stratotype and lower in Mount Messenger Formation, even in assemblages with large planktic representations. The lowest occurrence of *Neogloboquadrina pachyderma* is noted in R18/f65A, in the upper part of Purupuru Tuff, 180 m below the base of the Tongaporutuan stratotype. A thorough search of samples from the lower part of the section failed to find specimens of *Neogloboquadrina,* except for a small four-chambered specimen of *Neogloboquadrina mayeri* s.l. in R17/f498, 15 m above the base of Purupuru Tuff (Mohakatino Formation). This is a significant discovery as it is the first time *Neogloboquadrina mayeri* s.l. has been found in the coastal section.

The rarity of *Neogloboquadrina* in the lower part of the coastal section between Awakino and Tongaporutu River, and the presence of small but potentially significant contributions of dextral *Neogloboquadrina pachyderma* (R18/f65A) from the same part of the section, is comparable to Site 593, where the entry of *Neogloboquadrina pachyderma* is marked by very low abundances and small randomly coiled populations (see earlier). This suggests the coastal section may not extend down to the highest common occurrence of *Neogloboquadrina mayeri* s.l. and the stratigraphic level where the *B. quadrilatera* group enters in some eastern North Island sequences (e.g. Kaiti Beach). Consequently, these rocks are interpreted here to be Tongaporutuan even though they occur below the Tongaporutuan stratotype and have previously been assigned to the Waiauan (King et al. 1993).

Bolboforms (North Taranaki coast): Bolboforms are relatively rare in the coastal section, but small monospecific influxes have been found at two stratigraphic levels. The first occurs 90 m above the base of Purupuru Tuff, in R18/f66. It includes typical *Bolboforma gruetzmacheri* with robust, irregularly ridged and bladed ornaments (Figure 7.7). At Site 593, *Bolboforma gruetzmacheri* has a very short stratigraphic range, and it is confined to the lower part of the interval between the *Gc*-593/B and *Gc*-593/C intervals, slightly above the entry of *Neogloboquadrina pachyderma.*

The other influx of bolboforms occurs substantially higher in the coastal section, in the lower part of the *Gc*-TT interval. The bolboforms are all the same species, *Bolboforma metzmacheri* s.s., and they are found in several collections (Q18/f168, f171, f172, f174, and f9583) from a short interval that extends from 151-190 m above the base of the Tongaporutuan stratotype. *Bolboforma metzmacheri* s.s. is a very distinctive, cancellate-ridged species with a flat aboral surface (Figure 7.7). At Site 593 the same bolboform species is confined to two short zones in the vicinity of the *Gc*-593/C interval (Figure 7.4). This is substantially above the *Gc*-593/A interval, which has been correlated with the Kaiti Coiling Zone (Scott 1995).

***Hirsutella panda* (North Taranaki coast):** Collection R17/f498, near the base of Purupuru Tuff, has the only large representation of strongly keeled *Hirsutella panda* (0S:44D) in the coastal section (Figure 7.10). It is correlated with the top of the *Hirsutella panda* acme at Site 593 that occurs just below the highest occurrence of *Neogloboquadrina mayeri* s.l. and slightly above the *Gc*-593/B interval of dextrally-coiled *Globoconella*

miotumida. This supports the view that the coastal section between Awakino and Waitara does not extend down to the level of either *Gc*-593/B or *Gc*-593/A intervals at Site 593. They are presumably cut out by the unconformity at Awakino River, at the base of Purupuru Tuff (King et al. 1993).

Pukearuhe-1, northern Taranaki

Pukearuhe-1 was drilled in northern Taranaki, on the coastal headland (Pariokariwa Point) south of Whitecliffs (Figure 7.9). It drilled into a thick Miocene sequence of Mt Messenger, Mohakatino, and Manganui Formations, before penetrating an overthrusted Mesozoic sequence at 1458 m (Forder & Bennett 1988). The depths of all sampled horizons are given in metres below Kelly-Bushing (BKB). For the purpose of this study only the upper part of the Miocene biostratigraphic succession is examined, between 204-1240 m (Figure 7.11).

The upper part of the biostratigraphic succession between 204-1060 m is very similar to the coastal section between Pariokariwa Point and Awakino River, except for a disrupted interval between 830-900 m. Below 1060 m, the well penetrates an older Miocene succession, similar to that at Tirua Point (Nodder et al. 1990; King et al. 1993).

The faunal collections from Pukearuhe-1 were taken from cutting samples at stratigraphic intervals of 10 m. There were no major engineering problems while the Miocene section was drilled, but wire-line well logs identify some fine-grained intervals in Mt Messenger Formation where downhole caving may have occurred. This may adversely affect the reliability of some bioevents, particularly lowest occurrences. Important events from the faunal succession at Pukearuhe-1 are discussed below. A summary of the biostratigraphy is given in Figure 7.11 and comments on individual collections are included in Appendix 7.6. Crundwell (2002) gives a more detailed account of the Miocene biostratigraphy.

Deep-water lower slope assemblages occur throughout the biostratigraphic succession, but water depths shallow upwards from >1500 m at 1240 m BKB to depths of about 1000 m at the top of the succession (Figure 7.11). Most assemblages contain significant proportions of allochthonous taxa from shallower, slope environments. Assemblages below 1130 m and above 830 m BKB also contain allochthonous taxa from shelf environments. It is significant that Crundwell (2002) noted very high rates of sediment accumulation in the upper part of the sequence above 830 m (Figure 7.11). This suggests that at least some of

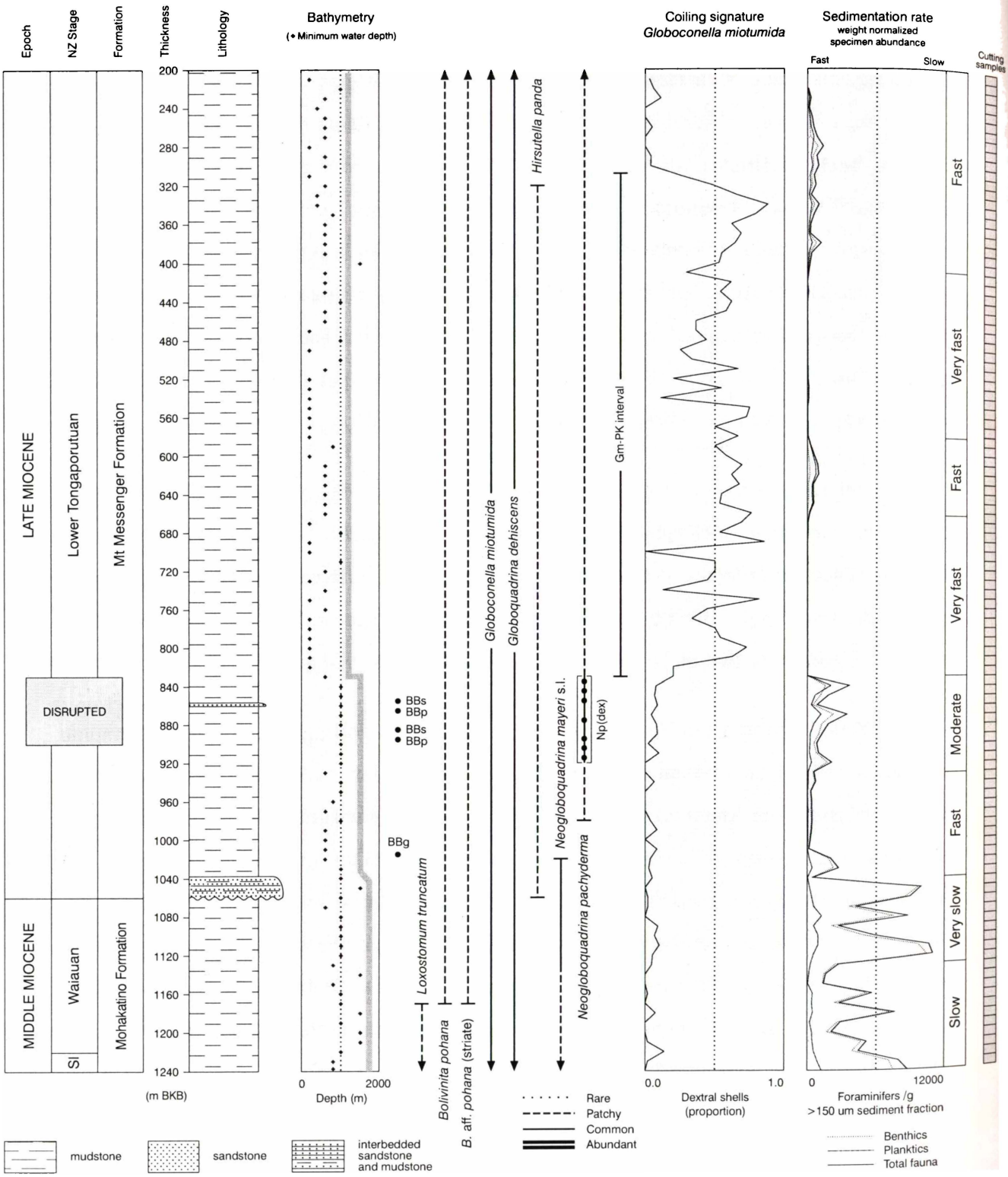


Figure 7.11 – Late Miocene lithostratigraphy and biostratigraphy of Pukearuhe-1, drilled in North Taranaki on the coastal headland (Pariokawa Point) south of Whitecliffs (Figure 7.9). Based on the geology of Forder & Bennett (1988) and biostratigraphy of Crundwell (2002). Details of individual collections are given in Appendix 7.6. BBs = *Bolboforma subfragoris* s.l., BBp = *B. penatspinosa,* BBg = *B. gruetzmacheri,* Np(dex) = dextrally-coiled *Neogloboquadrina pachyderma.*

the allochthonous taxa are associated with mass-emplaced units. The depositional setting is interpreted to range from a deep-water basin floor site overlain by an open-oceanic water mass, at the base of the sequence, to a deep-water lower slope site overlain by a neritic water mass, at the top of the sequence. The site appears to have been distal to any shelf margin at the base of the sequence, and proximal to a shelf margin at the top of the sequence.

Entry of the *Bolivinita quadrilatera* group (Pukearuhe-1): It is not possible from the lowest occurrence of the *B. quadrilatera* group to reliably locate the base of Tongaporutuan Stage in the Pukearuhe-1 well sequence. Isolated occurrences of *Bolivinita pohana* (individuals with rhomboidal spiral profiles) occur at 1170 and 980 m, and persistent occurrences of the same species, including rare individuals with moderately quadrate spiral profiles, occur above 880 m, close to the level where the contribution of allochthonous shelf taxa increases. Rare specimens of *Bolivinita* aff. *pohana* (striate) occur above 840 m. The order of species appearances differs from the coastal section, but this is probably due to downhole caving.

Dextrally-coiled *Globoconella miotumida* (Pukearuhe-1): Figure 7.11 shows the coiling signature – dextral proportion – of *Globoconella miotumida* at Pukearuhe-1 (204-1240 m BKB). It identifies only one interval with significant contributions of dextrally-coiled shells, between 300-830 m BKB (*Gc*-PK). Up-dip projections from the well suggest the interval of dextrally-coiled *Globoconella miotumida* corresponds to the *Gc*-TT interval in the lower part of the Tongaporutuan stratotype. The *Gc*-coiling signature is highly variable and is characterized by distinctive perturbations, but a reliable subzonal correlation could not be established between the well and the coastal section. This is presumably because of downhole caving, but local downslope reworking may also have contributed to the modification of the coiling signature.

***Neogloboquadrina* (Pukearuhe-1):** *Neogloboquadrina mayeri* s.l. is common in the lower part of the sequence, above the highest occurrences of *Fohsella peripheroronda*, *Globoconella amuria,* and *Globoconella conica* at the top of Lillburnian (1230 m), but its abundance decreases markedly above 1040 m. This denotes the highest common occurrence of *Neogloboquadrina mayeri* s.l., while the species highest occurrence is noted at 980 m, at the same level as the lowest occurrence of *Neogloboquadrina pachyderma.*

Significantly, both of these bioevents occur in Purupuru Tuff, near the base of the coastal section.

Bolboforms (Pukearuhe-1): Figure 7.7 shows bolboform species that have been identified in the Pukearuhe-1 well sequence. Small specimens of *Bolboforma subfragoris* s.l. with rudimentary spirospinose ornaments occur at 1050, 890, and 860 m, robust irregularly ridged and bladed specimens of *Bolboforma gruetzmacheri* occur at 1020 m, and small spinose specimens of *Bolboforma pentaspinosa* occur at 900 and 870 m. Surprisingly, *Bolboforma metzmacheri* s.s., which occurs in the coastal section within the *Gc*-TT interval of dextrally-coiled *Globoconella miotumida* (Figure 7.10), was not found in Pukearuhe-1.

The lower part of the bolboform sequence is similar to the well defined succession of appearances and disappearances at oceanic Sites 593 and 1123, but the upper part of the sequence is disrupted by the anomalous reappearance of *Bolboforma subfragoris* s.l. and *Bolboforma pentaspinosa.* The reappearance of these species suggests the well sequence includes reworked material and that part of the sequence at least may be disrupted. The precise stratigraphic extent of the disruption is unknown, but it is speculated that it may correspond to the slump-folded interval in the vicinity of the base of the Tongaporutuan stratotype. Disrupted beds of similar age also outcrop on the coast north of Awakino (Utley 1987). It is not known if these slump-folded beds are all part of the same disrupted sequence, but synsedimentary slumping along the line of the paleo-continental slope is the most likely cause of the disruption, and they could all be part of a mega-slump.

Other bioevents (Pukearuhe-1): *Loxostomum truncatum*, a shelfal benthic species that is diagnostic of the Waiauan and earliest Tongaporutuan (Hoskins 1978; Hornibrook et al. 1989) is found at 1180 m, but it has not been found in the coastal section, even in assemblages with allochthonous shallow-water taxa. This supports the view that the late Miocene part of the section is incomplete and does not extend down to the stratigraphic level of the entry of *Bolivinita pohana* at Kaiti Beach or Tukemokihi Stream.

GLOBOCONELLA MIOTUMIDA COILING ZONES

The preceding data from uplifted marine sequences in New Zealand identifies the same number of intervals of dextrally-coiled *Globoconella miotumida* as at oceanic Sites 593 and 1123, but to date no onland section is known to have all three intervals (Table 7.4).

The Kaiti Coiling Zone is the only interval that has been formally defined (Scott 1995) and the new names Mapiri and Tukemokihi are introduced here for those intervals not previously described.

Table 7.4 – Correlation of late Miocene coiling zones associated with the planktic foraminifer *Globoconella miotumida*. Magnetostratigraphic correlations based on Site 1123 (Study 5). *The Tukemokihi Coiling Zone does not maintain a consistent homotaxial position with respect to bioevents at Sites 1123 and 593, but is not significantly diachronous.

Onland sequences				Oceanic sequences		Coiling Zones	Magnetostratigraphic correlation		Age (Ma)
Kaiti Beach	Tukemokihi Stream	North Taranaki	Pukearuhe-1	DSDP 593	ODP 1123				
no age equivalent section	Gm-TS/B	Gm-TT	Gm-PK	Gm-593/C	Gm-1123/B	Tukemokihi (TCZ)	Top	C4Ar.2r(0.41)*	9.62
							Base	C4Ar.2n(0.71)*	9.42
	Gm-TS/A	missing	missing	Gm-593/B	?	Mapiri (MCZ)	Top	C5n.2n (lower)	?
							Base	C5n.2n (lower)	?
KCZ	missing	missing	missing	Gm-593/A	Gm-1123/A	Kaiti (KCZ)	Top	C5n.2n(0.87)	10.82
							Base	C5n.2n(0.98)	10.93

Kaiti Coiling Zone (KCZ)

Scott (1992) first noted narrow intervals of dextrally-coiled *Globoconella miotumida* near the base of the late Miocene and this led to the establishment of the Kaiti Coiling Zone (Scott 1995). When the KCZ was introduced by Scott (1995) it was thought to be a unique and widely distributed event, although the preceding data show that it is the oldest of at least three late Miocene intervals of dextrally-coiled *Globoconella miotumida* and that it occurs at Kaiti Beach in the vicinity of one of the earliest known New Zealand occurrences of the *B. quadrilatera* group (*Bolivinita pohana*) (Figure 7.6).

The KCZ is reliably correlated with the *Gc*-593/A interval at Site 593 (Table 7.4). It is also represented at Site 1123 (*Gc*-1123/A) and at sections in eastern Wairarapa, including Karamu South Stream. To date, the KCZ has not been found in northern Taranaki or the subsurface of Taranaki Basin. It appears to be cut-out by an unconformity that extends across much of the Taranaki Basin (King & Thrasher 1996). The interval that Scott (1995) mistakenly identified as the KCZ, near the base of the Tongaporutuan stratotype (*Gc*-TT), has been shown here to be the much younger Tukemokihi Coiling Zone (Table 7.4).

Distinguishing criteria: Stratigraphically, the KCZ occurs in the upper part of the *Bolboforma subfragoris* s.l. Zone. Its base is located very near to the highest common occurrence of *Neogloboquadrina mayeri* s.l. and the top of the KCZ occurs just below a very distinctive influx of strongly keeled *Hirsutella panda*, where the abundance of this typically rare species exceeds that of *Globoconella miotumida*. *Neogloboquadrina mayeri*

s.l. is very rare in the upper part of the KCZ where assemblages appear to be randomly-coiled (Figure 7.4). The KCZ maintains a constant position with respect to these events in all of the sections where it has been found.

Mapiri Coiling Zone (MCZ – new name)

The Mapiri Coiling Zone is introduced here for a very short late Miocene interval of dextrally-coiled *Globoconella miotumida* that corresponds to the *Gc*-593/B interval at Site 593 (Table 7.3). Scott (1995) included both *Gc*-593/A and *Gc*-593/B intervals in a single zone, which he correlated with the Kaiti Coiling Zone, but the present study suggests that they are discrete events in stratigraphic space and so should be mapped separately. Tukemokihi Stream is proposed as the reference section for the MCZ, which takes its name from the Mapiri Formation in which the coiling zone occurs – a widely distributed tuffaceous lithostratigraphic unit of Tongaporutuan age that was introduced by Ongley (1927) during his mapping of the Wairoa Subdivision. Specifically, the MCZ is defined in terms of the *Gc*-TS/A interval that is located between field collections MC97/2/29 and MC97/5/05 (non-inclusive) (Figure 7.8) (see Appendix 7.3 for comments on individual collections). This part of the section has excellent exposure, large neritic representations of planktic foraminifers, and the sequence is much expanded compared to the pelagic sequence at Site 593. These features permit detailed study of the coiling zone.

In addition to Site 593 and the reference section at Tukemokihi Stream, the Mapiri Coiling Zone has been provisionally identified at Table Cape, Mahia Peninsula, and at sections in eastern Wairarapa, including Karamu South Stream (Figure 7.1). An interval that is potentially a correlative of the MCZ has also been identified by the author in the subsurface of Taranaki Basin.

Distinguishing criteria: Stratigraphically, the MCZ occurs in the upper part of the *Bolboforma subfragoris* s.l. Zone, above the KCZ (Table 7.4). It occurs just below the lowest occurrence of *Neogloboquadrina pachyderma* and is associated with very rare and intermittent occurrences of randomly-coiled *Neogloboquadrina mayeri* s.l. (Figure 7.8). Distinctive influxes of strongly keeled *Hirsutella panda,* where abundances exceed those of *Globoconella miotumida,* occur near the base and top of the MCZ. These are the only intervals where this typically rare species is known to reach such high abundances, and they distinguish the MCZ from all other intervals of dextrally-coiled *Globoconella miotumida.* The influx of *Hirsutella panda* at the base of the MCZ extends down to the top

of the underlying KCZ, but there is no comparable influx of *Hirsutella panda* near the base of the KCZ.

Tukemokihi Coiling Zone (TCZ – new name)

The Tukemokihi Coiling Zone is introduced here for a narrow late Miocene interval of dextrally-coiled *Globoconella miotumida* that occurs substantially above the KCZ and MCZ. It corresponds to the interval in the vicinity of the base of the Tongaporutuan stratotype in North Taranaki, and similar intervals in the subsurface of Taranaki Basin that, until now, have mistakenly been identified as the KCZ (e.g. Scott 1995). Tukemokihi Stream has features (e.g. excellent exposure, specimen abundance, and completeness) that permit detailed study of the coiling zone and it is proposed here as the name bearer and reference section for the TCZ. Specifically, the TCZ is defined in terms of the *Gc*-TS/B interval that is located between collections MC97/3/21 and MC97/5/35 (non-inclusive) (Figure 7.8).

The Tukemokihi Coiling Zone is the most widely distributed of the known late Miocene intervals of dextrally-coiled *Globoconella miotumida*. In addition to the reference section at Tukemokihi Stream, the Tongaporutuan stratotype in northern Taranaki and numerous wells in Taranaki Basin where the TCZ has been found (e.g. Pukearuhe-1), it is also well represented at eastern North Island sites, including Table Cape, Karamu South Stream, Wainuioru River, and the Titihaoa-1 and Hawke Bay-1 wells drilled offshore (Figure 7.1). It has also been identified at ODP Site 1123, 1000 km east of New Zealand. A similar interval at Site 590B, 850 km northwest of New Zealand that was identified by Scott (1995) as the Kaiti Coiling Zone, is associated with *Bolboforma metzmacheri* s.s. (Grützmacher 1993) and it is suspected that it may be a correlative of the TCZ rather than the KCZ.

Distinguishing criteria: Stratigraphically, the TCZ occurs in the lower part of the *Bolboforma metzmacheri* Zone, below the highest occurrence of *Globoquadrina dehiscens,* in the upper part of the lower Tongaporutuan (Figure 7.4). It is associated with *Neogloboquadrina pachyderma* and weakly keeled specimens of *Hirsutella* aff. *ichinosekiensis*. These faunal criteria distinguish the TCZ from all other intervals of dextrally-coiled *Globoconella miotumida*. Rare expatriates of *Neogloboquadrina mayeri* s.l. (mostly four-chambered individuals) have also been found at Site 593 in the vicinity of the TCZ (Figure 7.4).

REVIEW OF STAGE CRITERIA

Entry of species of the *Bolivinita quadrilatera* group

The defining faunal criterion for the Tongaporutuan Stage – the entry of the *B. quadrilatera* group – has been reliably located in all of the onland sequences examined, except Pukearuhe-1, and its position has been noted with respect to named intervals of dextrally-coiled *Globoconella miotumida* and other important planktic foraminiferal and bolboform events (Figure 7.12).

At Kaiti Beach, Gisborne, the lowest occurrence of the *B. quadrilatera* group is marked by the appearance of *Bolivinita pohana,* which enters just below the Kaiti Coiling Zone. This occurs in the vicinity of a marked change in lithology where mass-emplaced alternating sandstones and mudstones of the Tatapouri Formation are replaced by massive mudstones of the Kaiti Formation (Figure 7.6). Benthic foraminiferal assemblages from the '*Cyclammina* bed', just below the appearance of the *B. quadrilatera* group, include distinctive agglutinated taxa that are indicative of lower and base of slope water depths (>1500 m), while assemblages from the overlying Kaiti Formation (where the *B. quadrilatera* group is well represented) are more typical of shallower slope depths ranging from 1000-1500 m (Figure 7.6).

At Tukemokihi Stream in northern Hawkes Bay, the first species of the *B. quadrilatera* group to appear (*Bolivinita pohana*) occurs below the Mapiri Coiling Zone, very close to the contact between massive mudstones of the Mapiri Formation and mass-emplaced alternating sandstones and mudstones of Makaretu Sandstone (Figure 7.8). The entry of *Bolivinita pohana* coincides with the disappearance of deep-water lower slope taxa that are indicative of water depths >1500 m (Figure 7.8). *Bolivinita* is well represented throughout the overlying Mapiri Formation where biofacies suggest deposition was in water depth of 1000-1500 m.

In the North Taranaki coastal section, *Bolivinita* is rarely found in lower slope biofacies deposited in water depths >1500 m, except for sequences that have mixed biofacies associated with mass-emplaced units. This is reflected in the very patchy distribution of *Bolivinita* aff. *pohana* (striate) in the deeper part of the North Taranaki coastal section, below the base of the Tongaporutuan stratotype (Gibson 1963; King et al. 1993). Specimens of *Bolivinita pohana* first appear near the base of the stratotype, where there is a predominance of allochthonous upper to mid slope taxa that are commonly found in

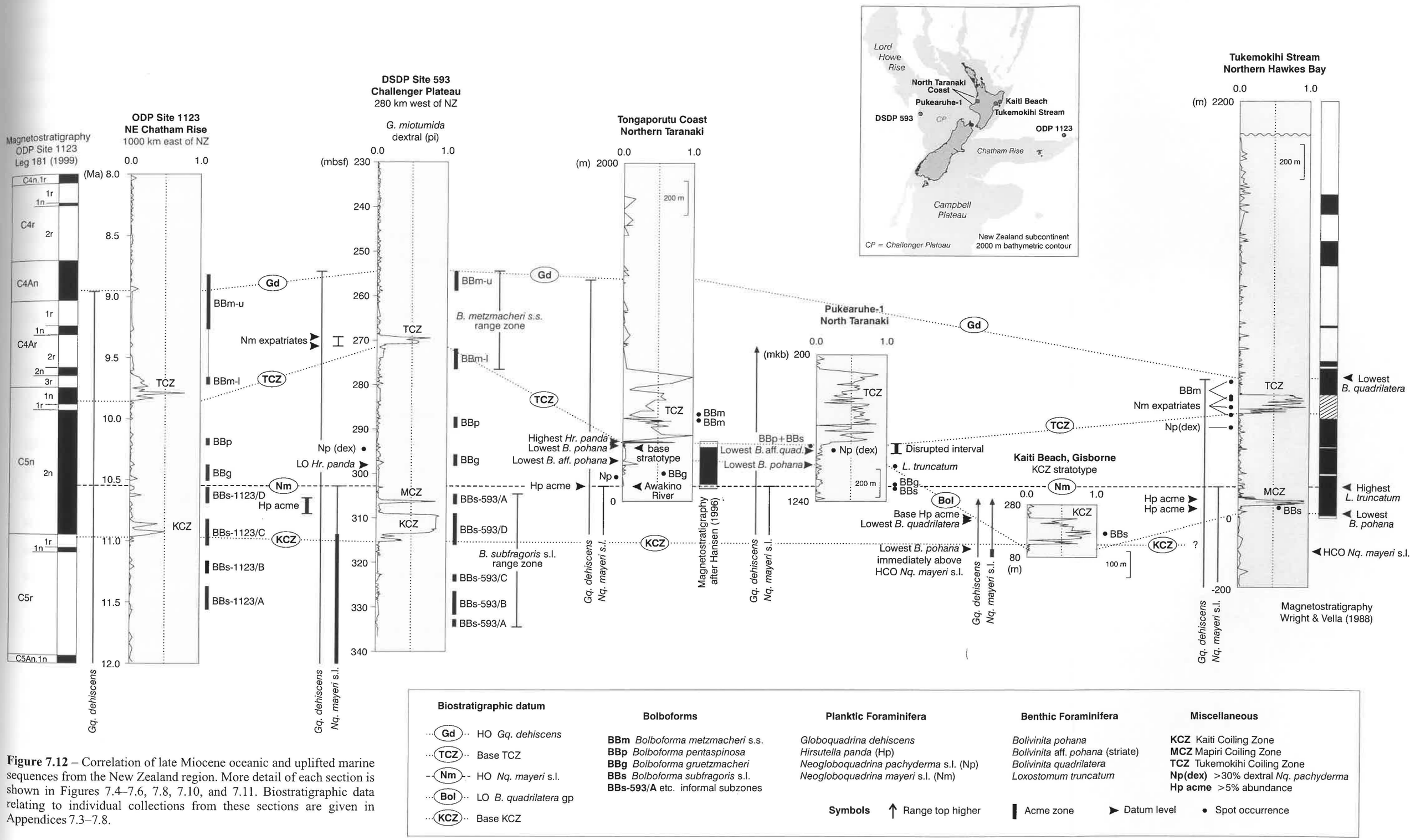


Figure 7.12 – Correlation of late Miocene oceanic and uplifted marine sequences from the New Zealand region. More detail of each section is shown in Figures 7.4–7.6, 7.8, 7.10, and 7.11. Biostratigraphic data relating to individual collections from these sections are given in Appendices 7.3–7.8.

water depths of 300-1000 m (Figure 7.10). King et al. (1993) highlighted the close relationship between the entry of *Bolivinita pohana* and the base of the Tongaporutuan stratotype and suggested it was a useful criterion for the base of the stage. This was largely based on the premise that the entry of *Bolivinita pohana* maintained a consistent (slightly lower stratigraphic position) than the Kaiti Coiling Zone. The previous data, however, show that the entry of *Bolivinita pohana* does not maintain a consistent stratigraphic position. As noted by Scott (1995), it occurs below intervals of dextrally-coiled *Globoconella miotumida,* but these intervals are not necessarily the Kaiti Coiling Zone. For example, at the Tongaporutuan stratotype, the entry of *Bolivinita* aff. *pohana* (striate) and *Bolivinita pohana* occur below the Tukemokihi Coiling Zone – an interval of dextrally-coiled *Globoconella miotumida* that is substantially younger than the Kaiti and Mapiri Coiling Zones (found in eastern North Island sections). These intervals have also been shown to occur in the vicinity of the lowest occurrence of *Bolivinita pohana* – the entry of the *B. quadrilatera* group (Figure 7.12). Such diachroneity does not support Hornibrook's (1987) paradigm of a rapid widespread regional invasion for the appearance of the *B. quadrilatera* group in New Zealand.

All of the sections examined represent regressive slope sequences and in this context species of the *B. quadrilatera* group are largely confined to slope biofacies deposited in water depths <1500 m. Very rare occurrences have been found in lower and base of slope biofacies deposited in water depths >1500 m, but they appear to be confined to mixed allochthonous biofacies with contributions from the upper to middle slope. These data suggest species of the *B. quadrilatera* group that appear in the studied sections may have occupied slope habitats similar to the extant species *Bolivinita quadrilatera* that occurs at slope depths (principally 900-1500 m) in the Pacific (Cushman 1921; Hofker 1951). The *B. quadrilatera* group is common in the upper part of the regressive North Taranaki coastal section, but specimens with quadrate and rhomboidal spiral profiles, such as those found near the base of the Tongaporutuan Stage, are less common in the upper part of the Urenui Formation and they disappear in shelfal biofacies (water depths <200 m) (Figure 7.10). Related species of *Bolivinita,* with compressed spiral profiles, appear in the uppermost part of the Urenui Formation, and *B. pliozea*-like forms appear for the first time at the top of the coastal section, in shelfal biofacies (water depths <200 m). These biofacies relationships and the diachronous entry of the *B. quadrilatera* group suggest the group is primarily a slope taxon and that its reliability as a stage criterion may be adversely affected by

unfavourable facies. Some distinction in niche may also be indicated by the succession of *Bolivinita* species that was once used to subdivide the Tongaporutuan (e.g. Vella 1954; Hornibrook et al. 1989).

Highest occurrence of *Neogloboquadrina mayeri* s.l.

At Kaiti Beach, the reference section for the Kaiti Coiling Zone – the oldest known interval of dextrally-coiled *Globoconella miotumida – Neogloboquadrina mayeri* s.l. occurs without *Neogloboquadrina pachyderma.* It is found throughout the Kaiti Beach section, but it is only common in rocks of the Tatapouri Formation, below the base of the Kaiti Coiling Zone (Figure 7.6). Significantly, the highest common *Neogloboquadrina mayeri* s.l. (where its abundance in planktic assemblages exceeds 5%) occurs in the vicinity of the base of the Tongaporutuan Stage, as defined by the lowest occurrence of *Bolivinita pohana* (the entry of the *B. quadrilatera* group).

Neogloboquadrina mayeri s.l. is also associated with the Mapiri Coiling Zone at Tukemokihi Stream, but it is very rare in rocks of the lower Mapiri Formation where it occurs without *Neogloboquadrina pachyderma* (Figure 7.8). It becomes more persistent near the base of the Mapiri Formation and in rocks of the Makaretu Sandstone below the entry of the *B. quadrilatera* group (*Bolivinita pohana*), but the highest common occurrence of *Neogloboquadrina mayeri* s.l. occurs immediately below the Makaretu Sandstone. This is substantially below the Tukemokihi and Mapiri Coiling Zones and the entry of the *B. quadrilatera* group.

In northern Taranaki, where the Tongaporutuan stratotype is associated with the Tukemokihi Coiling Zone, *Neogloboquadrina mayeri* s.l. has not been found in the vicinity of the stratotype (Gibson 1963; King et al. 1993), but it has been found for the first time in late Miocene rocks near the base of the coastal section, below rare occurrences of *Neogloboquadrina pachyderma* (Figure 7.10).

These relationships suggest the highest common occurrence of *Neogloboquadrina mayeri* s.l. maintains a consistent stratigraphic position, in the vicinity of the base of the Kaiti Coiling Zone and near to some of the earliest known New Zealand occurrences of the *B. quadrilatera* group. This is contrary to what Scott (1995) suggested. The highest common occurrence of *Neogloboquadrina mayeri* s.l. appears to be a reliable criterion for the base

of the faunally defined Tongaporutuan Stage, but it does not serve as a precise marker for the base of the Tongaporutuan stratotype.

REDEFINITION OF TONGAPORUTUAN STAGE

The preceding biostratigraphic data (summarized in Figure 7.12) demonstrate that neither the Tongaporutuan stratotype nor the adjoining North Taranaki coastal section, between Awakino and Kawau Pa, that underlies the stratotype, extends down to the stratigraphic level of the entry of the *B. quadrilatera* group in some eastern North Island sections. It has also been shown that the entry of the *B. quadrilatera* group does not maintain a consistent stratigraphic position with respect to reliable planktic foraminiferal and bolboform events. In hindsight, with our present understanding of biostratigraphy, the choice of the Tongaporutuan stratotype was unfortunate, as Waiauan and Kapitean rocks of the adjoining stages are not found in the vicinity of the stratotype. There is also considerable intraformational deformation in the vicinity of the base of the stratotype and it is difficult to establish stratigraphic relationships. The lower part of the stratotype includes mixed biofacies with considerable representations of allochthonous taxa transported from shelf and upper slope environments. Although the lag time between deposition and transport of the material into deep water may not be large, the data place a caveat on the reliability of bioevents near the base of the stratotype, including the entry of the *B. quadrilatera* group. This highlights the need for a new boundary parastratotype and faunal criterion for the base of the Tongaporutuan Stage.

Finlay & Marwick (1940) introduced the Tongaporutuan Stage at a time when local lithostratigraphic units were being selected as bases for distinctive biostratigraphic units that were associated with widely distributed molluscan and foraminiferal assemblages. Although the stage concept was based on an interval of time represented by the type locality on the North Taranaki coast, faunal events listed by Finlay & Marwick (1940) and considered to be unique to the stage included events that had not been found at the stratotype (Table 7.3). This suggests that Finlay & Marwick (1940) viewed the type locality as the name bearer and fundamental reference section for the stage, but not necessarily representative of all Tongaporutuan time.

Of the planktic foraminiferal events examined, only the base of the Kaiti Coiling Zone and the highest common occurrence of *Neogloboquadrina mayeri* s.l. occur in proximity to some of the earliest known Tongaporutuan occurrences of the *B. quadrilatera* group in

New Zealand, and have features (specimen abundance, wide distribution, and ease of identification) that make them potentially useful for the recognition and correlation of the Tongaporutuan Stage. Neither event has been found in the vicinity of the Tongaporutuan stratotype. They are cut out by an unconformity that extends across much of the Taranaki Basin (King & Thrasher 1996).

Globoconella miotumida is a robust planktic species that is more common than *Neogloboquadrina mayeri* s.l. in the lower Tongaporutuan and it is often found in shallow neritic facies with poor planktic representations. The coiling directions of shells that define the Kaiti Coiling Zone can also be determined with negligible error even from shell fragments, whereas the taxonomic distinction between *Neogloboquadrina mayeri* s.l. and other species of *Neogloboquadrina* can be difficult to resolve in poorly preserved material. Although it has been shown that the Kaiti Coiling Zone is not a unique event, it can be distinguished from other named intervals of dextrally-coiled *Globoconella miotumida* on the basis of ancillary faunal criteria. In practical application, the Mapiri Coiling Zone is most likely to be mistaken for the Kaiti Coiling Zone, but it is located very close to the Kaiti Coiling Zone and the maximum stratigraphic error that may result from any miscorrelation is likely to be less than 0.1 m.y. In comparison, the *B. quadrilatera* group appears about 1.3 m.y. earlier at Kaiti Beach than at the base of the Tongaporutuan stratotype in northern Taranaki.

Consequently, it is proposed that the base of the Kaiti Coiling Zone should be adopted as the primary faunal criterion for the base of the Tongaporutuan Stage. The highest common occurrence of *Neogloboquadrina mayeri* s.l. occurs in very close proximity to the base of the Kaiti Coiling Zone and it serves as a useful secondary criterion for the base of the stage. The lowest occurrence of the *B. quadrilatera* group remains a useful criterion for the base of the stage in favourable facies have paleowater depths of 300-1500 m. More work is needed before a new boundary parastratotype is established, but a suitable section may be found in eastern North Island.

STAGE CORRELATION AND DATING

Cooke (2002) has recently identified an important global isotope event, Zone Mi6 (Miller et al. 1991), in the vicinity of the base of the Tukemokihi Coiling Zone which occurs substantially above the Kaiti Coiling Zone and the base of the Tongaporutuan Stage. There is the possibility that the Kaiti Coiling Zone may be associated with a similar isotope

event, although this cannot be directly tested as there are no high-resolution stable isotope data available from immediately below Kaiti Coiling Zone. Significantly, just prior to the Kaiti Coiling Zone there is a very marked and abrupt decrease in the abundance of *Neogloboquadrina mayeri* s.l. It dominates planktic assemblages in the uppermost Waiauan and becomes very rare in the lowermost Tongaporutuan, where significant representations of dextrally-coiled *Globoconella miotumida* first appear (Study 2). At Site 1123, an interval of dextrally-coiled *Globoconella miotumida* that has been correlated with the Kaiti Coiling Zone (see earlier) occurs near the base of Chron C5n.2n (10.92 Ma). This locates the base of the Tongaporutuan Stage between isotope Zones Mi5 (11.4 Ma) and Mi6 (10.4 Ma) (Turco et al. 2001). In terms of the Berggren et al. (1995) time scale, the base of the Tongaporutuan Stage corresponds to the M13/M12 (N16/N15) (sub)tropical zonal boundaries and NN9a-b/NN8 (CN7a-b/CN6) calcareous nannoplankton boundaries, in earliest late Miocene time.

CONCLUSIONS

Of the faunal criteria surveyed, the entry of benthic foraminiferal species of the *B. quadrilatera* group is the least reliable event for recognition of the base of the Tongaporutuan Stage. It does not maintain a consistent position, below the Kaiti Coiling Zone, as suggested by Scott (1995), but is found below intervals of dextrally-coiled *Globoconella miotumida* that until now have been mistakenly correlated with the Kaiti Coiling Zone. These include the newly named lower Tongaporutuan Mapiri and Tukemokihi Coiling Zones, which are distinguished on the basis of distinctive planktic foraminiferal and bolboformid criteria. The order in which species of the *B. quadrilatera* group appear at the base of the stage also varies, and those that are diagnostic of the stage are generally not found at oceanic sites and in some shelf and deep slope facies – they are most common in paleowater depths of 200-1500 m. The base of the Kaiti Coiling Zone and the highest common occurrence of *Neogloboquadrina mayeri* s.l. have been found to be reliable homotaxial criteria for the base of the faunally-defined Tongaporutuan Stage, although neither event occurs in the vicinity of the Tongaporutuan stratotype in northern Taranaki. They are widely distributed planktic foraminiferal events that are closely separated in stratigraphic space and they occur near some of the earliest known New Zealand occurrences of the *B. quadrilatera* group, which define the base of the Tongaporutuan Stage.

The proposed redefinition of the Tongaporutuan Stage, based (primarily) on the base of the Kaiti Coiling Zone and (secondarily) on the highest common occurrence of *Neogloboquadrina mayeri* s.l. resolves a long-standing enigma of Tongaporutuan biostratigraphy, although as neither event has been found at the Tongaporutuan stratotype in northern Taranaki, it requires a new boundary parastratotype for the base of the stage. A suitable section where the new stage criteria can be reliably correlated with the entry of the *B. quadrilatera* group has yet to been found.

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Appendices

Appendix 7.1 – Biostratigraphic data from Kaiti Beach, Gisborne, including stratigraphic heights of samples, notes on individual collections, *Globoconella miotumida* coiling data, and minimum estimates of water depths. A summary is given in given Figure 7.6. (Page 1 of 3)

FR No. Y18/f---	GNS Lab No.	Field no. BDF---	Thickness (m)	Formation	Important taxa and comments on collection	G. miotumida Sin (n)	G.miotumida Dex (n)	G.miotumida Dex (pi)	Bolboforms	Min. water depth (m)
f548	F29249	49-77	278.2	Kaiti	*Hr. panda* (1S:60D), *Hr. scitula* (0S:1D), *Gq. dehiscens, Zg. druryi, Zg. nepenthes, B. pohana, E. bradyi, S. schlumbregeri, Planulina* sp. [Tuffaceous]	64	10	0.14	no	600
f547	F29248	49-76	273.7	Kaiti	*Nq. mayeri* s.l. (5S:1D), *Hr. panda* (16S:348D), *Hr. scitula* (1S:2D), *Gq. dehiscens, Zg. nepenthes, Zg. druryi, Gs. quadrilobatus, Ge. aequilateralis, Gd. hexagona, Cs. parvulus, B. pohana, K. bradyi, H. mioindex, Planulina* sp.	100	11	0.10	no	1000
f546	F29247	49-75	269.2	Kaiti	*Hr. panda* (3S:109D), *Hr. scitula* (1S:1D), *Gq. dehiscens, Mn.* cf. *menardii* (1S:0D), *Zg. druryi, K. bradyi, P. renzi*	133	4	0.03	*	
f545	F29246	49-74	264.0	Kaiti	*Hr. panda* (4S:90D), *Gq. dehiscens* (common), *Zg. nepenthes, K. bradyi, P. renzi*	202	4	0.02	*	
f544	F29245	49-73	258.7	Kaiti	*Hr. panda* (0S:100D), *Gq. dehiscens* (common), *Hr.* cf. *scitula* (1S:0D) inflated, *K. bradyi*	219	3	0.01	*	
f543	F29244	49-72	253.4	Kaiti	*Hr. panda* (9S:117D), *Gq. dehiscens, Zg. nepenthes, K. bradyi, S. schlumbergeri*	96	4	0.04	*	
f542	F29243	49-71	247.5	Kaiti	*Hr. panda* (1S:109D), *Gq. dehiscens, Zg. nepenthes* (common), *Sphaeroidinellopsis* sp., *Gs. quadrilobatus*	214	14	0.06	*	
f541	F29242	49-70	245.0	Kaiti	*Hr. panda* (0S:25D), *Hr. scitula* (0S:1D), *Gq. dehiscens, Planulina* sp.	94	1	0.01		1000
f540	F29241	49-69	242.5	Kaiti	*Hr. panda* (8S:69D), *Hr. scitula* (1S:1D), *Gq. dehiscens, Zg. druryi, Gs. quadrilobatus, B. pohana* (compressed)	107	3	0.03	no	
f539	F29240	49-68	239.9	Kaiti	*Hr. panda* (1S:91 D), *B. pohana*	88	2	0.02		
f538	F29239	49-67	237.4	Kaiti	*Hr. panda* (4S:38D), *Hr. scitula* (0S:1D), *Gq. dehiscens, Zg. druryi, B. pohana* (compressed)	51	1	0.02	no	
f537	F29238	49-66	234.9	Kaiti	*Hr. panda* (12S:80D), *Hr. scitula (0S:1D), H.* cf *.scitula* (1S:0D), *Gq. dehiscens, Zg. druryi, B. pohana* (compressed)	66	3	0.04	no	
f536	F29237	49-65	232.4	Kaiti	*Hr. panda* (common)	80	3	0.04	no	
f535	F29236	49-64	229.8	Kaiti	*Hr. panda* (2S:86D), *Hr. scitula* (1S:1D), *Planulina* sp.	90	2	0.02		1000
Top Kaiti Coiling Zone (KCZ)										
f534	F29235	49-63	227.3	Kaiti	*Hr. panda* (0S:4D), *Gq. dehiscens, E. bradyi*	28	74	0.73		600
f533	F29234	49-62	224.8	Kaiti	*Gq. dehiscens*	90	138	0.61	no	
f532	F29233	49-61	222.2	Kaiti	*Hr. panda* (0S:1D)	72	75	0.51		
f531	F29232	49-60	219.7	Kaiti	*Nq. mayeri* s.l. (9S:1D), *Nq. partimlabiata* (1S:0D), *Hr. panda* (1S:2D), *Hr. scitula* (0S:4D), *Gq. dehiscens, Zg. druryi, Globigerinella* sp.?, *Sphaeroidinellopsis* sp., *B. quadrilatera, B. pohana* (compressed), *L. truncatum, E. bradyi, S. schlumbergeri, P. alternans*	128	98	0.43	no	
f530	F29231	49-59	217.2	Kaiti	*Hr. panda* (0S:1D), *S. schlumberegri, Planulina* sp.	73	40	0.35		1000
f528	F29229	49-57	212.1	Kaiti	*E. bradyi, S. schlumbergeri, Planulina sp.*	62	53	0.46		1000
f521	F29222	49-50	209.6	Kaiti	?equivalent BDF49-56 = Y18/f527 (58S:49D) 54.2% Dextral, *Hr. panda* (1S:1D), *Gd. hexagona?, E. bradyi, G. medwayensis*	83	20	0.19		800
f520	F29221	49-49	207.1	Kaiti	?equivalent BDF49-55 = Y18/f526 (43S:63D) 40.6% Dextral, *Hr. panda* (0S:23D), *Hr. scitula* (0S:1D), *Zg. nepenthes*	39	33	0.46	no	
f519	F29220	49-48	204.5	Kaiti	*Hr. panda* (1S:20D), *Hr.* cf. *scitula* (1S:1D) inflated, *Gd.* cf. *hexagona, Gq. dehiscens, Gs. trilobus, Gs. quadrilobatus, K. bradyi , S. schlumbergeri,* [tuffaceous]; ?equivalent BDF49-54 (Y18/f525)	44	65	0.60	no	
f518	F29219	49-47	202.0	Kaiti	?equivalent BDF49-53 = Y18/f524 (58S:54D) 51.8% Dextral, *Hr. panda* (1S:4D), *B. pohana, E. bradyi, Bolivinopsis, Glomospira*	53	58	0.52		1000
f523	F29224	49-52	199.5	Kaiti	*E. bradyi, S. schlumbergeri*	59	53	0.47		600
f522	F29223	49-51	196.9	Kaiti	*Zg. nepenthes, S. schlumbergeri*	39	82	0.68		600
f517	F29218	49-46	192.7	Kaiti	*Nq. continuosa* (2S:0D), *Hr.* cf. *panda* (2S:1D), *Gq. dehiscens* (common), *Sphaeroidinellopsis* sp., *Zg. druryi, K. bradyi,* [tuffaceous]	69	131	0.66	no	

Appendix 7.1 – Kaiti Beach, biostratigraphic data. (Page 2 of 3)

FR No. Y18/f---	GNS Lab No.	Field no. BDF---	Thickness (m)	Formation	Important taxa and comments on collection	G. miotumida Sin (n)	G.miotumida Dex (n)	G.miotumida Dex (pi)	Bolboforms	Min. water depth (m)
f516	F29217	49-45	190.2	Kaiti		35	64	0.65		
f514	F29215	49-43	185.1	Kaiti	*E. bradyi, S. schlumbergeri, Planulina* sp.	41	80	0.66		1000
f513	F29214	49-42	182.6	Kaiti	*E. bradyi, Planulina* sp.	48	81	0.63		1000
f512	F29213	49-41	180.1	Kaiti	*Hr. panda* (0S:1D), *Hr. scitula* (0S:1D), *Zg. nepenthes, Spheroidinellopsis* sp., *B. pohana, E. bradyi, S. schlumbergeri, G. medwayensis, Planulina* sp.	10	96	0.91	no	1000
f511	F29212	49-40	177.6	Kaiti	*B. subfragoris* s.l., *Nq. continuosa* (3S:0D), *Hr. panda* (0S:1D), *Gs. quadrilobatus, B. pohana, L. truncatum, E. bradyi, S. schlumbergeri, Planulina* sp.	18	80	0.82	rare	1000
f510	F29211	49-39	175.0	Kaiti	*B. subfragoris* s.l., *Nq. mayeri* s.l. (7S:0D), *Hr. panda* (2S:0D), *Hr. scitula* (1S:1D), *Gs. quadrilobatus, Zg. druryi, Cs. parvulus, B. pohana, E. bradyi, S. schlumbergeri, O. bengalensis, G. medwayensis, Bolivinopsis*	45	56	0.55	few	800
f509	F29210	49-38	172.5	Kaiti	*B. subfragoris* s.l., *Nq. mayeri* s.l. (5S:5D), *Hr. panda* (25S:0D)+ aff. *menardii?, Gr. lenguaensis* (rare), *Zg. nepenthes, Gq. dehiscens, Gs. quadrilobatus, B. pohana* (compressed), *S. schlumbergeri, E. bradyi*	17	213	0.93	rare	600
f508	F29209	49-37	170.0	Kaiti	*B. subfragoris* s.l., *Nq. continuosa* (1S:0D), *M .panda* (2S:0D), *Hr.* cf. *scitula* (2S:0D), *Gq. dehiscens, Gs. quadrilobatus, Zg. druryi, Gr. lenguaensis, Cs. parvulus, B. pohana* (compressed), *E. bradyi, Planulina* sp., *Bolivinopsis* sp.	15	98	0.87	rare	1000
f507	F29208	49-36	167.4	Kaiti	*B. subfragoris* s.l., *Hr. panda* (8S:1D), *Gs. trilobus, Gs. quadrilobatus, Sphaeroidinellopsis* sp., *Zg. nepenthes, B. pohana* (compressed), *E. bradyi, S. schlumbergeri*	39	164	0.81	rare	1000
f506	F29207	49-35	164.9	Kaiti	*Hr. panda* (0S:6D), *Hr. scitula* (0S:6D), *Zg. nepenthes, B. pohana, B. pohana* (compressed), *S. schlumbergeri, V. pennetula*	29	63	0.68		800
f505	F29206	49-34	162.1	Kaiti	*Hr. panda* (2S:6D) aff. *menardii, Hr. scitula* (0S:2D), *Gq. dehiscens, Gs. quadrilobatus, Sphaeroidinellopsis sp., B. pohana, E. bradyi, P. renzi*	90	125	0.58	*	
f504	F29205	49-33	159.5	Kaiti	*Gq. dehiscens, B. pohana, S. schlumbergeri, G. medwayensis, Planulina* sp.	24	72	0.75		1000
f503	F29204	49-32	157.3	Kaiti	*Hr. panda* (6S:11D) sinistral specimens aff. *menardii, Hr. scitula* (0S:1D), *Gq. dehiscens, Gs. trilobus, Gs. quadrilobatus, E. bradyi*	45	172	0.79	*	
f502	F29203	49-31	154.8	Kaiti	*E. bradyi, S. schlumbergeri, G. medwayensis, T. zealandica*	22	71	0.76		1500
f501	F29202	49-30	152.3	Kaiti	*Nq. continuosa?, Hr. panda* (17S:18D), *Hr. scitula* (1S:1D), *Gq. dehiscens, Gs. trilobus, B. pohana, S. schlumbergeri*	47	174	0.79	*	
f500	F29201	49-29	149.7	Kaiti	*E. bradyi*	46	86	0.65		600
f499	F29200	49-28	147.2	Kaiti	*Nq. continuosa?, Hr. panda* (0S:72D), *Hr. scitula* (0S:2D), *Gq. dehiscens* (common), *Gs. quadrilobatus, Sphaeroidinellopsis* sp., *B. pohana*	124	76	0.38	*	
f498	F29199	49-27	144.7	Kaiti	*Gq. dehiscens, Hr. panda, B. pohana, E. bradyi, S. schlumbergeri, T. zealandica*	78	2	0.03	no	1500
f497	F29198	49-26	142.1	Kaiti	*Nq. continuosa* (3S:0D), *Hr. panda* (0S:18D), *Zg. nepenthes, B. pohana, S. schlumbergeri, G. medwayensis*	89	31	0.26		800
f496	F29197	49-25	139.6	Kaiti	*Hr. panda* (0S:1D), *Gq. dehiscens, Sphaeroidinellopsis, B. pohana, E. bradyi, S. schlumbergeri, G. medwayensis, V. pennetula, Planulina* sp.	35	66	0.65		1000
f561	F29739	50-168	137.0	Kaiti	*Nq. mayeri* s.l. (6S:0D), *Hr. panda* (2S:13D), *Zg. nepenthes, Sphaeroidinellopsis, B. pohana, S. schlumbergeri, V. pennatula*	72	47	0.39		800
f560	F29738	50-169	134.4	Kaiti	*Nq. mayeri* s.l. (12S:0D), *B. pohana, E. bradyi, S. schlumbergeri*	47	63	0.57		600
f559	F29737	50-170	131.8	Kaiti	*Nq. continuosa* (1S:0D), *Hr. panda* (2S:38D), *B. pohana* (rhomboidal + compressed), *S. schlumbergeri*	29	81	0.74		600
Base Kaiti Colling Zone (KCZ)										
f558	F29736	50-171	129.2	Kaiti	*B. pohana, S. schlumbergeri, C. robertsonianus*	101	2	0.02		1000
f557	F29735	50-172	126.6	Kaiti	*Hr. panda* (1S:22D), *Gq. dehiscens?, Spaeroidinellopsis sp.?, S. schlumbergeri*	100	5	0.05		600

Appendix 7.1 – Kaiti Beach, biostratigraphic data. (Page 3 of 3)

FR No. Y18/f---	GNS Lab No.	Field no. BDF---	Thickness (m)	Formation	Important taxa and comments on collection	G. miotumida Sin (n)	G.miotumida Dex (n)	G.miotumida Dex (pi)	Bolboforms	Min. water depth (m)
f556	F29734	50-173	124.0	Kaiti	*Hr. scitula* (0S:1D), *B. pohana*	110	0	0.00		
f555	F29733	50-174	121.4	Kaiti	*Hr. panda* (4S:51D), *Gq. dehiscens* (common), *Gr. lenguaensis?, S. schlumbergeri, B. pohana* (compressed)	210	9	0.04	no	
f554	F29732	50-175	118.5	Kaiti	*Hr. panda (0S:16D), Zg. nepenthes, B. pohana* (rhomboidal), *S. schlumbergeri, T. zealandica?*	102	0	0.00		1000?
f553	F29731	50-176	115.6	Kaiti	*Nq. continuosa* (2S:0D), *Hr. panda* (5S:2D), *Gq. dehiscens* (common), *Zg. druryi, Sphaeroidinellopsis* sp., *Gs. quadrilobatus, Gs. trilobus, B. pohana* (rhomboidal), *E. bradyi, S. schlumbergeri*	200	5	0.02	no	
f552	F29730	50-177	112.7	Kaiti	*Gq. dehiscens, B. pohana, E. bradyi, S. schlumbergeri*	94	4	0.04		600
Base Tongaporutuan Stage										
f551	F29729	50-178	109.8	Kaiti	*Nq. mayeri* s.l. (77S:9D), *Hr. panda* (0S:1D), *Hr. scitula* (0S:1D), *Gq. dehiscens* (common), *Sphaeroidinellopsis* sp., *Zg. nepenthes, S. schlumbergeri*	49	0	0.00	rare	
f550	F29728	50-179	106.9	Kaiti	*Nq. mayeri* s.l. (8S:0D), *Gq. dehiscens, Zg. nepenthes, E. bradyi, S. schlumbergeri*	109	5	0.04		600
f562	F29740	50-180	106.0	Kaiti	*Nq. continuosa* (0S:2D), *Hr. panda* (0S:1D), *Gq. dehiscens, Zg. druryi, K. bradyi, S. schlumbergeri, H. mioindex,* [tuffaceous]	30	1	0.03		1000
f549	F29727	50-181	103.9	Kaiti	*Nq. mayeri* s.l. (5S:0D), *Hr. scitula (0S:2D), Gq. dehiscens, S. schlumbergeri, V. pennatula, H. mioindex,* [from 5 m thick "Cyclammina Tuff"]	106	1	0.01	*	1500
f563	F29741	50-182	87.2	Tatapouri	*Nq. mayeri* s.l. (20S:4D), *Fohsella sp.?, Hr. panda* (1S:1D), *Gq. dehiscens, Zg. druryi, S. notohispida, Bolivinopsis,* [below base of "Cyclammina Tuff"]	25	0	0.00	*	1500

Appendix 7.2 – Biostratigraphic data from Tukemokihi Stream, northern Hawkes Bay (I.C. Wright core-plug sample suite), including stratigraphic heights of samples, notes on individual collections, *Globoconella miotumida* and *Hirsutella panda* coiling data, and minimum estimates of water depths. A summary is given in given Figure 7.8. (Page 1 of 9)

VUW Lab No.	Field No. ICW---	Thickness (m)	Polarity	Number of plugs	Formation	NZ Stage	Important taxa and comment on collection	*Gc. miotumida* Sin (n)	*Gc. miotumida* Dex (n)	*Gc. miotumida* Dex (Pi)	*Hr. panda* Sin (n)	*Hr. panda* Dex (n)	*Hr. panda* Dex (Pi)	Min. water depth (m)
19208	217	2158	?	4	Opoiti	uTk	*Gc. sphericomiozea* (unkeeled morphotypes dominate), [glauconitic, tuffaceous]	0	0	0				
19207	216	2158	R	4	Opoiti	uTk	NOT EXAMINED							
19206	215	2157	R	4	Opoiti	uTk	NOT EXAMINED							
19205	214	2157	?	4	Opoiti	uTk	NOT EXAMINED							
19204	213	2156	R	4	Opoiti	uTk	NOT EXAMINED							
19203	212	2155	?	4	Opoiti	uTk	*Gc. sphericomiozea* (some dextral), *Gc. pliozea*, *Tr. crassaformis?* (rounded, sinistral specimen)	0	0	0				
19202	211	2154	R	4	Opoiti	uTk	*Gc. sphericomiozea* (Sin/Dex - subequal)	0	0	0				
19201	210	2142	R	4	Opoiti	uTk	*Gc. sphericomiozea*	0	0	0				
19200	209	2130	R	4	Opoiti	uTk	*Gc. sphericomiozea*, *Mn.* cf. *menardii* (1S:0D), *Hr. scitula* (1S:0D)	0	0	0				
19199	208	2115	R	4	Opoiti	uTk	*Gc. sphericomiozea*, *Gc. mons*, *Tr. crassaformis* (0S:1D)	0	0	0				
Miocene/Pliocene Unconformity (or possibly a fault)														
19198	207	2096	R	3	Mapiri	uTk?	*Gc. sphericomiozea?*, *Mn*. cf. *menardii* (1S:0D)	108	1	0.01				
19197	206	2081	?	3	Mapiri	uTk?	*Gc. sphericomiozea?*, *Zg. nepenthes*, *H. mioindex*, *B. pohana*	0	0	0.00				1000
19196	205	2075	R	4	Mapiri	Tk?	*Hr. scitula* (2S:0D)	74	2	0.03				
19195	204	2069	?	4	Mapiri	Tk?	*Hr. scitula* (0S:1D)	195	5	0.03				
19194	203	2063	R	4	Mapiri	Tk?	*Sphaeroidinellopsis*, *Zg. nepenthes*	195	5	0.03				
19193	202	2056	R	4	Mapiri	Tk?	*Hr. scitula* (1S:0D), *Zg. nepenthes*	26	1	0.04				
19192	201	2050	?	4	Mapiri	Tk?	*Hr. scitula* (1S:0D), *B.* cf. *elegantissima*	35	4	0.10				
19191	200	2043	?	5	Mapiri	Tk?	*Mn.* cf. *menardii* (1S:0D), *Hr. scitula* (8S:7D), *Zg. nepenthes*, *B. elegantissima*, *B. pohana*, *B. pliozea*	150	4	0.03				
19190	199	2036	R	4	Mapiri	Tk?	*Mn.* cf. *menardii* (1S:0D), *Hr. scitula* (0S:2D), *S. schlumbergeri*	90	10	0.10				600
19189	198	2030	R	4	Mapiri	Tk?	*Hr. scitula* (0S:1D), *B*. cf. *pliozea*, *S. schlumbergeri*	9	0	0.00				600
19188	197	2023	?	4	Mapiri	Tk?	*Gc. miotumida* (biconvex), *Hr. scitula* (1S:10D), *B. plioblqua*, *E. brayi*, (*Z. parri*, *Elphidium*, *Notorotalia* - downslope)	17	0	0.00				600
19187	196	2017	?	0	Mapiri	Tk?	[no sample]							
19186	195	2010	?	4	Mapiri	Tk?	*B. compressa*	32	1	0.03				
19185	194	2004	R	4	Mapiri	Tk?	[tuffaceous]	61	1	0.02				
19184	193	1996	R	5	Mapiri	Tk?	*Gc. miotumida* (not biconvex as below), *B. compressa*, [tuffaceous]	44	4	0.08				
19183	192	1984	R	4	Mapiri	Tk?	*Zg. nepenthes* (common), *Globigerinoides*, *B. compressa*, *Bulimina* (abundant)	35	2	0.05				
19182	191	1975	R	4	Mapiri	Tk?	*Hr. scitula* (1S:4D), [tuffaceous]	115	5	0.04				
19181	190	1964	R	4	Mapiri	Tk?	*B. compressa*, *S. schlumbergeri*	50	1	0.02				600
?Unconformity														
19180	189	1959	R	4	Mapiri	Tt	*Gc. miotumida* (biconvex), *Gc.* cf. *sphericomiozea* (2S:0D), *Mn.* cf. *menardii* (0S:4D), *Hr. scitula* (0S:1D), *Nq. pachyderma*, *Sphaeroidinellopsis*, *Zg. nepenthes*, *B. compressa*, [tuffaceous]	166	12	0.07				
19179	188	1954	?	4	Mapiri	Tt	*Mn.* cf. *menardii* (0S:8D), *Hr. scitula* (4S:1D), *Nq. pachyderma*, *B. compressa*	15	1	0.06				
19178	187	1945	R	4	Mapiri	Tt	*Nq. pachyderma*, *B. compressa*, *S. notohispida*, [tuffaceous]	36	2	0.05				1000
19177	186	1936	R	5	Mapiri	Tt	*B. compressa*	37	2	0.05				
19176	185	1927	?	4	Mapiri	Tt	*Hr. scitula* (1S:0D), *Siphouvigerina*	8	1	0.11				
19175	184	1918	R	5	Mapiri	Tt	*Gc. miotumida* (biconvex), *Zg.* cf. *nepenthes*, *B. compressa*, *S. schlumbergeri*, [tuffaceous]	16	0	0.00				600
19174	183	1909	?	4	Mapiri	Tt	*Hr. scitula* (1S:0D), *Nq. pachyderma*, *B. compressa*	6	1	0.14				
19173	182	1901	R	5	Mapiri	Tt	*Hr. scitula* (1S:3D), *B. compressa*	25	0	0.00				

Appendix 7.2 – Tukemokihi Stream, biostratigraphic data (Page 2 of 9)

VUW Lab No.	Field No. ICW--	Thickness (m)	Polarity	Number of plugs	Formation	NZ Stage	Important taxa and comment on collection	*Gc. miotumida* Sin (n)	*Gc. miotumida* Dex (n)	*Gc. miotumida* Dex (Pi)	*Hr. panda* Sin (n)	*Hr. panda* Dex (n)	*Hr. panda* Dex (Pi)	Min. water depth (m)
19172	181	1892	?	4	Mapiri	Tt	*Gc. miotumida* (biconvex), *Hr. scitula* (1S:0D), *B. cf. compressa, S. schlumbergeri*, [tuffaceous]	12	1	0.08				600
19171	180	1884	R	5	Mapiri	Tt	*Nq. pachyderma* (0S:1D), *B. compressa, S. schlumbergeri*	30	1	0.03				600
19170	179	1875	R	4	Mapiri	Tt		11	2	0.15				
19169	178	1866	?	5	Mapiri	Tt	*B. compressa*	21	0	0.00				
19168	177	1857	N	4	Mapiri	Tt	*Nq. pachyderma*	35	1	0.03				
19167	176	1848	?	4	Mapiri	Tt	*Gc. miotumida* (biconvex, Dex aff. *panda*)	42	3	0.07				
19166	175	1836	N	4	Mapiri	Tt	*Sphaeroidinellopsis, S. schlumbergeri*	28	1	0.03				600
19165	174	1825	?	4	Mapiri	Tt		26	0	0.00				
19164	173	1816	N	4	Mapiri	Tt	*B. compressa*	3	0	0.00				
19163	172	1807	N	3	Mapiri	Tt	*B. compressa*	6	1	0.14				
19162	171	1801	N	4	Mapiri	Tt	[tuffaceous]	48	1	0.02				
19161	170	1794	N	4	Mapiri	Tt	*Gc. miotumida* (aff. *panda*), *Zg. nepenthes*	33	0	0.00				
19160	169	1787	?	0	Mapiri	Tt	[No sample]							
19159	168	1779	N	5	Mapiri	Tt	*Zg. nepenthes*	97	3	0.03				
19158	167	1772	N	4	Mapiri	Tt		24	2	0.08				
19157	166	1767	N	4	Mapiri	Tt	*Globigerinoides, Sphaeroidinellopsis, Zg. cf. nepenthes, B. compressa, S. schlumbergeri*	7	1	0.13				600
19156	165	1762	N	4	Mapiri	Tt		28	2	0.07				
19155	164	1757	?	0	Mapiri	Tt	[No sample]							
19154	163	1751	?	0	Mapiri	Tt	[No sample]							
19153	162	1650	R	4	Mapiri	Tt	*Gc. miotumida* (biconvex), *Zg. cf. nepenthes, S. schlumbergeri*	17	0	0.00				600
19152	161	1649	R	4	Mapiri	Tt		43	1	0.02				
19151	160	1643	R	4	Mapiri	Tt	*Globigerinoides, S. schlumbergeri*	20	0	0.00				600
19150	159	1638	?	3	Mapiri	Tt		10	1	0.09				
19149	158	1633	?	4	Mapiri	Tt		26	0	0.00				
19148	157	1627		0	Mapiri	Tt	[No sample]							
19147	156	1622	R	3	Mapiri	Tt		4	0	0.00	0	0	0.0	
19146	155	1616	R	4	Mapiri	Tt		18	1	0.05	0	0	0.0	
19145	154	1612	R	3	Mapiri	Tt		18	2	0.10	0	0	0.0	
19144	153	1608	R	3	Mapiri	Tt	*Sphaeroidinellopsis, Zg. nepenthes*, [tuffaceous]	16	2	0.11	0	0	0.0	
19143	152	1604	R	4	Mapiri	Tt		122	6	0.05	0	0	0.0	
19142	151	1599	?	3	Mapiri	Tt	*Zg. nepenthes, S. notohispida*	47	7	0.13	0	0	0.0	1000
19141	150	1595	N	4	Mapiri	Tt	*S. notohispida*	80	0	0.00	0	0	0.0	1000
19140	149	1590	?	3	Mapiri	Tt	*Nq. pachyderma, S. notohispida*	13	0	0.00	0	0	0.0	1000
19139	148	1585	N	4	Mapiri	Tt	*S. notohispida*	41	0	0.00	0	0	0.0	1000
19138	147	1580	N	3	Mapiri	Tt		26	0	0.00	0	0	0.0	
19137	146	1574	N	4	Mapiri	Tt	*S. notohispida*	27	1	0.04	0	0	0.0	1000
19136	145	1569	N	4	Mapiri	Tt	*S. notohispida*	81	0	0.00	0	0	0.0	1000
19135	144	1564	N	4	Mapiri	Tt	*S. notohispida*	45	1	0.02	0	0	0.0	1000
19134	143	1560	N	4	Mapiri	Tt	*B. cf. elegantissima, S. notohispida*	196	4	0.02	0	0	0.0	1000
19133	142	1556	N	4	Mapiri	Tt	*Zg. nepenthes, Nq. pachyderma, S. notohispida*, [tuffaceous]	53	0	0.00	0	0	0.0	
19132	141	1552	N	3	Mapiri	Tt	(200+ *Gc. miotumida*), *Spheroidinellopsis* (rare)	197	3	0.02	0	0	0.0	
19131	140	1548	N	4	Mapiri	Tt	(200+ *Gc. miotumida*), *Sphaeroidinellopsis, Zg. nepenthes, S. notohispida*	197	3	0.02	0	0	0.0	1000
19130	139	1542	?	0	Mapiri	Tt	[No sample]							
19129	138	1536	N	3	Mapiri	Tt	*Zg. nepenthes, Nq. pachyderma, B. cf. elegantissima, S. notohispida*, [tuffaceous]	105	4	0.04	0	0	0.0	1000
19128	137	1530	N	3	Mapiri	Tt	*Gc. miotumida* (aff. *panda*, few variants), *B. cf. elegantissima*	125	2	0.02	0	0	0.0	

Appendix 7.2 – Tukemokihi Stream, biostratigraphic data (Page 3 of 9)

VUW Lab No.	Field No. ICW--	Thickness (m)	Polarity	Number of plugs	Formation	NZ Stage	Important taxa and comment on collection	*Gc. miotumida* Sin (n)	*Gc. miotumida* Dex (n)	*Gc. miotumida* Dex (Pi)	*Hr. panda* Sin (n)	*Hr. panda* Dex (n)	*Hr. panda* Dex (Pi)	Min. water depth (m)
19127	136	1524	?	3	Mapiri	Tt	*Zg. nepenthes, Sphaeroidinellopsis, S. notohispida*	184	3	0.02	0	0	0.0	1000
19126	135	1518	N	4	Mapiri	Tt	*Zg. nepenthes, Nq. pachyderma, Gs. ruber?, B.* cf. *elegantissima, S. notohispida*	202	2	0.01	0	0	0.0	1000
19125	134	1512	N	3	Mapiri	Tt	*Zg. nepenthes, B.* cf. *elegantissima, S. notohispida*	209	6	0.03	0	0	0.0	1000
19124	133	1507	?	0	Mapiri	Tt	[No sample]							
19123	132	1501	N	3	Mapiri	Tt	*Zg. nepenthes* (common), *Sphaeroidinellopsis, B.* cf. *elegantissima, S. notohispida*	128	3	0.02	0	0	0.0	1000
19122	131	1495	N	4	Mapiri	Tt	*Gc. miotumida* (aff. *panda*, few variants), *Zg. nepenthes, Globigerinoides, Sphaeroidinellopsis, B.* cf. *elegantissima*	190	5	0.03	0	0	0.0	
19121	130	1490	N	3	Mapiri	Tt	*Globigerinoides, Nq. pachyderma, B.* cf. *elegantissima, S. notohispida*	103	2	0.02	0	0	0.0	1000
19120	129	1485	N	3	Mapiri	Tt	*Globigerinoides* (common), Zg. nepenthes, Sphaeroidinellopsis, Nq. pachyderma, B. cf. *elegantissima, S. notohispida*	36	1	0.03	0	0	0.0	1000
19119	128	1479	N	3	Mapiri	Tt	*Zg. nepenthes, B.* cf. *elegantissima, S. notohispida*	54	1	0.02	0	0	0.0	1000
19118	127	1473	N	3	Mapiri	Tt	*Gc. miotumida* (aff. *panda*, few variants), *B.* cf. *elegantissima, S. notohispida*	64	7	0.10	0	0	0.0	1000
19117	126	1467	N	4	Mapiri	Tt	*Globigerinoides, Zg. nepenthes, S. notohispida*	195	0	0.00	0	0	0.0	1000
19116	125	1461	N	4	Mapiri	Tt	*Zg. nepenthes, Nq. pachyderma, B.* cf. *elegantissima, S. notohispida*	72	0	0.00	0	0	0.0	1000
19115	124	1456	R	4	Mapiri	Tt	*Zg. nepenthes, Sphaeroidinellopsis, S. notohispida*	194	6	0.03	0	0	0.0	1000
19114	123	1450	R	4	Mapiri	Tt	(200+ *Gc. miotumida*), *Zg. nepenthes, B.* cf. *elegantissima, S. notohispida*	197	3	0.02	0	0	0.0	1000
19113	122	1445	?	4	Mapiri	Tt	*S. notohispida, B.* cf. *elegantissima*	195	5	0.03	0	0	0.0	1000
19112	121	1439	?	4	Mapiri	Tt	*Globigerinoides, Zg. nepenthes, S. notohispida*	195	5	0.03	0	0	0.0	1000
19111	120	1433	R	3	Mapiri	Tt	(200+ Gc. miotumida), *Sphaeroidinellopsis, S. notohispida*	194	6	0.03	0	0	0.0	1000
19110	119	1427	R	4	Mapiri	Tt	*Zg. nepenthes, S. notohispida,* [tuffaceous]	211	4	0.02	0	0	0.0	1000
19109	118	1421	?	3	Mapiri	Tt	(200+ *Gc.miotumida*), *Sphaeroidinellopsis, Globigerinopsis, Zg. nepenthes*	198	2	0.01	0	0	0.0	
19108	117	1415	R	4	Mapiri	Tt	*Zg. nepenthes, Globigerinopsis, S. notohispida*	168	1	0.01	0	0	0.0	1000
19107	116	1409	R	4	Mapiri	Tt	*Zg. nepenthes, Sphaeroidinellopsis*	79	3	0.04	0	0	0.0	
19106	115	1403	R	4	Mapiri	Tt		101	1	0.01	0	0	0.0	
19105	114	1345	R	3	Mapiri	Tt		18	0	0.00	0	0	0.0	
19104	113	1339	?	4	Mapiri	Tt	*Sphaeroidinellopsis, S. notohispida, Zg. nepenthes, Globigerinopsis, B.* cf. *elegantissima*	58	7	0.11	0	0	0.0	1000
19103	112	1334	R	4	Mapiri	Tt	*Globigerinoides, Zg. nepenthes, B.* cf. *elegantissima*	32	0	0.00	0	0	0.0	
19102	111	1329	?	4	Mapiri	Tt	*Zg. nepenthes, B.* cf. *elegantissima,* [tuffaceous]	89	1	0.01	0	0	0.0	
19101	110	1324	R	3	Mapiri	Tt	*Globigerinoides, Zg. nepenthes, B. elegantissima*	92	1	0.01	0	0	0.0	
19100	109	1319	?	4	Mapiri	Tt	*Sphaeroidinellopsis, Zg.* cf. *nepenthes*	62	3	0.05	0	0	0.0	
19099	108	1314	R	3	Mapiri	Tt	*Zg. nepenthes, Sphaeroidinellopsis*	152	2	0.01	0	0	0.0	
19098	105	1298	R	4	Mapiri	Tt		119	2	0.02	0	0	0.0	
19097	104	1293	R	4	Mapiri	Tt	*Globigerinoides, S. notohispida*	52	0	0.00	0	0	0.0	1000
19096	103	1287	R	4	Mapiri	Tt	*Globigerinoides* (common)	42	0	0.00	0	0	0.0	
19095	102	1282	R	4	Mapiri	Tt	*Globigerinoides, Zg. nepenthes, Nq. pachyderma*	70	1	0.01	0	0	0.0	
19094	101	1277	R	4	Mapiri	Tt	*Globigerinoides*	56	4	0.07	0	0	0.0	
19093	100	1272	R	4	Mapiri	Tt		85	2	0.02	0	0	0.0	
19092	99	1261	R	4	Mapiri	Tt	*Globigerinoides* (common), *Zg. nepenthes*	96	4	0.04	0	0	0.0	
??	98	1259	?	4	Mapiri	Tt	*Globigerinoides* (common), *Sphaeroidinellopsis, S. notohispida*	87	0	0.00	0	0	0.0	1000
19091	97	1256	?	5	Mapiri	Tt	*Globigerinoides*	129	0	0.00	0	0	0.0	
19090	96	1250	R	4	Mapiri	Tt	*Mn.* cf. *menardii?, Globigerinoides, Nq. pachyderma, Zg. nepenthes*	26	0	0.00	0	0	0.0	
19089	95	1245	R	5	Mapiri	Tt	*Nq. pachyderma, Globigerinoides, S. notohispida*	21	1	0.05	0	0	0.0	1000
19088	93	1230	R	4	Mapiri	Tt	*Zg. nepenthes, Globigerinoides*	15	0	0.00	0	0	0.0	

Appendix 7.2 – Tukemokihi Stream, biostratigraphic data (Page 4 of 9)

VUW Lab No.	Field No. ICW--	Thickness (m)	Polarity	Number of plugs	Formation	NZ Stage	Important taxa and comment on collection	*Gc. miotumida* Sin (n)	*Gc. miotumida* Dex (n)	*Gc. miotumida* Dex (Pi)	*Hr. panda* Sin (n)	*Hr. panda* Dex (n)	*Hr. panda* Dex (Pi)	Min. water depth (m)
19087	92	1225	R	3	Mapiri	Tt	*Globigerinoides, Sphaeoridinellopsis*	11	0	0.00	0	0	0.0	
19086	91	1220	R	4	Mapiri	Tt	*Globigerinoides, Nq. pachyderma*	37	0	0.00	0	0	0.0	
19085	90	1215	R	3	Mapiri	Tt	*Globigerinoides, Nq. pachyderma*	38	0	0.00	0	0	0.0	
19084	89	1210	?	3	Mapiri	Tt	*Mn. cf. menardii?, Globigerinoides*	15	0	0.00	0	0	0.0	
19083	88	1205	R	3	Mapiri	Tt	*Mn. cf. menardii?, Globigerinoides* (common), *Zg. nepenthes*	18	0	0.00	0	0	0.0	
19082	87	1200	R	6	Mapiri	Tt	*Globigerinoides* (common)	69	2	0.03	0	0	0.0	
19081	86	1195	R	4	Mapiri	Tt	*Globigerinoides* (common), *Nq. pachyderma*	27	0	0.00	0	0	0.0	
19080	85	1190	R	4	Mapiri	Tt	*Globigerinoides* (common)	26	0	0.00	0	0	0.0	
19079	84	1184	R	5	Mapiri	Tt		10	0	0.00	0	0	0.0	
19078	83	1179	R	5	Mapiri	Tt		21	0	0.00	0	0	0.0	
19077	82	1173	R	4	Mapiri	Tt	*Globigerinoides, Sphaeroidinellopsis, Nq. pachyderma*	35	0	0.00	0	0	0.0	
19076	81	1168	R	4	Mapiri	Tt	*Globigerinoides*	19	0	0.00	0	0	0.0	
19075	80	1163	R	3	Mapiri	Tt	*Globigerinoides*	9	0	0.00	0	0	0.0	
19074	79	1157	R	4	Mapiri	Tt		10	0	0.00	0	0	0.0	
19073	78	1152	R	3	Mapiri	Tt	*Globigerinoides, Zg. cf. nepenthes, S. notohispida*	6	0	0.00	0	0	0.0	1000
19072	77	1147	R	3	Mapiri	Tt		8	0	0.00	0	0	0.0	
19071	76	1142	?	4	Mapiri	Tt		10	0	0.00	0	0	0.0	
19070	75	1137	R	3	Mapiri	Tt	*Globigerinoides*	10	0	0.00	0	0	0.0	
19069	74	1132		0	Mapiri	Tt	[No sampe]							
19068	73	1127	R	3	Mapiri	Tt	*Globigerinoides*	9	1	0.10	0	0	0.0	
19067	72	1121	R	4	Mapiri	Tt	*Globigerinoides*	9	0	0.00	0	0	0.0	
19066	71	1116	R	4	Mapiri	Tt	*Globigerinoides*	1	0	0.00	0	0	0.0	
19065	70	1110	N	3	Mapiri	Tt		21	0	0.00	0	0	0.0	
19064	69	1105	N	4	Mapiri	Tt		28	1	0.03	0	0	0.0	
19063	68	1100	R	4	Mapiri	Tt	*Globigerinoides*	22	0	0.00	0	0	0.0	
19062	67	1095	?	3	Mapiri	Tt	*Globigerinoides*	19	0	0.00	0	0	0.0	
19061	66	1090	R	4	Mapiri	Tt	*Globigerinoides, Nq. pachyderma*	30	0	0.00	0	0	0.0	
19060	65	1084	R	4	Mapiri	Tt		11	0	0.00	0	0	0.0	
19059	64	1077	R	4	Mapiri	Tt	*Hr. cf. scitula* (flat dorsal surface)	30	0	0.00	0	0	0.0	
19058	63	1071	R	4	Mapiri	Tt	*Globigerinoides, S. notohispida* [6.8 ±0.2 Ma fission-track date on tephra @ 1074 m, Peter Kamp pers. comm. 1998]	27	0	0.00	0	0	0.0	1000
19057	62	1065	R	4	Mapiri	Tt	*Globigerinoides*	5	0	0.00	0	0	0.0	
19056	61	1060	R	3	Mapiri	Tt		0	0	0.00	0	0	0.0	
19055	60	1054	R	4	Mapiri	Tt	*Nq. pachyderma* (4S:0D), *Hr. cf. scitula* (0S:3D), *Gs. quadrilobatus, B. pohana, O. culter*	8	1	0.11	0	0	0.0	700
19054	59	1050	?	0	Mapiri	Tt	[No sample]							
19053	58	1045	R	3	Mapiri	Tt	*Nq. pachyderma*	17	0	0.00	0	0	0.0	
19052	57	1040	R	4	Mapiri	Tt	*Hr. cf. scitula* (Sin), *Globigerinoides, Nq. pachyderma, Zg. nepenthes*	41	1	0.02	0	0	0.0	
19051	56	1035	R	4	Mapiri	Tt	*Sphaeroidinellopsis, Nq. pachyderma*	61	0	0.00	0	0	0.0	
19050	55	1030	R	4	Mapiri	Tt	*Globigerinoides*	48	1	0.02	0	0	0.0	
19049	54	1024	R	4	Mapiri	Tt	*Sphaeroidinellopsis, Nq. pachyderma, S. notohispida*	18	0	0.00	0	0	0.0	1000
19048	53	1019	R	3	Mapiri	Tt	*Sphaeroidinellopsis, Globigerinoides*	28	0	0.00	0	0	0.0	
19047	52	1013	R	3	Mapiri	Tt	*Sphaeroidinellopsis, Nq. pachyderma*	16	0	0.00	0	0	0.0	
19046	51	1008	R	3	Mapiri	Tt	*Sphaeroidinellopsis, Nq. pachyderma*	3	0	0.00	0	0	0.0	
19045	50	1003	R	3	Mapiri	Tt	*Globigerinoides, Nq. pachyderma*	9	0	0.00	0	0	0.0	
19044	49	998	R	4	Mapiri	Tt		14	0	0.00	0	0	0.0	
19043	48	993	R	4	Mapiri	Tt	*Globigerinoides* (common), *N. pachyderna* (common)	11	0	0.00	0	0	0.0	
19042	47	988	R	4	Mapiri	Tt	*Nq. pachyderma*	20	0	0.00	0	0	0.0	

Appendix 7.2 – Tukemokihi Stream, biostratigraphic data (Page 5 of 9)

VUW Lab No.	Field No. ICW--	Thickness (m)	Polarity	Number of plugs	Formation	NZ Stage	Important taxa and comment on collection	*Gc. miotumida* Sin (n)	*Gc. miotumida* Dex (n)	*Gc. miotumida* Dex (Pi)	*Hr. panda* Sin (n)	*Hr. panda* Dex (n)	*Hr. panda* Dex (Pi)	Min. water depth (m)
19041	46	983	R	4	Mapiri	Tt	*Nq. pachyderma* (common), *Globigerinoides* (common)	17	2	0.11	0	0	0.0	
19040	45	978	R	4	Mapiri	Tt	*Nq. pachyderma* (76S:4D), *Hr. cf. scitula* (0S:3D), *G. cf. dehiscens, B. pohana, S. schlumbergeri*	10	1	0.09	0	0	0.0	600
19039	44	973	R	4	Mapiri	Tt	*Zg. nepenthes* (rare), *Nq. pachyderma*	12	0	0.00	0	0	0.0	
19038	43	968	?	2	Mapiri	Tt	*Globigerinoides, Nq. pachyderma*	11	0	0.00	0	0	0.0	
19037	42	963	R	4	Mapiri	Tt	*Mn. cf. menardii* (Sin), *Gs. quadrilobatus, Zg. nepenthes, Sphaeroidinellopsis, Nq. pachyderma, S. notohispida*	151	5	0.03	0	0	0.0	1000
19036	41	958	R	4	Mapiri	Tt	*Globigerinoides* (common), *S. notohispida*	25	0	0.00	0	0	0.0	1000
19035	40	954	?	4	Mapiri	Tt	*Gc. miotumida* (includes cf. *panda* variants), *Globigerinoides, B. cf. elegantissima*	51	1	0.02	0	0	0.0	
19034	39	949	?	3	Mapiri	Tt	*Globigerinoides*	31	1	0.03	0	0	0.0	
19033	38	944	?	4	Mapiri	Tt		6	0	0.00	0	0	0.0	
19032	37	939	R	4	Mapiri	Tt		43	1	0.02	0	0	0.0	
19031	36	934	R	4	Mapiri	Tt	*Mn. limbata, Nq. dutertrei* (1S:0D), *Nq. pachyderma* (0S:1D), *Zg. nepenthes, B. cf. elegantissima, S. schlumbergeri*	54	0	0.00	0	0	0.0	600
19030	35	929	R	4	Mapiri	Tt	*Nq. pachyderma* (3S:0D), *Hr. scitula* (2S:1D), *Zg. druryi, Zg. nepenthes?, B. pohana, B. elegantissima, E. bradyi, S. schlumbregeri, S. notohispida*	38	0	0.00	1	0	0.0	1000
19029	34	925	R	4	Mapiri	Tt	*Globigerinoides, S. notohispida*	11	0	0.00	0	0	0.0	1000
19028	33	921	R	4	Mapiri	Tt		56	1	0.02	0	0	0.0	
19027	32	916	R	4	Mapiri	Tt		27	1	0.04	0	0	0.0	
19026	31	911	R	4	Mapiri	Tt		23	1	0.04	0	0	0.0	
19025	30	906	N	4	Mapiri	Tt	*Globigerinoides (common)*	35	0	0.00	0	0	0.0	
19024	29	900	N	4	Mapiri	Tt	*Globigerinoides*	30	0	0.00	0	0	0.0	
19023	28	895	N	4	Mapiri	Tt	*Globigerinoides* (common), *Sphaeroinellopsis* (rare), *B. cf. elegantissima*	41	0	0.00	0	0	0.0	
19022	27	889	N	4	Mapiri	Tt	*Zg. nepenthes*	29	2	0.06	0	0	0.0	
19021	26	883	N	3	Mapiri	Tt	*Sphaeroidinellopsis*	31	0	0.00	0	0	0.0	
19020	25	878	N	4	Mapiri	Tt	*Hr. cf. panda, Globigerinoides, Zg. nepenthes*	69	3	0.04	1	0	0.0	
19019	24	873	?	3	Mapiri	Tt		24	1	0.04	0	0	0.0	
19018	23	868	R	4	Mapiri	Tt	*Sphaeroidinellopsis*	9	0	0.00	0	0	0.0	
19017	22	864	N	3	Mapiri	Tt		6	0	0.00	0	0	0.0	
19016	21	859	N	3	Mapiri	Tt		14	0	0.00	0	0	0.0	
19015	20	854	N	3	Mapiri	Tt	*Sphaeroidinellopsis, Zg. nepenthes, Globigerinoides*	22	0	0.00	0	0	0.0	
19014	19	850	N	4	Mapiri	Tt	*Zg. nepenthes*	10	0	0.00	0	0	0.0	
19013	18	845	N	4	Mapiri	Tt	*Hr. scitula, Zg. nepenthes, Sphaeroidinellopsis, S. schlumbergeri, B. pohana*	3	0	0.00	0	0	0.0	600
19012	17	840	N	4	Mapiri	Tt	*Zg. nepenthes, Sphaeroidinellopsis*	28	3	0.10	0	0	0.0	
19011	16	835	N	4	Mapiri	Tt	*Mn. menardii* (1S:0D), *Globigerinoides* (common), *Sphaeroidinellopsis* (common), *Hr. scitula, Zg. nepenthes, S. schlumbergeri, E. bradyi*	111	0	0.00	0	0	0.0	600
19010	15	830	N	4	Mapiri	Tt	*Zg. nepenthes, Nq. pachyderma*	72	1	0.01	0	0	0.0	
19009	14	825	N	4	Mapiri	Tt	*Zg. nepenthes, Sphaeroidinellopsis*	57	0	0.00	0	0	0.0	
19008	13	820	N	5	Mapiri	Tt	*Zg. nepenthes* (common), *Globigerinoides sp., Ga. glutinata, S. schlumbergeri, B. pohana* (cf. *quadrilatera*), *B. pohana, Bolivinopsis* sp.	86	5	0.05	1	0	0.0	600
19007	12	815	N	3	Mapiri	Tt	*Mn. menardii* (7S:0D), *Globigerinoides* sp. (common), *Sphaeroidinellopsis* sp., *Hr. scitula, Zg. nepenthes, Ga. glutinata, S. sigmoilopsis, B. pohana* (cf. *quadrilatera*),	96	0	0.00	1	0	0.0	600
19006	11	810	N	3	Mapiri	Tt	*Hr. cf. scitula* (flat dorsal surface), *Zg. nepenthes, Ga. glutinata, S. schlumbergeri*	33	1	0.03	0	0	0.0	600
19005	10	805	?	4	Mapiri	Tt	HO *Gq. dehiscens, Zg. nepenthes* (common), *Sphaeroidinellopsis* sp., *Ga. glutinata, S. schlumbergeri, H. mioindex*	33	1	0.03	0	0	0.0	1000
19004	9	799	?	4	Mapiri	Tt	*Zg. nepenthes, S. schlumbergeri, B. pohana*	23	1	0.04	0	0	0.0	600

Appendix 7.2 – Tukemokihi Stream, biostratigraphic data (Page 6 of 9)

VUW Lab No.	Field No. ICW--	Thickness (m)	Polarity	Number of plugs	Formation	NZ Stage	Important taxa and comment on collection	*Gc. miotumida* Sin (n)	*Gc. miotumida* Dex (n)	*Gc. miotumida* Dex (Pi)	*Hr. panda* Sin (n)	*Hr. panda* Dex (n)	*Hr. panda* Dex (Pi)	Min. water depth (m)
19003	8	793	N	4	Mapiri	Tt	*Globigerinoides sp.* (common), *Zg. nepenthes, H. mioindex, Bolivinopsis* sp.	20	0	0.00	0	0	0.0	1000
19002	7	788	N	4	Mapiri	Tt	*Bolboforma metzmacheri* (rare), *Zg. nepenthes, S. schlumbergeri, H. mioindex*	9	0	0.00	0	0	0.0	1000
19001	6	783	N	4	Mapiri	Tt	*Zg. nepenthes* (common), *Globigerinoides* sp., *S. schlumbergeri, B. pohana, Bolivinopsis* sp.	49	2	0.04	0	0	0.0	600
19000	5	778	N	??	Mapiri	Tt	*Gq. dehiscens, Zg. nepenthes, S. schlumbergeri*	16	0	0.00	0	1	100.0	600
18999	4	773	N	3	Mapiri	Tt	*Zg. nepenthes, Sphaeroidinellopsis*	34	2	0.06	1	0	0.0	
18998	3	769	N	4	Mapiri	Tt	*Zg. nepenthes* (common), *Gq. dehiscens*	43	0	0.00	0	1	100.0	
18997	2	764	N	4	Mapiri	Tt	*Zg. nepenthes* (common), *Gq. dehiscens*	91	1	0.01	0	4	100.0	
18996	1	759	N	?	Mapiri	Tt	*Zg. nepenthes, Sphaeroidinellopsis* sp., *S. schlumbergeri*	97	2	0.02	0	0	0.0	600
18995	218	723	N	?	Mapiri	Tt	*B. pohana, S. notohispida*	140	3	0.02	0	0	0.0	1000
Top Tukemokihi Coiling Zone (TCZ) = Gm-TS/2 interval														
18994	219	714	?	?	Mapiri	Tt	*Zg. nepenthes, B. pohana, B. cf. compressa, S. schlumbergeri*	8	91	0.92	3	3	50.0	600
18993	220	705	N	?	Mapiri	Tt	*Mn. menardii, Zg. nepenthes, Sphaeroidinellopsis* sp., *B. pohana, S. schlumbergeri*	12	42	0.78	1	3	75.0	600
18992	221	695	?	3	Mapiri	Tt	*Sphaeroidinellopsis*	25	32	0.56	0	0	0.0	
18991	222	686	R	?	Mapiri	Tt	*Zg. nepenthes, B. pohana, S. schlumbergeri*	5	20	0.80	0	1	100.0	600
18990	223	677	?	?	Mapiri	Tt	[No sample]							
18989	224	668	?	?	Mapiri	Tt	*Zg. nepenthes, B. pohana, S. schlumbergeri*	20	118	0.86	1	40	97.6	600
18988	225	658	?	?	Mapiri	Tt	[No sample]							
18987	226	648	N	?	Mapiri	Tt	*Zg. nepenthes, B. cf. compressa, S. schlumbergeri*	11	7	0.39	1	4	80.0	600
18986	227	639	?	?	Mapiri	Tt	[No sample]							
18985	228	630	N	?	Mapiri	Tt	*Zg. nepenthes, B. cf. compressa, S. schlumbergeri*	21	17	0.45	32	2	5.9	600
Base Tukemokihi Coiling Zone (TCZ) = Gm-TS/2 interval														
18984	229	621	?	?	Mapiri	Tt	[No sample]							
18983	230	612	N	?	Mapiri	Tt	*Zg. nepenthes, B. cf. compressa, S. schlumbergeri*	28	3	0.10	1	21	95.5	600
18982	231	602	?	?	Mapiri	Tt	[No sample]							
18981	232	593	?	?	Mapiri	Tt	*Hr. cf. panda, Zg. nepenthes, B. cf. compressa, S. schlumbergeri*	58	2	0.03	9	1	10.0	600
18980	233	584	?	4	Mapiri	Tt	*Gq. dehiscens (common), Zg. nepenthes*	44	0	0.00	0	0	0.0	
18979	234	580	?	0	Mapiri	Tt	[No sample]							
18978	235	575	N	4	Mapiri	Tt		97	0	0.00	0	0	0.0	
Possible fault or unconformity (position uncertain - may be slightly lower or higher?)														
18977	236	571	N	4	Mapiri	Tt	*Gq. dehiscens* (common), *Zg. nepenthes*	43	1	0.02	1	0	0.0	
18976	237	566	N	4	Mapiri	Tt	*Gc. miotumida* ("*conoidea*" variants), *Gq. dehiscens* (common), *S. notohispida*	93	3	0.03	0	0	0.0	1000
18975	238	562	?	4	Mapiri	Tt	*Gq. dehiscens* (common), *Sphaeoridinellopsis, S. notohispida*	114	3	0.03	0	0	0.0	1000
18974	239	557	?	3	Mapiri	Tt	(200+ *Gc. miotumida*)	198	2	0.01	0	0	0.0	
18973	240	552	N	4	Mapiri	Tt		185	5	0.03	0	1	100.0	
18972	241	547	N	4	Mapiri	Tt	*Sphaeroidinellopsis, Nq. pachyderma* s.l.?, *S. notohispida*	40	0	0.00	0	0	0.0	1000
18971	242	542	N	4	Mapiri	Tt	*Nq. pachyderma* s.l.	41	0	0.00	0	0	0.0	1000
18970	243	537	N	4	Mapiri	Tt	*S. notohispida*	100	3	0.03	0	0	0.0	1000
18969	244	532	N	4	Mapiri	Tt	*Globigerinoides, Nq. pachyderma* s.l.?	53	3	0.05	0	0	0.0	
18968	245	527	N	3	Mapiri	Tt	*Nq. pachyderma* s.l. (1S:36D), *Hr. scitula* (1S:7D), *Gq. dehiscens, Zg. nepenthes, Gs. quadrilobatus, B. pohana, E. bradyi, S. schlumbergeri, H. mioindex*	181	6	0.03	0	0	0.0	1000
18967	246	521	?	4	Mapiri	Tt	*Nq. pachyderma* s.l. (3S:46D), *Gq. dehiscens, Gs. quadrilobatus, Sphaeroidinellopsis* sp., *B. pohana, E. bradyi, S. schlumbergeri,* [tuffaceous]	9	0	0.00	0	0	0.0	600
18966	247	515	?	3	Mapiri	Tt	*Zg. nepenthes*	75	3	0.04	0	0	0.0	
18965	248	509	N	4	Mapiri	Tt		106	2	0.02	0	0	0.0	

Appendix 7.2 – Tukemokihi Stream, biostratigraphic data (Page 7 of 9)

VUW Lab No.	Field No. ICW--	Thickness (m)	Polarity	Number of plugs	Formation	NZ Stage	Important taxa and comment on collection	*Gc. miotumida* Sin (n)	*Gc. miotumida* Dex (n)	*Gc. miotumida* Dex (Pi)	*Hr. panda* Sin (n)	*Hr. panda* Dex (n)	*Hr. panda* Dex (Pi)	Min. water depth (m)
18964	249	503	N	4	Mapiri	Tt	*S. notohispida*	103	2	0.02	0	0	0.0	1000
18963	250	497	N	3	Mapiri	Tt	*Nq. pachyderma* (1S:0D), *Hr. scitula* (1S:0D), *Gq. dehiscens*, *Zg. druryi*, *B. pohana*, *E. bradyi*, *S. schlumbergeri*, *G. medwayensis*, *H. mioindex*	19	2	0.10	0	0	0.0	1000
18962	251	492	N	4	Mapiri	Tt		61	1	0.02	0	0	0.0	
18961	252	487	N	4	Mapiri	Tt	*Gq. dehiscens*	51	0	0.00	0	0	0.0	
18960	253	481	N	4	Mapiri	Tt		156	4	0.03	0	0	0.0	
18959	254	476	N	4	Mapiri	Tt		252	7	0.03	0	0	0.0	
8958	255	470	N	3	Mapiri	Tt		43	1	0.02	0	0	0.0	
18957	256	465	N	4	Mapiri	Tt	*Gq. dehiscens*	61	3	0.05	0	0	0.0	
18956	257	460	N	4	Mapiri	Tt	*Gq. dehiscens*, *Zg. nepenthes*	33	2	0.06	0	0	0.0	
18955	258	454	N	3	Mapiri	Tt	*Sphaeroidinellopsis*	71	1	0.01	0	0	0.0	
18954	259	449	N	4	Mapiri	Tt		19	1	0.05	0	0	0.0	
18953	260	443	N	4	Mapiri	Tt	*Hr. cf. panda*, *Gq. dehiscens* (common)	59	1	0.02	5	0	0.0	
18952	261	438	N	3	Mapiri	Tt	*Gq. dehiscens*, *B. elegantissima*	27	1	0.04	0	0	0.0	
18951	262	432	N	4	Mapiri	Tt	*Globigerinoides*, *Zg. nepenthes*, *B. elegantissima*	32	1	0.03	0	0	0.0	
18950	263	427	N	5	Mapiri	Tt	*Gq. dehiscens*	60	1	0.02	0	0	0.0	
18949	264	424	N	4	Mapiri	Tt		18	0	0.00	0	9	100.0	
18948	265	421	N	4	Mapiri	Tt	*B. cf. elegantissima*	17	0	0.00	0	2	100.0	
18947	266	418	N	4	Mapiri	Tt	*Gq. dehiscens* (common)	31	1	0.03	0	0	0.0	
18946	267	415	N	3	Mapiri	Tt	*Gq. dehiscens* (common), *B. elegantissima*	21	1	0.05	0	2	100.0	
18945	268	412	N	3	Mapiri	Tt	*Gq. dehiscens* (common), *B. elegantissima*	19	0	0.00	0	0	0.0	
18944	269	409	R	4	Mapiri	Tt	*Gq. dehiscens* (common), *Globigerinoides*, *B. pohana*, *B. elegantissima*	33	2	0.06	0	1	100.0	
18943	270	406	N	4	Mapiri	Tt	*Gq. dehiscens*	42	0	0.00	0	2	100.0	
18942	271	403	N	4	Mapiri	Tt	*Gq. dehiscens*	52	4	0.07	3	10	76.9	
18941	272	399	?	4	Mapiri	Tt	*Gq. dehiscens*, *Zg. nepenthes*, *B. pohana* (common), *B. elegantissima* (rare), *E. bradyi*, *S. sclumbergeri*	28	4	0.13	0	1	100.0	600
18940	273	396	N	4	Mapiri	Tt	*Gq. dehiscens* (common), *Zg. nepenthes*, *B. pohana*, *B. elegantissima* (rare), *S. schlumbergeri*	27	0	0.00	0	3	100.0	600
18939	274	392	?	4	Mapiri	Tt	*Gq. dehiscens*, *B. elegantissima*	6	0	0.00	0	2	100.0	
18938	275	389	N	3	Mapiri	Tt	*Gq. dehiscens* (common)	100	4	0.04	0	3	100.0	
18937	276	385	N	4	Mapiri	Tt		42	0	0.00	1	1	50.0	
18936	277	381	N	4	Mapiri	Tt		73	1	0.01	0	6	100.0	
18935	278	375	N	4	Mapiri	Tt		6	0	0.00	0	10	100.0	
18934	279	370	N	4	Mapiri	Tt		33	1	0.03	0	0	0.0	
18933	280	364	N	4	Mapiri	Tt		62	2	0.03	0	0	0.0	
18932	281	359	N	4	Mapiri	Tt		83	0	0.00	0	0	0.0	
18931	282	353	N	4	Mapiri	Tt		41	0	0.00	0	2	100.0	
18930	283	348	?	0	Mapiri	Tt	[no sample]							
18929	284	342	?	3	Mapiri	Tt		11	0	0.00	0	0	0.0	
18928	285	336	N	4	Mapiri	Tt		72	1	0.01	0	0	0.0	
18927	286	330	?	0	Mapiri	Tt	[no sample]							
18926	287	323	N	4	Mapiri	Tt		112	4	0.03	0	1	100.0	
18925	288	316	N	4	Mapiri	Tt	*S. notohispida*	153	4	0.03	0	0	0.0	1000
18924	289	310	N	4	Mapiri	Tt		192	4	0.02	1	18	94.7	
18923	290	303	N	3	Mapiri	Tt	*S. notohispida*	61	1	0.02	1	10	90.9	1000
18922	291	297	N	3	Mapiri	Tt		39	0	0.00	1	11	91.7	
18921	292	290	N	4	Mapiri	Tt	*S. notohispida*	84	4	0.05	0	5	100.0	1000
18920	293	284	N	4	Mapiri	Tt	*S. notohispida*	153	2	0.01	0	0	0.0	1000

Appendix 7.2 – Tukemokihi Stream, biostratigraphic data (Page 8 of 9)

VUW Lab No.	Field No. ICW--	Thickness (m)	Polarity	Number of plugs	Formation	NZ Stage	Important taxa and comment on collection	*Gc. miotumida* Sin (n)	*Gc. miotumida* Dex (n)	*Gc. miotumida* Dex (Pi)	*Hr. panda* Sin (n)	*Hr. panda* Dex (n)	*Hr. panda* Dex (Pi)	Min. water depth (m)
18919	294	278	N	3	Mapiri	Tt		58	1	0.02	1	10	90.9	
18918	295	272	N	4	Mapiri	Tt		30	1	0.03	0	4	100.0	
18917	296	266	N	4	Mapiri	Tt		59	2	0.03	1	12	92.3	
18916	297	260	N	4	Mapiri	Tt		102	14	0.12	0	4	100.0	
18915	298	254	?	4	Mapiri	Tt		90	1	0.01	1	10	90.9	
18914	299	249	R	3	Mapiri	Tt		32	0	0.00	3	1	25.0	
18913	300	243	N	4	Mapiri	Tt		74	0	0.00	10	3	23.1	
18912	301	238	N	4	Mapiri	Tt	*Hr. cf. panda, S. notohispida*	57	0	0.00	21	1	4.5	1000
18911	302	232	N	4	Mapiri	Tt	*Hr. cf. panda*	49	0	0.00	4	0	0.0	
18910	303	227	N	3	Mapiri	Tt		30	1	0.03	2	0	0.0	
18909	304	221	N	3	Mapiri	Tt		18	1	0.05	0	0	0.0	
18908	305	216	N	4	Mapiri	Tt	*Gq. dehiscens* (common), *S. notohispida*	10	0	0.00	0	2	100.0	1000
18907	306	210	?	4	Mapiri	Tt	*Globigerinoides, S. notohispida*	33	0	0.00	0	2	100.0	1000
18906	307	205	N	3	Mapiri	Tt		5	0	0.00	0	0	0.0	
18905	308	199	N	3	Mapiri	Tt		30	3	0.09	0	0	0.0	
18904	309	194	N	3	Mapiri	Tt		19	2	0.10	0	1	100.0	
18903	310	189	?	2	Mapiri	Tt		25	0	0.00	0	0	0.0	
18902	311	184	N	2	Mapiri	Tt		26	2	0.07	0	0	0.0	
18901	312	179	N	4	Mapiri	Tt		120	7	0.06	0	0	0.0	
18900	313	174	N	3	Mapiri	Tt		36	4	0.10	0	2	100.0	
18899	314	169	N	4	Mapiri	Tt		51	0	0.00	0	1	100.0	
18898	315	163	N	3	Mapiri	Tt		36	1	0.03	0	0	0.0	
18897	316	158	N	4	Mapiri	Tt		8	0	0.00	0	31	100.0	
18896	317	152	N	4	Mapiri	Tt		34	0	0.00	0	55	100.0	
18895	318	147	N	4	Mapiri	Tt		18	0	0.00	0	23	100.0	
18894	319	138	N	4	Mapiri	Tt		30	5	0.14	0	28	100.0	
Top Mapiri Coiling Zone (MCZ) = Gm-TS/1 interval														
18893	320	129	N	4	Mapiri	Tt		2	16	0.89	0	1	100.0	
18892	321	120	N	3	Mapiri	Tt		4	55	0.93	0	17	100.0	
18891	322	111	?	3	Mapiri	Tt		6	27	0.82	0	14	100.0	
18890	323	102	N	3	Mapiri	Tt		1	19	0.95	0	9	100.0	
18889	324	92	N	4	Mapiri	Tt		11	13	0.54	3	121	97.6	
18888	325	82	N	4	Mapiri	Tt		15	36	0.71	0	2	100.0	
Base Mapiri Coiling Zone (MCZ) = Gm-TS/1 interval														
18887	326	72	N	3	Mapiri	Tt		34	2	0.06	0	1	100.0	
18886	327	62	N	4	Mapiri	Tt		42	2	0.05	0	1	100.0	
18885	328	57	N	3	Mapiri	Tt		56	1	0.02	0	4	100.0	
18884	329	52	N	3	Mapiri	Tt		41	1	0.02	3	69	95.8	
18883	330	48	N	0	Mapiri	Tt	[Y18/f96] *Hr. panda* (0S:8D), *Zg. nepenthes, Zg. druryi, Cs. parvulus?, B. compressa, B. pohana* (rhomboidal), *S. schlumbergeri, G. medwayensis, H. mioindex?*	36	1	0.03	0	3	100.0	1000
18882	331	43	N	4	Mapiri	Tt		25	1	0.04	0	3	100.0	
18881	332	38	?	1	Mapiri	Tt	[Y18/f97] *Nq. mayeri* (0S:1D), *Hr. panda* (2S:11D), *Zg. nepenthes, Zg. druryi, Gs. quadrilobatus, E. bradyi, S. schlumbergeri, G. medwayensis, B. pohana* (rhomboidal)	27	4	0.13	0	14	100.0	800
18880	333	33	N	4	Mapiri	Tt	*B. pohana* (compressed, relatively common)	39	2	0.05	3	100	97.1	
18879	334	27	N	0	Mapiri	Tt	[Y18/f98] *Hr. scitula* (0S:1D), *B. pohana, S. schlumbergeri, G. medwayensis, H. mioindex*	73	4	0.05	1	56	98.2	1000
18878	335	21	N	3	Mapiri	Tt	*B. pohana*	14	0	0.00	0	2	100.0	

Appendix 7.2 – Tukemokihi Stream, biostratigraphic data (Page 9 of 9)

VUW Lab No.	Field No. ICW--	Thickness (m)	Polarity	Number of plugs	Formation	NZ Stage	Important taxa and comment on collection	*Gc. miotumida* Sin (n)	*Gc. miotumida* Dex (n)	*Gc. miotumida* Dex (Pi)	*Hr. panda* Sin (n)	*Hr. panda* Dex (n)	*Hr. panda* Dex (Pi)	Min. water depth (m)
18877	336	15	N	0	Mapiri	Tt	[Y18/f99] *Nq. mayeri* s.l. (0S:1D), *Hr. panda* (0S:7D), *Gq. dehiscens, Zg. nepenthes,* LO *Bolivinita (B. pohana), S. schlumbergeri*	32	1	0.03	0	25	100.0	600
18876	337	9	R	3	Mapiri	Tt	*Nq. mayeri* s.l., *Gr. lenguaensis, Sphaeroidinellopsis* sp., *Gq. dehiscens* (common), *S. schlumbergei, H. mioindex*	195	5	0.03	0	0	0.0	1000
18875	338	7	?	1	Mapiri	Tt	[Y18/f100] *Nq. mayeri* s.l., *Zg. nepenthes* (common), *Zg. druryi,* HO *L. truncatum* (rare), *S. schlumbergeri, H. mioindex*	66	1	0.01	0	0	0.0	1000
18874	339	6	R	4	Mapiri	Tt	*Nq. mayeri s.l., Gr. lenguaensis?, Zg. nepenthes* (abundant), *Zg. druryi, Gq. dehiscens* (common), *Sphaeoridinellopsis* sp., *Globigerinoides* sp., *L. truncatum* (rare), *S. schlumbergeri, H. mioindex*	197	3	0.02	1	0	0.0	1000
18873	340	5	R	1	Mapiri	Tt	[Y18/f101] *Nq. mayeri* s.l., *Gr. lenguaensis, Zg. nepenthes* (abundant), *Gq. dehiscens, Sphaeroidinellopsis* sp., *L.truncatum* (rare), *E. bradyi, S. schlumbergeri, H. mioindex*	195	5	0.03	0	2	100.0	1000
18872	341	4	R	4	Mapiri	Tt	*Zg. nepenthes* (abundant), *Gq. dehiscens, Sphaeroidinellopsis* sp., *Globigerinoides* sp., *S. schlumbergeri, H. mioindex, Bolivina barnwelli* (also rare occurrences in overlying samples)	198	2	0.01	0	0	0.0	1000
18871	342	3	R	3	Mapiri	Tt	Rich planktic fauna (200+ *Gc. miotumida*)	196	4	0.02	0	2	100.0	
18870	343	2	R	3	Mapiri	Tt	Rich planktic fauna (200+ *Gc. miotumida*)	196	4	0.02	0	0	0.0	
MC97/2	25	0			Mapiri		M.cf.panda (slightly biconvex), Z.nepenthes?, G.dehiscens, N.continuosa (common?), N.mayeri? (see ref. slide), Elphidium+Cribirrotalia (displaced biofacies), S.schlumbergeri, H.mioindex	70	2	0.03	4	0	0.0	1000
MC97/2	24	-5			Makaretu		(Planktic rich 200+), *Gq. dehiscens* (common), *Sphaeroidinellopsis?, Zg. nepenthes?, S. schlumbergeri, H. mioindex*	195	5	0.03	0	0	0.0	1000
MC97/2	23	-11			Makaretu		(Planktic rich 200+), *Gc.*cf. *conica* (keeled?), *Gq. dehiscens, Zg. nepenthes, Nq. continuosa, S. schlumbergeri, H. mioindex*	194	6	0.03	0	0	0.0	1000
MC97/2	22.5	-29			Makaretu		*Gq. dehiscens (common), Globigerinoides, Nq. continuosa, Zg. nepenthes, Sphaeroidinellopsis, L. truncatum, S. schlumbergeri, H. mioindex*	198	2	0.01	0	0	0.0	1000
MC97/2	22	-35			Makaretu		*Nq. mayeri, Nq. nympha, Nq. continuosa, Gq. dehiscens, Zg. nepenthes?* (common), (*Cibicides,* common ?displaced biofacies), *S. schlumbergeri, H. mioindex*	44	1	0.02	0	0	0.0	1000
MC97/2	21	-49			Makaretu		*Gq. dehiscens* (common), *Zg. nepenthes, Sphaeroidinellopsis, S. schlumbergeri*	54	0	0.00	0	0	0.0	600
MC97/2	20	-59			Makaretu		*Z.nepenthes?, S.schlumbergeri,* (similar assemblage to MC97/2/22)	52	4	0.07	0	0	0.0	600
MC97/2	19	-81			Makaretu		*Nq. mayeri, Gq. dehiscens, Nq. continuosa, L. truncatum? + Elphidium + Notorotalia* (displaced biofacies), *S. schlumbergeri*	52	2	0.04	1	0	0.0	600
MC97/2	18	-89			Makaretu		(Planktic rich, 200+ *Gc. miotumida*), *Nq. mayeri, H. mioindex, S. schlumbergeri*	200	0	0.00	1	0	0.0	1000
MC97/2	17	-95			Makaretu		*N.mayeri* (common), *N.continuosa* (common), *G.dehiscens* (common), *S.schlumbergeri, H.mioindex*	191	2	0.01	2	0	0.0	1000
MC97/2	16	-106			Makaretu		*Nq. mayeri* (rare), *Zg. nepenthes, Sphaeroidinellopsis, Nq. continuosa, Gq. dehiscens, Globigerinoides, T. gladizea? + Elphidium + Cribrorotalia + Notorotalia* (dispaced biofacies), *S. schlumbergeri*	43	2	0.04	1	0	0.0	1000
MC97/2	15	-121			Makaretu		*Gc. miotumida* (4-chambered), *Gq. dehiscens, Zg. nepenthes, Nq. mayeri, L. truncatum, Z. parri + Notorotalia + Cribrorotalia* (displaced biofacies), *S. schlumbergeri*	150	3	0.02	12	0	0.0	600
MC97/2	14	-130			Makaretu		*Hr.* cf. *panda, Gq. dehiscens* (common), *S. schlumbergeri*	144	6	0.04	9	0	0.0	600
MC97/2	0	-145			Tunanui		*Hr.* cf. *panda, Gq. dehiscens, Nq. mayeri, Sphaeroidinellopsis*	199	1	0.01	28	1	0.03	
MC97/2	1	-154			Tunanui		*Gq. dehiscens* (common), *Nq. mayeri, S. schlumbergeri*	170	30	0.15	2	0	0.0	600
MC97/2	2	-165			Tunanui		*Gc. miotumida* (includes mostly *Gc. conica* variants), *Nq. mayeri?, Fs. peripheroronda?, Hr.* cf. scitula, Gq. dehiscens (common), S. notohispida?	148	4	0.03	1	0	0.0	1000
MC97/2	3	-176			Tunanui		(Planktic rich 200+), *Nq. mayeri* (rare), *panda?/peripheroacuta?* (6S:6D, see ref. slide), *Nq. continuosa, G.dehiscens, Sphaeroidinellopsis*	195	5	0.03	0	1	1.00	
MC97/2	4	-188			Tunanui		*Hr.* cf. *scitula*, *Gq. dehiscens* (common), *Nq. mayeri, Fs. peripheroronda, S. schlumbergeri,* [?Rads, subspherical]	194	4	0.02	51	5	0.09	600

Appendix 7.3 – Biostratigraphic data from Tukemokihi Stream, northern Hawkes Bay (high-resolution sample suite through *Gc*-TS/A interval), including stratigraphic heights of samples, notes on individual collections, *Globoconella miotumida* and *Hirsutella panda* coiling data, and minimum estimates of water depths. (Page 1 of 2)

Sample No.	Measured (m)	Scaled (m)	Formation	Important taxa and notes on collection	*Gc. miotumida* Sin (n)	*Gc. miotumida* Dex (n)	*Gc. miotumida* Dex (Pi)	*Hr. panda* Sin (n)	*Hr. panda* Dex (n)	Min. Water depth (m)
MC97/5/15	94.1	152.0	Mapiri	HO *Nq. mayeri* s.l. (8S:9D), *Mn.* cf. *menardii* (2S:0D), *Hr. scitula* (0S:6D), *Gq. dehiscens, Gr. paralenguaensis* (5-chambers), *B. pohana, B. elegantissima* (rare), *L. truncatum* (rare)	99	1	0.01	0	0	
MC97/5/14	91.8	149.5	Mapiri	*Nq. mayeri* s.l. (6S:0D), *Mn.* cf. *menardii* (1S:0D), *Gr. paralenguaensis, Gs. quadrilobatus* (common), *Zg. woodi, S. notohispida, L. truncatum* (rare)	97	3	0.03	0	0	1000
MC97/5/13	89.5	147.1	Mapiri	*Gr. paralenguaensis*	98	2	0.02	0	0	
MC97/5/12	87.0	144.4	Mapiri	*Hr.* cf. *panda* (0S:4D), *Gr. paralenguaensis, S. notohispida*	92	4	0.04	0	4	1000
MC97/5/11	84.5	141.8	Mapiri	*Hr.* cf. *panda* (0S:1D)	97	9	0.08	0	1	
MC97/5/10	82.3	139.4	Mapiri	*Nq. mayeri* s.l. (11S:5D), *Nq. partimlabiata?, Hr. panda?* (0S:1D), *Gr. paralenguaensis, Gs. quadrilobatus, Gq. dehiscens, Zg. woodi,*	99	1	0.01	0	1	
MC97/5/09	79.0	136.0	Mapiri	*Hr. panda* (0S:7D), *Gr. paralenguaensis, S. notohispida*	76	3	0.04	0	7	
MC97/5/08	75.8	132.5	Mapiri	*Hr.* cf. *panda* (1S:0D), *Gr. paralenguaensis, S. notohispida*	98	2	0.02	1	0	1000
MC97/5/07	72.5	129.0	Mapiri	*Nq. mayeri* s.l. (14S:4D), *Hr. panda* (0S:81D), *Gr. paralenguaensis, Gq. dehiscens, Zg. nepenthes, Zg. woodi*	94	6	0.06	0	81	
MC97/5/06	70.3	126.7	Mapiri	*Hr. panda* (2S:109D), *Gr. paralenguaensis, S. notohispida*	73	0	0.00	2	109	1000
MC97/5/05	68.1	124.4	Mapiri	*Hr. panda* (7S:225D), *Nq. mayeri?* (1S:0D), *Nq. partimlabiata* (0S:1D), *Gs. quadrilobatus, Gq. dehiscens, Zg. woodi, Zg. nepenthes?, Zg. druryi, S. notohispida*	54	2	0.04	7	225	1000
Top Mapiri Coiling Zone (MCZ) = Gm-TS/1 interval										
MC97/2/53	65.7	121.9	Mapiri	*Hr. panda* (1S:12D), *Gr. paralenguaensis?* (1S:0D), *Nq. mayeri* s.l. (0S:2D), *Gs. quadrilobatus?, Ga. glutinata, Zg. nepenthes, B. pohana, S. schlumbergeri, E. bradyi*	16	5	0.24	1	12	600
MC97/2/52	63.6	119.6	Mapiri	*Hr. panda* (0S:15D), *Gr. paralenguaensis?* (2S:1D), *Nq. mayeri s.l.* (2S:0D), *Zg. nepenthes, Zg. woodi gp., Ga. glutinata, Gq. dehiscens, B. pohana, S. notohispida*	7	0	0.00	0	15	1000
MC97/2/51	61.5	117.4	Mapiri	*Hr. panda (1S:0D), Hr. scitula? (0S:4D), Gr. paralenguaensis? (2S:0D), Nq. mayeri s.l. (2S:1D), B. pohana, S. schlumbergeri, H. mioindex*	16	1	0.06	1	0	1000
MC97/2/50	59.4	115.2	Mapiri	*Globorotalia* sp. (2S:0D), *Nq. mayeri s.l.?* (1S:0D), *B. pohana, B.* cf. *quadrilatera, S. notohispida,* [minor downslope material]	21	6	0.22	0	4	1000
MC97/2/49	57.3	112.9	Mapiri	*Globorotalia* sp. (2S:0D), *S. notohispida, B. pohana, B. quadrilatera,* [minor downslope material]	26	9	0.26	0	3	1000
MC97/2/48	55.3	110.8	Mapiri	*Hr. panda* (1S:19D), *Gr. paralenguaensis* (1S:0D), *Nq. mayeri s.l.* (2S:0D), *Gq. dehiscens, Zg. nepenthes, Zg. woodi gp., Ga. glutinata, Globigerina sp., B. pohana, S. schlumbergeri, S. notohispida*	29	3	0.09	1	19	1000
MC97/2/47	53.3	108.7	Mapiri	*Hr. panda* (9S:0D), *Hr.* cf. *scitula?* (2S:0D), *Nq. mayeri s.l.* (2S:0D), *Gd. hexagona* (0S:1D), *Gq. dehiscens, Gs. quadrilobatus, Zg. nepenthes, Zg. woodi* gp., *Ga. glutinata, Globigerina sp., B. pohana, S. schlumbergeri, S. notohispida*	8	3	0.27	0	9	1000
MC97/2/45	49.4	104.5	Mapiri	*Nq. mayeri s.l.* (3S:0D), *B. pohana, S. notohispida*	4	3	0.43	1	3	1000
MC97/2/44	47.4	102.4	Mapiri	*Globorotalia* sp. (1S:0D), *B. pohana, S. notohispida*	4	31	0.89	0	18	1000
MC97/2/43	45.5	100.4	Mapiri	*B. pohana, S. notohispida*	3	47	0.94	0	25	1000
MC97/2/42	43.5	98.3	Mapiri	*B. pohana, S. notohispida*	5	42	0.89	2	3	1000
MC97/2/41	41.6	96.3	Mapiri	*Globorotalia* sp. (1S:0D), *B. pohana, S. notohispida*	3	45	0.94	0	3	1000
MC97/2/40	39.6	94.1	Mapiri	*Globorotalia* sp. (2S:0D), *B. pohana, S. notohispida*	72	24	0.25	0	11	1000
MC97/2/39	37.6	92.0	Mapiri	*Globorotalia* sp. (1S:0D), *B. pohana, S. notohispida*	3	9	0.75	0	27	1000
MC97/2/38	35.7	90.0	Mapiri	*Nq. mayeri* s.l. (1S:0D), *Gr. paralenguaensis?* (2S:0D), *B. pohana, B. quadrilatera* (rare), *S. notohispida*	7	15	0.68	1	37	1000
MC97/2/37	33.7	87.9	Mapiri	*Nq. mayeri* s.l. (0S:1D), *Nq. continuosa* (1S:1D), *Zg. druryi, B. pohana, S. notohispida*	5	81	0.94	0	20	1000
MC97/2/36	33.0	87.1	Mapiri	*Nq. mayeri* s.l. (1S:1D), *Gs. quadrilobatus, B. pohana, S. notohispida*	4	31	0.89	0	9	1000
MC97/2/35	30.9	84.9	Mapiri	*Nq. mayeri* s.l. (3S:0D) + (2S:0D), *Gr. paralenguaensis?* (1S:0D), *B. pohana, S. notohispida*	6	29	0.83	0	28	1000

Appendix 7.3 – Tukemokihi Stream, biostratigraphic data through Mapiri Coiling Zone (Page 2 of 2)

Sample No.	Measured (m)	Scaled (m)	Formation	Important taxa and notes on collection	*Gc. miotumida* Sin (n)	*Gc. miotumida* Dex (n)	*Gc. miotumida* Dex (Pi)	*Hr. panda* Sin (n)	*Hr. panda* Dex (n)	Min. Water depth (m)
MC97/2/34	28.8	82.6	Mapiri	*Mn. menardii?* (1S:0D), *Nq. mayeri* s.l.? (1S:0D), *Gs. quadrilobatus, Zg. nepenthes, B. pohana, S. notohispida*	41	43	0.51	2	44	1000
MC97/2/33	26.7	80.4	Mapiri	*Nq. mayeri s.l.?* (3S:0D) + (0S:1D), *Gs. quadrilobatus, S. notohispida, B. pohana, Elphidium* sp. [rare, downslope material]	29	121	0.81	0	2	1000
MC97/2/32	24.7	78.3	Mapiri	*Nq. mayeri* s.l. (1S:0D) + (1S:0D), *Ss. paenedehiscens, S. schlumbergeri, B.* cf. *quadrilatera* (rare), *Elphidium* sp. [rare, downslope material]	13	17	0.57	8	0	600
MC97/2/31	22.7	76.2	Mapiri	*Nq. continuosa* (3S:0D), *Hr.* cf. *scitula* (inflated), *B. pohana, S. notohispida*	17	28	0.62	2	1	1000
MC97/2/30	19.9	73.2	Mapiri	*Nq. mayeri* s.l. (3S:0D), *Gs. quadrilobatus, Ss. paenedehiscens?, B. pohana, S. schlumbergeri*	19	7	0.27	0	1	600
Base Mapiri Coiling Zone (MCZ) = Gm-TS/1 Interval										
MC97/2/29	17.0	70.1	Mapiri	*B. subfragoris* s.l., *Nq. mayeri?* (1S:0D), *Nq. nympha* (2S:0D), *Nq. continuosa* (5S:2D), *S. notohispida, B. pohana, L. pakaurangiensis* (Po-Sw), *Elphidium* + *Notorotalia* [minor downslope material]	85	3	0.03	2	7	1000
MC97/2/28	14.2	67.1	Mapiri	*Nq. mayeri* s.l. (1S:1D), *B. pohana, S. notohispida*	85	5	0.06	2	0	1000
MC97/2/27	11.4	64.2	Mapiri	*Nq. mayeri* s.l. (1S:1D), *B. pohana, S. notohispida*	52	3	0.05	0	3	1000
MC97/2/26	8.5	61.1	Mapiri	*Nq. mayeri* (1S:0D), *B. pohana, S. notohispida*	34	1	0.03	1	0	1000
MC97/5/01	6.1	58.5	Mapiri	Hr. panda (2S:128D)	96	4	0.04	2	128	
MC97/5/02	4.4	56.7	Mapiri	*B. subfragoris s.l., Hr. panda* (2S:115D)	86	5	0.05	2	115	
MC97/5/03	2.4	54.5	Mapiri	*Hr. panda* (2S:68D)	96	4	0.04	2	68	
MC97/5/04	0.0	52.0	Mapiri	*B. subfragoris* s.l., *Hr. panda* (1S:93D), *Hr. scitula?* (rare), *Gr. paralenguaensis* (common), *Ga. glutinata, Gg. angustiumbilicata, Zg. nepenthes* (common), *Gq. dehiscens* (common)	97	3	0.03	1	93	

Appendix 7.4 – Biostratigraphic data from Tukemokihi Stream, northern Hawkes Bay (high-resolution sample suite through *Gc*-TS/B interval), including stratigraphic heights of samples, notes on individual collections, *Globoconella miotumida* and *Hirsutella panda* coiling data, and minimum estimates of water depths. (Page 1 of 2)

Sample No.	Measured (m)	Scaled (m)		Important taxa and notes on collection	*Gc. miotumida* Sin (n)	*Gc. miotumida* Dex (n)	*Gc. miotumida* Dex (Pi)	*Hr. panda* Sin (n)	*Hr. panda* Dex (n)	Min. water depth (m)
MC97/3/04	140.8	723.0	Mapiri	*Gq. dehiscens (common), B. pohana, S. schlumbergeri,* [minor volcanic glass]	200	4	0.02	4	0	600
MC97/5/29	138.4	720.4	Mapiri	*Hr. cf. scitula (1S:0D), Gq. dehiscens, B. pohana, S. schlumbergeri,* [minor volcanic glass]	95	5	0.05	0	0	600
MC97/3/05	135.9	717.8	Mapiri	*Gq. dehiscens (common), B. pohana, S. notohispida,* [minor volcanic glass]	100	1	0.01	2	0	1000
MC97/5/30	135.2	717.1	Mapiri	*Gr. lenguaensis?, Gq. dehiscens, B. pohana, S. notohispida,* [common volcanic glass]	96	4	0.04	0	0	1000
MC97/5/31	134.5	716.3	Mapiri							
MC97/5/32	133.7	715.6	Mapiri	*Hr.* cf. *scitula*? (1S:0D), *Gq. dehiscens* (common), *B. pohana, S. notohispida,* [highly tuffaceous]	99	1	0.01	0	0	1000
MC97/5/33	133.0	714.8	Mapiri	*Gq. dehiscens, B. pohana, S. notohispida* [common volcanic glass]	100	3	0.03	0	0	1000
MC97/5/34	132.3	714.0	Mapiri	*Hr.* cf. *scitula* (small)?, *Gq. dehiscens* (common), *B. pohana, S. notohispida,* [minor volcanic glass]	98	2	0.02	0	0	1000
MC97/5/35	131.6	713.3	Mapiri	*Gq. dehiscens, S. notohispida,* [minor volcanic glass]	97	3	0.03	0	0	1000
Top Tukemokihi Coiling Zone (TCZ) = Gm-TS/2 interval										
MC97/5/36	130.8	712.5	Mapiri	*Gq. dehiscens, B. pohana, [volcanic glass]*	40	100	0.71	0	0	
MC97/3/06	130.1	711.8	Mapiri	*Gq. dehiscens* (common), *S. schlumbergeri, B. pohana,* [common volcanic glass + biotite]	21	79	0.79	2	0	600
MC97/5/37	127.2	708.7	Mapiri	*Gq. dehiscens, B. pohana, S. notohispida,* [common volcanic glass]	39	100	0.72	0	0	1000
MC97/3/07	124.3	705.7	Mapiri	*Gq. dehiscens, S. schlumbergeri, B. pohana*	24	84	0.78	7	1	600
MC97/5/38	121.2	702.4	Mapiri	*Hr. cf. scitula (0S:1D), B. pohana, S. schlumbergeri,* [minor volcanic glass]	24	100	0.81	0	0	600
MC97/3/08	118.1	699.1	Mapiri	*Nq. mayeri s.l.* (2S:0D), *Nq. pachyderma* (0S:2D), *S. schlumbergeri, B. pohana*	21	78	0.79	1	1	600
MC97/5/39	114.7	695.5	Mapiri	*Hr.* cf. *scitula* (spiroconical), *Gq. dehiscens* (rare), *B. pohana, S. schlumbergeri*	16	100	0.86	0	0	600
MC97/3/09	111.2	691.9	Mapiri	*Nq. pachyderma* (2S:0D), *S. schlumbergeri, B. pohana*	1	10	0.91	1	0	600
MC97/5/40	107.8	688.3	Mapiri	*Hr.* cf. *scitula* (1S:0D), *B. pohana*	30	70	0.70	1	1	
MC97/3/10	104.3	684.6	Mapiri	*Nq. pachyderma* (1S:0D), *S. schlumbergeri, B. pohana*	36	69	0.66	0	2	600
MC97/5/41	101.1	681.2	Mapiri	*B. pohana*	41	100	0.71	0	0	
MC97/3/11	97.8	677.8	Mapiri	*S. schlumbergeri, B. pohana*	3	39	0.93	0	0	
MC97/5/42	94.1	673.9	Mapiri	*Gr. lenguaensis, B. pohana*	54	50	0.48	0	0	
MC97/3/12	90.4	670.0	Mapiri	*Bolboforma metzmacheri, S. schlumbergeri, B. pohana*	79	57	0.42	0	0	
MC97/5/43	87.0	666.4	Mapiri		12	100	0.89	0	0	
MC97/3/13	83.5	662.8	Mapiri	*S. schlumbergeri, B. pohana*	7	43	0.86	0	31	
MC97/5/44	80.0	659.1	Mapiri	*B. pohana*	36	100	0.74	0	0	
MC97/3/14	76.5	655.4	Mapiri	*Gq. dehiscens, H. mioindex, B. pohana*	69	80	0.54	3	30	1000
MC97/5/45	73.0	651.7	Mapiri	*Gr. lenguaensis, B. pohana, S.sigmoilopsis*	63	31	0.33	9	7	600
MC97/3/15	69.5	648.1	Mapiri	*Nq. pachyderma (0S:1D), S. schlumbergeri, B. pohana, B. elegantissima*	5	8	0.62	1	3	600
MC97/5/46	66.0	644.4	Mapiri	*B. pohana*	46	100	0.68	?	?	
MC97/3/16	62.5	640.7	Mapiri	*Nq. mayeri s.l.* (1S:1D), *S. schlumbergeri, B. pohana*	1	22	0.96	5	2	600
MC97/5/47	59.4	637.4	Mapiri	*Gr. lenguaensis, B. pohana*	67	97	0.59	?	?	
MC97/3/17	56.2	634.1	Mapiri	*Gq. dehiscens, H. mioindex, B. pohana*	59	94	0.61	14	5	1000
MC97/5/48	52.6	630.3	Mapiri	*Gq. dehiscens* (common), *S. notohispida*	197	3	0.02	0	0	1000
MC97/3/18	49.0	626.5	Mapiri	*Hr.* cf. *scitula, Gq. dehiscens, S. schlumbergeri, B. pohana*	12	27	0.69	23	1	600
MC97/5/49	45.5	622.8	Mapiri	*Gq. dehiscens* (common), *B. pohana*	102	30	0.23	?	?	

Appendix 7.4 – Tukemokihi Stream, biostratigraphic data through Tukemokihi Coiling Zone (Page 2 of 2)

Sample No.	Measured (m)	Scaled (m)		Important taxa and notes on collection	*Gc. miotumida* Sin (n)	*Gc. miotumida* Dex (n)	*Gc. miotumida* Dex (Pi)	*Hr. panda* Sin (n)	*Hr. panda* Dex (n)	Min. water depth (m)
MC97/3/19	42.0	619.1	Mapiri	*Gq. dehiscens* (common), *H. mioindex*, *B. pohana*	71	14	0.16	29	3	1000
MC97/5/50	38.5	615.5	Mapiri	*Gq. dehiscens*, *B. pohana*	48	100	0.68	0	0	
MC97/3/20	35.0	611.8	Mapiri	*Gq. dehiscens*, *H. mioindex*, *B. pohana*	62	13	0.17	1	0	1000
MC97/3/20.5	30.8	607.4	Mapiri	*Gq. dehiscens* (common), *Nq. dutertrei*, *H. mioindex*, *B. pohana*	26	13	0.33	2	1	1000
Top Tukemokihi Coiling Zone (TCZ) = Gm-TS/2 interval										
MC97/3/21	28.0	604.4	Mapiri	Gq. dehiscens, S. schlumbergeri, B. pohana	100	0	0.00	0	0	
MC97/3/22	21.0	597.1	Mapiri	*Nq. pachyderma* (1S:0D), *Nq. mayeri* s.l. (1S:0D), *H. mioindex*, *B. pohana*, [incomplete disaggregation]	24	2	0.08	1	0	1000
MC97/3/23	14.0	589.7	Mapiri	*Nq. pachyderma*? (5S:1D), *H. mioindex*, *B. pohana*	43	0	0.00	7	0	1000
MC97/3/24	7.0	582.4	Mapiri	*Nq. pachyderma*? (1S:0D), *Nq. dutertrei* (1S:0D), *S. schlumbergeri*, *B. pohana*	71	0	0.00	3	0	600
MC97/3/25	0.0	575.0	Mapiri	*Nq. pachyderma* (1S:1D), *S. notohispida*, *B. pohana*	56	1	0.02	2	0	1000

Appendix 7.5 – Biostratigraphic data from North Taranaki coastal section, including stratigraphic heights of samples, geographic markers, notes on individual collections, *Globoconella miotumida* coiling data, minimum estimates of water depths, and planktic percentages. A summary is given in given Figure 7.10. (Page 1 of 7)

FR No.	Lab No.	Collection	Thickness (m)	Formation	Important taxa and notes on collection	G. miotumida Sin (n)	G. miotumida Dex (n)	G. miotumida Dex (pi)	Quality of fauna	Min. water depth (m)	Planktic (pi)
Q19/f6548		GWG	1925	Urenui							
Q19/f2	F22019	GHS	1885	Urenui							
Q19/f6547		GWG	1885	Urenui							
Q19/f3	F22020	GHS	1850	Urenui	*B. pliobliqua?*				poor	<200	0.40
Q19/f6546		GWG	1840	Urenui							
Q19/f68	F25477	GHS	1840	Urenui	*B.* aff. *quadrilatera*	4	0	0.00	poor	<200	0.40
Q19/f4	F22021	GHS	1840	Urenui	*B. pohana* (rhomboidal)				poor	<200	0.30
Q19/f6545		GWG	1835	Urenui	*Globigerinoides*	0	0	0.00	poor	<200	0.05
Q19/f6544		GWG	1830	Urenui							
Q19/f5	F22022	GHS	1830	Urenui	*Gs. quadrilobatus, B. pohana* (rhomboidal), *P. bulloides*	6	0	0.00		200	0.15
Waiau Stream			1825								
Q19/f6543		GWG	1805	Urenui	*Gs. quadrilobatus, B. pohana* (rhomboidal), *B.* aff. *quadrilatera*	1	0	0.00		c.200	0.25
Q19/f6542		GWG	1805	Urenui	*B. pohana* (rhomboidal)	4	0	0.00		c.200	0.05
Q19/f6541		GWG	1790	Urenui	*Hr. scitula?* (1S:0D), *Gs. quadrilobatus, B.* aff. *quadrilatera, C. molestus*	5	1	0.17		300	0.10
Q19/f6	F22023	GHS	1780	Urenui	*Gs. quadrilobatus, C. molestus*					300	0.10
Q19/f6540		GWG	1780	Urenui							
Q19/f6539		GWG	1730	Urenui	*B. pohana* (rhomboidal), *B.* aff. *quadrilatera, C. molestus*	12	0	0.00		300	0.10
Q19/f7	F22024	GHS	1730	Urenui	*Gs. quadrilobatus, B. pohana* (rhomboidal), *C. molestus*	3	0	0.00		300	0.10
Q19/f6538		GWG	1720	Urenui	*B. pohana, B. pohana* (rhomboidal)	1	0	0.00	poor	c.200	0.05
Q19/f8	F22025	GHS	1710	Urenui	*B. pohana* (rhomboidal), *C. molestus*	6	0	0.00	poor	300	0.25
Q19/f6536		GWG	1665	Urenui					poor	c.200	0.05
Q19/f9	F22026	GHS	1665	Urenui	*B. pohana* (rhomboidal), *B. pohana* (rhomboidal). *P. bulloides*	7	1	0.13		200	0.10
Q19/f6534		GWG	1635	Urenui	*B. pohana, Hr. scitula?* (2S:0D), *Nq. pachyderma* (1S:0D), *B. pohana* (rhomboidal), *B.* cf. *elegantissima*	26	1	0.04		<200	0.10
Q19/f35	F25284	GHS	1635	Urenui	*Hr. scitula?* (2S:0D), *B. pohana*	7	1	0.13		c.200	0.30
Q19/f55	F26669	GHS	1630	Urenui	*B. pohana* (rhomboidal)	6	0	0.00	poor	c.200	0.20
Onaero River			1615								
Q19/f6533		GWG	1575	Urenui	*Hr. scitula?* (10S:1D), *B. pohana*	14	1	0.07		200	0.30
Q19/f6532		GWG	1575	Urenui	*Hr. scitula?* (3S:0D), *C. molestus*	7	0	0.00		300	0.15
Q19/f10	F22027	GHS	1575	Urenui	*Bolivina barnwelli* (dominant)	2	0	0.00	poor	c.200	0.10
Q19/f6530		GWG	1550	Urenui	*Hr. scitula?* (1S:2D), *Nq. pachyderma* (1S:0D)	9	0	0.00		200	0.30
Q19/f11	F22028	GHS	1510	Urenui							
Urenui River			1485								
Q19/f12	F22029	GHS	1480	Urenui	*Bolivina barnwelli* (dominant)				poor	c.200	0.05
Q19/f13	F22030	GHS	1475	Urenui							
Q19/f6529		GWG	1475	Urenui		0	0	0.00	poor	<200?	0.30
Q19/f14	F22031	GHS	1455	Urenui							
Q19/f6528		GWG	1455	Urenui							
Q19/f15	F22032	GHS	1455	Urenui							
Q19/f6527		GWG	1455	Urenui					porr		
Q19/f16	F22033	GHS	1455	Urenui							
Q19/f17	F22034	GHS	1430	Urenui	*Gs. quadrilobatus, Sphaeroidinellopsis, B. pohana, K. cylindrica, O. culter*	13	0	0.00		700	0.05
Q19/f6526		GWG	1430	Urenui				###			
Q19/f6525		GWG	1430	Urenui	*Hr. scitula?* (2S:0D), *Globigerinoides, B. pohana* (compressed), *K. cylindrica, G. medwayensis*	12	0	0.00		700	0.30
Q19/f6524		GWG	1430	Urenui	*B. pohana, K. cylindrica*	19	0	0.00		400	0.30
Q19/f18	F22035	GHS	1420	Urenui							

Appendix 7.5 – North Taranaki coast, biostratigraphic data (Page 2 of 7)

FR No.	Lab No.	Collection	Thickness (m)	Formation	Important taxa and notes on collection	G. miotumida Sin (n)	G. miotumida Dex (n)	G. miotumida Dex (pi)	Quality of fauna	Min. water depth (m)	Planktic (pi)
Q19/f19	F22036	GHS	1395	Urenui	*B. pohana* (rhomboidal), *C. molestus*					300	0.10
Q19/f20	F22037	GHS	1395	Urenui							
Q19/6523		GWG	1395	Urenui		2	0	0.00			
Mimi River			1385								
Q19/f21	F22038	GHS	1365	Urenui	*Nq. pachyderma* (3S:0D), *Zg. nepenthes, B. pohana, K. cylindrica*	15	1	0.06		400	0.10
Q19/f6522		GWG	1365	Urenui	*B. pohana* (rhomboidal), *B. aff. quadrilatera, K. cylindrica*	1	0	0.00		400	0.20
Q19/f38	F25287	GHS	1335	Urenui	*Hr. scitula* (2S:6D), *Hr. scitula?* (0S:1D), *Gs. quadrilobatus, Zg. nepenthes, B. pohana, K. cylindrica, S. schlumbergeri*	36	3	0.08		600	0.10
Q19/f6520		GWG	1335	Urenui	*Hr. scitula* (0S:8D), *Nq. pachyderma (3S:1D), Zg. nepenthes, Sphaeroidinellopsis, B. pohana, K. cylindrica, G. medwayensis, O. bengalensis*	21	0	0.00		700	0.35
Q18/f43	F25288	GHS	1335	Urenui	*Zg. nepenthes, Sphaeroidinellopsis, Globigerinopsis, B. pohana* (rhomboidal), *S. schlumbergeri, V. pennatula*	11	0	0.00		800	0.30
Q18/f44	F25289	GHS	1335	Urenui	*Hr. scitula* (0S:6D), *Zg. nepenthes, S. schlumbergeri, V. pennatula*	22	0	0.00		800	0.30
Q18/f8519		GWG	1335	Urenui	*Hr. scitula?* (spiroconical, 0S:1D), *B. pohana* (rhomboidal), *K. cylindrica*	2	0	0.00		400	0.10
Q18/f45	F25290	GHS	1332	Urenui	*Hr. scitula?* (1S:6D), *Zg. nepenthes, B. pohana, S. schlumbergeri, G. medwayensis, O. bengalensis, P. alternans*	14	0	0.00		700	0.20
Q18/f53	F25485	GHS	1327	Urenui							
Q18/f54	F25486	GHS	1315	Urenui	*Mn. limbata* (1S:1D), *Zg. nepenthes, B. pohana* (rhomboidal), *G. medwayensis*	8	0	0.00		700	0.15
Q18/f1	F22039	GHS	1310	Urenui	HO *Gq. dehiscens, Mn. limbata* (3S:0D), *Hr. scitula* (1S:0D), *Gs. quadrilobatus* (common), *Zg. nepenthes, Sphaeroidinellopsis, B. pohana, S. schlumbergeri*	29	0	0.00		600	0.30
Q18/f2	F22040	GHS	1310	Urenui							
Q18/f8517		GWG	1295	Urenui	*Hr. scitula* (0S:1D), *Gs. quadrilobatus, Sphaeroidinellopsis, B. pohana, B. aff. quadrilatera, K. cylindrica, O. culter*	20	0	0.00		700	0.35
Waiti Stream			1295								
Q18/f8516		GWG	1295	Urenui	*Hr. scitula?* (10S:2D), *Nq. pachyderma* (8S:2D), *B. pohana* (compressed), *S. schlumbergeri, G. medwayensis, O. bengalensis*	41	1	0.02		700	0.35
Q18/f3	F22041	GHS	1290	Urenui	*Gs. trilobus, Sphaeroidinellopsis, B. pohana, S. schlumbergeri, G. medwayensis, O. bengalensis*	11	0	0.00		700	0.35
Q18/f46	F25291	GHS	1270	Urenui	*B. pohana* (compressed), *S. schlumbergeri, O. bengalensis*	15	0	0.00		700	0.10
Q18/f8515		GWG	1190	Urenui							
Q18/f8514		GWG	1190	Urenui							
Q18/f4	F22042	GHS	1190	Urenui	*Gq. dehiscens, Zg. nepenthes, V. pennatula*	18	0	0.00		800	0.15
Q18/f8513		GWG	1130	Urenui	*Gq. dehiscens, Hr. scitula?* (5S:9D), *Gs. quadrilobatus, B. pohana, C. molestus, O. bengalensis*	15	1	0.06		700	0.40
Q18/f5	F22043	GHS	1130	Urenui	*Gq. dehiscens, C. molestus*	2	0	0.00	poor	300	0.15
Q18/f6	F22044	GHS	1125	Urenui	*Gq. dehiscens, Hr. scitula* (1S:0D), *Gs. quadrilobatus, B. pohana, P. alternans*	7	0	0.00		700	0.10
Q18/f7	F22045	GHS	1120	Urenui	*Gq. dehiscens, Gs. quadrilobatus, B. pohana, V. pennatula*	16	1	0.06		800	0.25
Q18/f8512		GWG	1115	Urenui	*Gq. dehiscens, Hr. scitula?* (0S:21D), *Nq. pachyderma* (6S:4D), *Gs. quadrilobatus, B. compressa, B. pohana* (rhomboidal), *V. pennatula*	31	0	0.00		800	0.50
Pariokariwa Point			1075								
Q18/f8511		GWG	1060	Urenui	*Gq. dehiscens, Hr. scitula?* (10S:0D) + *Hr. scitula* (spiroconical, 0S:24D), *Hr. cf. ichinoseikiensis* (0S:3D), *Nq. pachyderma* (1S:0D), *Gs. quadrilobatus, B. pohana, V. pennatula*	110	2	0.02		800	0.65
Q18/f8510		GWG	1055	Urenui							
Q18/f8	F22046	GHS	1050	Urenui	*B. pohana, O. bengalensis*	42	0	0.00		700	0.20
Q18/f9	F22047	GHS	995	Urenui	*Gq. dehiscens, Zg. nepenthes, V. pennatula, O. culter, Z. parri*	53	4	0.07		800	0.10
Q18/f10	F22048	GHS	985	Urenui	(Sparse fauna onslide), *V. pennatula*	19	2	0.10	poor	800	0.25
Q18/f11	F22049	GHS	945	Mt Messenger	*Gq. dehiscens, Mn. limbata?* (1S:0D), *Zg. nepenthes, Sphaeroidinellopsis, B. pohana, O. bengalensis,* [plant debris]	69	1	0.01		700	0.45
(Pukearuhe Conglomerate)			940								

Appendix 7.5 – North Taranaki coast, biostratigraphic data (Page 3 of 7)

FR No.	Lab No.	Collection	Thickness (m)	Formation	Important taxa and notes on collection	G. miotumida Sin (n)	G. miotumida Dex (n)	G. miotumida Dex (pi)	Quality of fauna	Min. water depth (m)	Planktic (pi)
Q18/f8510		GWG	1055	Urenui							
Q18/f8	F22046	GHS	1050	Urenui	*B. pohana, O. bengalensis*	42	0	0.00		700	0.20
Q18/f9	F22047	GHS	995	Urenui	*Gq. dehiscens, Zg. nepenthes, V. pennatula, O. culter, Z. parri*	53	4	0.07		800	0.10
Q18/f10	F22048	GHS	985	Urenui	(Sparse fauna onslide), *V. pennatula*	19	2	0.10	poor	800	0.25
Q18/f11	F22049	GHS	945	Mt Messenger	*Gq. dehiscens, Mn. limbata?* (1S:0D), *Zg. nepenthes, Sphaeroidinellopsis, B. pohana, O. bengalensis,* [plant debris]	69	1	0.01		700	0.45
(Pukearuhe Conglomerate)			940								
Q18/f150	F30408	MPC	939.8	Mt Messenger	*C. molestus*	4	0	0.00	poor	300	0.15
Q18/f151	F30409	MPC	939.0	Mt Messenger	*Gq. dehiscens, Zg. nepenthes, B. pohana, S. schlumbergeri, O. bengalensis*	40	0	0.00		700	0.29
Q18/f152	F30410	MPC	938.0	Mt Messenger	*Gq. dehiscens, Zg. nepenthes, B. pohana, S. schlumbergeri, O. bengalensis*	21	0	0.00		700	0.25
Q18/f153	F30411	MPC	937.3	Mt Messenger	*Hr. scitula* (0S:2D), *Gq. dehiscens, Zg. nepenthes, B. pohana, B. pohana* (rhomboidal), *S. schlumbergeri, O. bengalensis, V. pennatula*	83	1	0.01		800	0.32
Q18/f154	F30412	MPC	936.3	Mt Messenger	*Hr. scitula* (0S:1D), *Gq. dehiscens, Zg. nepenthes, B. pohana, B. pohana* (rhomboidal), *S. schlumbergeri, O. bengalensis, Z. parri*	59	1	0.02		700	0.36
Q18/f155	F30413	MPC	935.6	Mt Messenger	*Hr. scitula* (spiroconical, 0S:5D), *Gq. dehiscens, Zg. nepenthes, B. pohana, S. schlumbergeri, P. altemans, O. bengalensis*	58	0	0.00		700	0.38
Q18/f156	F30414	MPC	934.7	Mt Messenger	*Gq. dehiscens, Zg. nepenthes?, B. pohana, C. molestus, K. cylindrica?, O. bengalensis*	32	2	0.06		700	0.30
Q18/f157	F30415	MPC	933.8	Mt Messenger	*Hr. scitula* (spiroconical, 1S:2D), *Gq. dehiscens, B. pohana, S. schlumbergeri, O. bengalensis*	12	1	0.08		700	0.13
Q18/f158	F30416	MPC	933.1	Mt Messenger	*Hr. scitula* (spiroconical, 0S:4D), *Gq. dehiscens, Zg. nepenthes, B. pohana* (rhomboidal), *V. pennatula*	38	1	0.03		800	0.21
Q18/f159	F30417	MPC	932.2	Mt Messenger	*Gq. dehiscens, S. schlumbergeri, V. pennatula*	20	0	0.00		800	0.29
Q18/f160	F30418	MPC	931.3	Mt Messenger	*Hr. scitula* (spiroconical, 0S:3D), *Gq. dehiscens, Zg. nepenthes, B. pohana, S. schlumbergeri, O. bengalensis*	26	0	0.00		700	0.29
Q18/f161	F30419	MPC	930.0	Mt Messenger	*Sphaeroidinellopsis, S. schlumbergeri, G. medwayensis, O. bengalensis*	25	1	0.04		700	0.19
Q19/f8509		GWG	925	Mt Messenger	*Gq. dehiscens, Hr. scitula* (1S:0D), *Hr. scitula?* (3S:0D), *Gs. quadrilobatus, Gs. trilobus, B. pohana, V. pennatula, Z. parri*	33	2	0.06		800	0.65
Q18/f8508		GWG	915	Mt Messenger	*Hr. scitula?* (9S:0D), *Hr. scitula* (0S:1D), *Nq. pachyderma* (1S:0D), *Globigerinoides, G. medwayensis, O. bengalensis*	4	0	0.00	poor	700	0.65
Waipingau Stream (Whitecliffs			865								
Q18/f12		GHS	795	Mt Messenger							
Q18/f8507		GWG	785	Mt Messenger	*Gq. dehiscens, Hr. scitula?* (S:D), *Gs. quadrilobatus, B. pohana, E. bradyi*	98	5	0.05		600	0.65
Q18/f13		GHS	765	Mt Messenger							
Q18/f8506		GWG	735	Mt Messenger							
Top Gm-TT interval = Tukemokihi Coiling Zone (TCZ)											
Q18/f142	F25283	GHS	735	Mt Messenger	*Gq. dehiscens, Hr. scitula* (spiroconical, 0S:2D), *Mn. limbata* (11S:0D). *Sphaeroidinellopsis, Zg. nepenthes, B. pohana, V. pennatula*	1	113	0.99		800	0.70
Q18/f14		GHS	735	Mt Messenger							
Q18/f9590		GWG	700	Mt Messenger	*Cs. parvulus?, Nq. pachyderma* (1S:0D), *Hr. scitula* (21S:1D), *Hr. scitula* (0S:8D), *O. bilobata, B. pohana, V. pennatula,*	31	74	0.70		800	0.80
Waikorora Stream			680								
Q18/f141	F25282	GHS	675	Mt Messenger	*Zg. nepenthes, B. pohana, V. pennatula, S. notohispida*	106	25	0.19		1000	0.80
Q18/f140	F25281	GHS	660	Mt Messenger							
Q18/f9589		GWG	660	Mt Messenger	*Hr. scitula?* (1S:0D)	10	1	0.09	poor	200	0.85
Q18/f139	F25280	GHS	640	Mt Messenger	*Zg. nepenthes*	10	14	0.58	bias	200	0.75
Q18/f9588		GWG	635	Mt Messenger					poor		
Q18/f138	F25279	GHS	620	Mt Messenger	*Hr. scitula* (0S:3D), *Gq. dehiscens, Zg. nepenthes, E. bradyi, O. bengalensis*	76	87	0.53		700	0.75
Waikiekie Stream			600								
Q18/f15	F22053	GHS	600	Mt Messenger	*Zg. nepenthes, B. pohana (rhomboidal), V. pennatula*	52	83	0.61		800	0.55

Appendix 7.5 – North Taranaki coast, biostratigraphic data (Page 4 of 7)

FR No.	Lab No.	Collection	Thickness (m)	Formation	Important taxa and notes on collection	G. miotumida Sin (n)	G. miotumida Dex (n)	G. miotumida Dex (pi)	Quality of fauna	Min. water depth (m)	Planktic (pi)
Q18/f9587		GWG	600	Mt Messenger	*Gq. dehiscens, Zg. nepenthes, O. bengalensis, Z. parri*	24	20	0.45		700	0.60
Q18/f9585		GWG	565	Mt Messenger	*Hr. scitula* (3S:5D), *Gq. dehiscens, Zg. nepenthes, Gs. quadrilobatus, O. bilobata, S. notohispida*	34	16	0.32		1000	0.55
Q18/f9584		GWG	535	Mt Messenger	(very sparse fauna onslide), *Hr. scitula* (1S:0D), *Zg. nepenthes*	5	4	0.44		?	>0.90
Q18/f16	F22054	GHS	535	Mt Messenger	*Gq. dehiscens, Gs. quadrilobatus, Zg. nepenthes, B. pohana* (rhomboidal), *C. molestus*	3	1	0.25		300	0.10
Q18/f9583		GWG	515	Mt Messenger	*Bolboforma metzmacheri* s.s., *Gs. trilobus, O. culter*	0	0		poor	700	0.40
Q18/f35	F25276	GHS	510	Mt Messenger	*B. pohana, S. notohispida, H. mioindex*	61	6	0.09		1000	0.45
Q18/f9582		GWG	510	Mt Messenger							
Ohanga Stream			500								
Q18/f183	F30717	MPC	497	Mt Messenger	*Hr. scitula* (0S:1D), *Zg. nepenthes, S. notohispida*	39	13	0.25		1000	0.82
Q18/f184	F30718	MPC	495	Mt Messenger	*Zg. nepenthes, S.* aff. *notohispida* (smooth walled)	15	14	0.48		1000	0.64
Q18/f182	F30716	MPC	493	Mt Messenger	(poor benthic assemblage) *B. pohana, O. bengalensis*	213	10	0.04		700	0.84
Q18/f177	F30711	MPC	491.8	Mt Messenger	*Gq. dehiscens, Zg. nepenthes, P. alternans, O. bengalensis?, C. cenop?, S.* aff. *notohispida* (smooth)	142	1	0.01		1000	0.91
Q18/f176	F30710	MPC	489.5	Mt Messenger	*Zg. nepenthes?, B. pohana, O. bengalensis*	349	17	0.05		700	0.86
Q18/f175	F30709	MPC	487.9	Mt Messenger	*Nq. pachyderma* (1S:0D), *S. notohispida*	194	13	0.06		1000	0.86
Q18/f174	F30708	MPC	486.0	Mt Messenger	*Bolboforma metzmacheri* s.s., *Hr. scitula* (0S:3D), *Zg. nepenthes?, S. schlumbergeri, P. wuellerstorfi, Z. parri?*	118	20	0.14		1200	0.76
Q18/f173	F30707	MPC	483.6	Mt Messenger	*Hr. scitula* (0S:1D), *K. cylindrica*	66	36	0.35		400	0.83
Q18/f172	F30706	MPC	481.4	Mt Messenger	*Bolboforma metzmacheri* s.s., *Zg. nepenthes, B. pohana, S. notohispida*	28	32	0.53		1000	0.75
Q18/f171	F30705	MPC	480.4	Mt Messenger	*Bolboforma metzmacheri* s.s., *Zg. nepenthes, B. pohana, S. notohispida*	42	27	0.39		1000	0.68
Q18/f170	F30704	MPC	479.5	Mt Messenger	*Zg. nepenthes, B. pohana, S. schlumbergeri, O. bengalensis?, N. flemingi*	34	43	0.56		700	0.77
Q18/f169	F30703	MPC	478.1	Mt Messenger	*Zg. nepenthes, B. pohana, S. notohispida, N. flemingi*	37	26	0.41		1000	0.68
Q18/f168	F30702	MPC	475.6	Mt Messenger	*Bolboforma metzmacheri s.s., Hr. scitula?* (1S:0D), *Zg. nepenthes, B. pohana, S. schlumbergeri, S. notohispida*	29	39	0.57		1000	0.66
Q18/f167	F30701	MPC	475.4	Mt Messenger	*Zg. nepenthes, B. pohana, S. schlumbergeri, S. notohispida, Z. parri*	21	48	0.70		1000	0.67
Q18/f166	F30700	MPC	475.1	Mt Messenger	*Hr. scitula* (0S:1D), *Zg. nepenthes, B. pohana, S. notohispida*	11	3	0.21		1000	0.45
Q18/f165	F30699	MPC	473.9	Mt Messenger	*Zg. nepenthes, B. pohana, S. notohispida, N. flemingi*	5	7	0.58		1000	0.74
Q18/f9578		GWG	465	Mt Messenger	*Hr. scitula?* (1S:2D), *Zg. nepenthes, B. pohana* (rhomboidal), *S. notohispida*	39	18	0.32		1000	0.85
Q18/f9577		GWG	450	Mt Messenger							
Q18/f37	F25278	GHS	445	Mt Messenger	*Mn. limbata?* (0S:1D), *Zg. nepenthes, B. pohana, S. notohispida*	16	30	0.65		1000	0.35
Q18/f9576		GWG	440	Mt Messenger	*Hr. scitula?* (2S:0D), *Zg. nepenthes, S. notohispida*	3	2	0.40		1000	0.65
Q18/f79	F29040	GHS	395	Mt Messenger	*Zg. nepenthes, S. notohispida, C. cenop*	18	23	0.56	bias	1000	c 0.9
Q18/f9575		GWG	390	Mt Messenger	*Zg. nepenthes, E. bradyi*	0	1	1.00	poor	600	0.70
Putangata Island			390								
Q18/f9574		GWG	360	Mt Messenger							
Q18/f9573		GWG	355	Mt Messenger		1	0	0.00	poor	?	c 0.9
Tongaporutu River (base Sst)			355								
f109	F30367	MPC	354.9	Mt Messenger	*Mn. limbata* (1S:0D), *Gq. dehiscens, Zg. nepenthes, S. schlumbergeri, E. bradyi, O. culter, C. robertsonianus?*	74	9	0.11		700	0.63
f110	F30368	MPC	354.8	Mt Messenger	*Mn. limbata* (12S:0D), *Hr. cf. ichinosekiensis* (0S:1D), *Gq. dehiscens, Zg. nepenthes, H. mioindex*	66	4	0.06		1000	0.71
f111	F30369	MPC	354.3	Mt Messenger	*Mn. limbata* (4S:2D), *Gq. dehiscens, S. schlumbergeri, E. bradyi, O. culter*	60	11	0.15		700	0.77
f112	F30370	MPC	354.2	Mt Messenger	*Mn. limbata* (8S:0D), *Gq. dehiscens, Zg. nepenthes, S. schlumbergeri, E. bradyi, O. culter*	75	3	0.04		700	0.77
f113	F30371	MPC	354.1	Mt Messenger	*Hr. scitula* (1S:1D), *Gq. dehiscens, O. culter, G. medwayensis*	44	6	0.12		700	0.77
f114	F30372	MPC	354.0	Mt Messenger	*Hr. panda?* (0S:2D), *Hr. scitula* (0S:2D), *S. schlumbergeri, E. bradyi, O. bengalensis*	49	9	0.16		700	0.78

Appendix 7.5 – North Taranaki coast, biostratigraphic data (Page 5 of 7)

FR No.	Lab No.	Collection	Thickness (m)	Formation	Important taxa and notes on collection	G. miotumida Sin (n)	G. miotumida Dex (n)	G. miotumida Dex (pi)	Quality of fauna	Min. water depth (m)	Planktic (pi)
f115	F30373	MPC	353.8	Mt Messenger	*Mn. limbata* (0S:1D), *Hr. scitula* (0S:1D), *Gq. dehiscens, Zg. nepenthes, S. schlumbergeri, E. bradyi, O. culter*	33	10	0.23		700	0.75
f116	F30374	MPC	353.6	Mt Messenger	*Gq. dehiscens. Zg. nepenthes?, S. schlumbergeri, O. bengalensis*	3	1	0.25		700	0.10
f117	F30375	MPC	353.4	Mt Messenger	*Nq. pachyderma* (1S:1D), *Zg. nepenthes, S. schlumbergeri, E. bradyi, O. culter*	6	0	0.00		700	0.10
f118	F30376	MPC	353.2	Mt Messenger	*Gq. dehiscens, E. bradyi, O. bengalensis*	4	2	0.33		700	0.07
f119	F30377	MPC	353.0	Mt Messenger	*Gq. dehiscens, K. cylindrica, O. bengalensis*	3	4	0.57		700	0.09
Base Gm-TT interval = Tukemokihi Coiling Zone (TCZ)											
f120	F30378	MPC	352.8	Mt Messenger	*Gq. dehiscens, Gs. quadrilobatus, K. cylindrica, O. bengalensis*	18	0	0.00		700	0.07
f121	F30379	MPC	352.6	Mt Messenger	*Gq. dehiscens, C. molestus, O. bengalensis*	7	1	0.13		700	0.09
f122	F30380	MPC	352.4	Mt Messenger	*Gq. dehiscens, C. molestus, O. bengalensis?*	12	0	0.00		300	0.08
f123	F30381	MPC	352.2	Mt Messenger	*Gq. dehiscens, K. cylindrica, O. bengalensis*	8	0	0.00		700	0.10
f124	F30382	MPC	352.0	Mt Messenger	*Gq. dehiscens, C. molestus, O. bengalensis*	12	0	0.00		700	0.06
f125	F30383	MPC	351.8	Mt Messenger	*Gq. dehiscens, C. molestus, O. bengalensis*	6	1	0.14		700	0.09
f126	F30384	MPC	351.6	Mt Messenger	*Gq. dehiscens, C. molestus, O. bengalensis*	10	0	0.00		700	0.08
f127	F30385	MPC	351.4	Mt Messenger	*Gq. dehiscens, C. molestus, O. bengalensis?*	30	3	0.09		300	0.23
f128	F30386	MPC	351.2	Mt Messenger	*Gq. dehiscens, C. molestus, O. bengalensis*	37	4	0.10		700	0.10
f129	F30387	MPC	351.0	Mt Messenger	*Gq. dehiscens, K. cylindrica*	3	1	0.25		400	0.07
f130	F30388	MPC	350.8	Mt Messenger	*Gq. dehiscens, K. cylindrica*	2	5	0.71		400	0.10
f131	F30389	MPC	350.6	Mt Messenger	*Gq. dehiscens, Zg. nepenthes, C. molestus*	4	1	0.20		300	0.06
f132	F30390	MPC	350.4	Mt Messenger	*Hr. scitula* (0S:1D), *Gq. dehiscens, Sphaeroidinellopsis, B.* aff. *quadrilatera* (rhomboidal), *K. cylindrica, O. bengalensis?*	7	9	0.56		400	0.09
f133	F30391	MPC	350.2	Mt Messenger	*Gq. dehiscens, Sphaeroidinellopsis, C. molestus*	3	2	0.40		300	0.10
f134	F30392	MPC	350.0	Mt Messenger	*C. molestus, K. cylindrica*	1	0	0.00		400	0.06
f137	F30395	MPC	349.4	Mt Messenger	(very sparse poorly preserved fauna), *C. molestus*					300	?
f138	F30396	MPC	349.2	Mt Messenger	*Gq. dehiscens, B. pohana* (rhomboidal), *C. molestus, O. bengalensis?*	12	3	0.20		300	0.17
f139	F30397	MPC	349.0	Mt Messenger	*Zg. nepenthes?, B. pohana* (rhomboidal), *K. cylindrica, E. bradyi, S. schlumbergeri, O. bengalensis*	29	3	0.09		700	0.19
f140	F30398	MPC	348.8	Mt Messenger	*Mn. limbata* (1S:0D), *Hr. panda?* (0S:8D), *Zg. nepenthes, S. schlumbergeri, O. bengalensis, V. pennatula*	41	1	0.02		800	0.18
f141	F30399	MPC	347.9	Mt Messenger	*Gq. dehiscens, K. cylindrica, O. bengalensis?*	1	3	0.75		700	0.08
f142	F30400	MPC	347.0	Mt Messenger	*Gq. dehiscens, K. cylindrica*	2	1	0.33		400	0.08
f143	F30401	MPC	346.1	Mt Messenger	*Gq. dehiscens, B. pohana, C. molestus, O. culter*	26	5	0.16		700	0.30
f144	F30402	MPC	345.2	Mt Messenger	*B. pohana* (rhomboidal), *S. schlumbergeri, G. medwayensis, O. culter*	16	1	0.06		700	0.17
f146	F30404	MPC	343.4	Mt Messenger	*B. pohana* (rhomboidal), *K. cylindrica, O. bengalensis*	46	0	0.00		700	0.19
f178	F30712	MPC	342.4	Mt Messenger	*Gq. dehiscens, Zg. nepenthes, S. schlumbergeri, C. cicatricosus, S.* aff. *notohispida* (smooth walled)	142	1	0.01		1000	0.54
f179	F30713	MPC	342.1	Mt Messenger	*Gq. dehiscens, B.* aff. *pohana* (striate), *S. schlumbergeri, S. notohispida*	59	2	0.03		1000	0.62
f180	F30714	MPC	341.6	Mt Messenger	*Gq. dehiscens, Zg. nepenthes, S. schlumbergeri, C. cicatricosus, S. notohispida, P. wuellerstorfi?*	87	1	0.01		1200	0.67
f181	F30715	MPC	341.1	Mt Messenger	*Gq. dehiscens, S. schlumbergeri, P. altemans, C. cicatricosus?, S. notohispida*	36	1	0.03		1000	0.64
f185	F30719	MPC	340.7	Mt Messenger	*Hr. scitula?* (1S:0D), *Gq. dehiscens, B. aff. pohana* (striate), *Zg. nepenthes, S. notohispida, P. wuellerstorfi?*	63	1	0.02		1200	0.69
f186	F30720	MPC	340.0	Mt Messenger	*Hr. scitula* (0S:1D), *Gq. dehiscens, Zg. nepenthes?, Ss. disjuncta, S. schlumbergeri, C. cicatncosus, P. wuellerstorfi?*	33	1	0.03		1200	0.52
f188	F30722	MPC	333.6	Mt Messenger	(Very sparse fauna poorly preserved fauna)	5	0	0.00	Poor	?	0.37
f187	F30721	MPC	332.6	Mt Messenger	(sparse fauna poorly preserved fauna) *S. schlumbergeri*	22	1	0.04		600	0.69
f189	F30723	MPC	330.9	Mt Messenger	(non-calcareous, very poorly preserved fauna)				NF		
f191	F30725	MPC	330.2	Mt Messenger	*Hr. scitula?* (0S:1D), *Gq. dehiscens, Zg. nepenthes, S. schlumbergeri*	41	0	0.00		600	0.61

Appendix 7.5 – North Taranaki coast, biostratigraphic data (Page 6 of 7)

FR No.	Lab No.	Collection	Thickness (m)	Formation	Important taxa and notes on collection	G. miotumida Sin (n)	G. miotumida Dex (n)	G. miotumida Dex (pi)	Quality of fauna	Min. water depth (m)	Planktic (pi)
f192	F30726	MPC	329.3	Mt Messenger	*Nq. pachyderma* (1S:0S), *Hr. scitula* (0S:1D), *Gq. dehiscens, B.* aff. *pohana* (striate), *S. notohispida, P. wuellerstorfi*	63	2	0.03		1200	0.73
Coast north of Tongaporutu River											
Q18/f74	F25471	GHS		Mt Messenger	*Zg. nepenthes*	41	0	0.00	biased	200	0.75
Q18/f75	F25472	GHS		Mt Messenger	*Hr. panda?* (0S:1D), *Hr. scitula?* (1S:0D), *C. molestus*	37	1	0.03		300	0.75
Q18/f34	F25275	GHS		Mt Messenger	*B. pohana* (rhomboidal), *S. notohispida, Z. parri* + shell debris	15	6	0.29		1000	>0.15
Q18/f76	F25473	GHS		Mt Messenger	*B. pohana* (rhomboidal), *C. molestus, Z. parri*	10	5	0.33		300	0.10
Q18/f77	F25474	GHS		Mt Messenger	*Hr. scitula* (1S:1D), *E. bradyi*	40	3	0.07		600	0.85
Q18/f9570		GWG		Mt Messenger	*Hr. scitula* (0S:3D), *Zg. nepenthes, S. schlumbergeri, E. bradyi, O. bengalensis*	10	5	0.33		700	0.85
Q18/f33	F25274	GHS		Mt Messenger		0	2	1.00	poor	<200	0.20
Q18/f9569		GWG		Mt Messenger	*Mn. limbata?* (1S:0D), *Hr. scitula?* (2S:0D), *B. pohana* (rhomboidal), *B.* aff. *quadrilatera, S. notohispida, Z. parri*	4	0	0.00		1000	0.35
Q18/f69	F28466	GHS		Mt Messenger					poor		
Rapanui Stream			???								
Q18/f9567		GWG		Mt Messenger	*Mn. limbata?* (4S:0D), *Zg. nepenthes, B. pohana* (rhomboidal)	51	3	0.06		200	0.75
Q18/f9566		GWG		Mt Messenger	*Mn. limbata* (1S:0D), *O. culter*	31	3	0.09		700	0.60
Q18/f19	F22057	GHS		Mt Messenger	*Gq. dehiscens, S. notohispida*	92	3	0.03		1000	0.75
Q18/f9565		GWG		Mt Messenger	*Gq. dehiscens, B. pohana, S. notohispida*	38	2	0.05		1000	0.85
Q18/f9564		GWG		Mt Messenger							
Q18/f9563		GWG		Mt Messenger	*Mn. limbata?* (1S:0D)	1	0	0.00	poor	?	>0.90
Q18/f73	F28470	GHS		Mt Messenger	*Gq. dehiscens, Zg. nepenthes, S. notohispida*	39	1	0.03	biased	1000	0.70
Q18/f72	F28469	GHS		Mt Messenger	*Gq. dehiscens, Zg. nepenthes?, B. pohana, E. bradyi, O. bengalensis, Z. parri*	24	6	0.20		700	0.40
Q18/f20	F22058	GHS		Mt Messenger	*Gq. dehiscens, P.* aff. *wuellerstorfi*	221	7	0.03		1200	0.65
Q18/f9562		GWG		Mt Messenger	*Globigerinella, Gq. dehiscens, B.* aff. *pohana* (striate), *O. bengalensis*	8	1	0.11	poor	700	0.75
Q18/f9561		GWG		Mt Messenger	*Hr. scitula* (0S:2D), *Hr. scitula?* (5S:0D), *Gq. dehiscens, S. notohispida*	16	0	0.00		1000	0.75
Q18/f9560		GWG		Mt Messenger							
Q18/f9559		GWG		Mt Messenger							
Q18/f70	F28467	GHS		Mt Messenger	*Gq. dehiscens, S. notohispida, P.* aff. *wuellerstorfi*	131	1	0.01		1200	0.90
Q18/f71	F28468	GHS		Mt Messenger	*Gq. dehiscens, S. notohispida, T. zealandica*	50	1	0.02		1500	0.75
Q18/f21	F22059	GHS		Mt Messenger	*Mn. limbata?* (1S:0D), *Gq. dehiscens, B.* aff. *pohana* (striate), *S. notohispida, H. mioindex*	24	0	0.00		1000	0.65
Q18/f9557		GWG		Mt Messenger	*S. notohispida*	4	0	0.00		1000	c 0.9
Q18/f22	F22060	GHS		Mt Messenger	*Hr. scitula* (0S:1D), *Gq. dehiscens, S. notohispida, H. mioindex, P.* aff. *wuellerstorfi*	45	1	0.02		1200	0.55
Q18/f9556		GWG		Mt Messenger	*Gq. dehiscens, O. bengalensis*	45	0	0.00	poor	700	0.65
Q18/f23	F22061	GHS		Mt Messenger	*Hr. scitula?* (2S:0D), *Zg. nepenthes, Globigerinella, Gq. dehiscens, B.* aff. *pohana* (striate), *S. notohispida, P.* aff. *wuellerstorfi*	16	0	0.00		1200	0.50
Otukehu Stream			???								
Q18/f32	F25273	GHS		Mt Messenger	*Hr. scitula* (0S:1D), *Hr. scitula* (1S:0D), *Gq. dehiscens, S. notohispida, P.* aff. *wuellerstofi*	26	1	0.04		1200	0.45
Q18/f24	F22062	GHS		Mt Messenger	*Gq. dehiscens, P. wuellerstorfi, T. zealandica*	13	0	0.00		1500	0.55
Q18/f9551		GWG		Mt Messenger	*Gq. dehiscens, T. zealandica*	16	0	0.00		1500	0.70
Kawau Pa (base Tt-stratotype			325								
Q18/f25	F22063	GHS	325	Mt Messenger	*Mn. limbata?* (1S:0D), *Hr. scitula?* (0S:2D), *S. notohispida, P. renzi* (large)	57	0	0.00		1200	0.60
Q18/f9550		GWG	325	Mt Messenger	*Hr. scitula* (5S:3D), *Cs. parvulus, S. notohispida*	48	2	0.04		1000	0.85
Q18/f9549		GWG	320	Mt Messenger	*Gq. dehiscens, Gq. venezuelana?* (common), *T. zealandica*	57	1	0.02		1500	0.85
Q18/f26	F22064	GHS	310	Mt Messenger	*Mn. limbata?* (1S:0D), *Hr. scitula* (0S:2D), *Zg. nepenthes, Globigerinopsis, Gq. dehiscens, G. venezuelana?, S. notohispida, T. zealandica*	47	2	0.04		1500	0.85

Appendix 7.5 – North Taranaki coast, biostratigraphic data (Page 7 of 7)

FR No.	Lab No.	Collection	Thickness (m)	Formation	Important taxa and notes on collection	G. miotumida Sin (n)	G. miotumida Dex (n)	G. miotumida Dex (pi)	Quality of fauna	Min. water depth (m)	Planktic (pi)
Q18/f27	F22065	GHS	255	Mt Messenger	*Hr. scitula?* (2S:1D), *Gq. dehiscens, B.* aff. *pohana* (striate), *S. notohispida*	43	2	0.04		1200	0.70
Q18/f9548		GWG	240	Mt Messenger	*Hr. scitula?* (5S:0D), *Gq. dehiscens, S. notohispida*	89	1	0.01		1200	0.80
Q18/f9547		GWG	240	Mt Messenger	*Nq. pachyderma* (2S:0D), *Hr. scitula* (36S:8D), *Cs. parvulus, Gs. quadrilobatus, Gq. dehiscens, S. notohispida*	30	0	0.00		1000	0.85
Q18/f28	F22066	GHS	240	Mt Messenger					NF		
Awaawaroa Stream			240								
Q18/f31	F25272	GHS	240	Mt Messenger	*Gq. dehiscens*	4	0	0.00	poor	?	0.65
Q18/f9546		GWG	240	Mt Messenger	*Gq. dehiscens, S. notohispida*	7	0	0.00	poor	1000	0.40
Q18/f9545		GWG	240	Mt Messenger							
Q18/f7657		GWG	240	Mt Messenger	*Gq. dehiscens, S. notohispida*	3	0	0.00	poor	1000	
R18/f67	F25497	GHS	240	Mt Messenger	*Gq. dehiscens, S. notohispida*	21	0	0.00	poor	1000	0.50
Q18/f49	F25481	GHS	240	Mt Messenger	*Gq. dehiscens, S. notohispida, N. novozealandica*	25	0	0.00		1000	0.65
Q18/f30	F25271	GHS	220	Mt Messenger	*Gq. dehiscens, Hr. scitula* (0S:1D), *S. notohispida*	7	2	0.22	poor	1000	0.85
Q18/f7656		GWG	220	Mt Messenger							
R18/f6655		GWG	215	Mt Messenger	*S. schlumbergeri*	24	0	0.00	poor	600	
R18/f6654		GWG	210	Mt Messenger	*Gq. dehiscens, E. bradyi, O. culter, P. alternans*	46	2	0.04		700	
R18/f28	F22067	GWG	210	Mt Messenger							0.95
R18/f6652		GWG	190	Mt Messenger		4	0	0.00	poor		
R18/f6653		GWG	185	Mt Messenger	*Gq. dehiscens, Gr.* cf. *lenguaensis, S. schlumbergeri*	38	2	0.05	poor	600	
Mohakatino River											
R18/f58	F25266	GHS	180	Purupuru	*Mn. limbata* (1S:0D), *Hr. scitula?* (5S:0D), *Hr. scitula* (0S:11D), *Zg. nepenthes, T. zealandica*	101	1	0.01		1500	0.90
Q18/f48	F25480	GHS	180	Purupuru	*Hr.* cf. *ichinosekiensis, S. notohispida*	54	0	0.00		1200	0.65
R18/f66	F25496	GHS	165	Purupuru	*Bolboforma gruetzmacheri, Hr. scitula* (0S:2D), *Hr. scitula?* (1S:0D), *Gq. dehiscens, Sphaeroidinellopsis, C. kullengeri*	25	1	0.04		1300	0.65
R18/f63	F25474	GHS	155	Purupuru		1	0	0.00	poor	?	0.50
Mokau River (fault South Hea			150								
R18/f65A	F25495	GHS	145	Purupuru	*Nq. pachyderma* (0S:2D)	4	0	0.00	poor	?	<0.10
R18/f65	F25495	GHS	145	Purupuru		2	0	0.00	poor	?	<0.10
R17/f496		GHS	105	Purupuru							
R17/f498	F25491	GHS	90	Purupuru	*Nq. continuosa (1S:0D), Hr. panda* (1S:57D), *Zg. druryi, Gq. dehiscens, S. notohispida, H. mioindex, Planulina* sp.	196	3	0.02		1200	0.90
Awakino River (base Purupuru			75								

Appendix 7.6 – Biostratigraphic data from Pukearuhe-1, North Taranaki, including stratigraphic heights of samples, notes on individual collections, *Globoconella miotumida, Neogloboquadrina pachyderma,* and *Neogloboquadrina mayeri* s.l. coiling data, paleodepth indicators, mollusc fragments, downslope reworking, minimum estimates of water depths, estimates of water depths. A summary is given in given Figure 7.11. (Page 1 of 3)

Depth (m BKB)		Important taxa and notes on collection	*Gc. miotumida* Sin (n)	*Gc. miotumida* Dex (n)	*Gc. miotumida* Dex (Pi)	Planktics (n)	Benthics (n)	Planktic (Pi)	>200	>400	>600	>800	>1000	>1500	Mollusc fragments	Downslope	Minimum depth (m)	Depth zone depth (m)
210	ITt	*C. neoperforatus?*	33	1	0.03				x								200	1000-1500
220	ITt	*S. notohispida, H. mioindex, Notorotalia*	16	1	0.06			0.38					x		R	R	1000	1000-1500
230	ITt	*Hr. scitula* (0S:1D), *O. bengalensis, E. charlottensis*	16	2	0.11			0.38			x				R	R	600	1000-1500
240	ITt	*K. cylindrica*	18	0	0.00			0.50		x					R		400	1000-1500
250	ITt	*O. bengalensis*	18	0	0.00			0.44			x				F		600	1000-1500
260	ITt	*O. bengalensis*	58	3	0.05			0.43			x				R		600	1000-1500
270	ITt	*S. schlumbergeri*	55	0	0.00			0.33			x				F		600	1000-1500
280	ITt	*C. molestus*	36	0	0.00			0.64	x						R		200	1000-1500
290	ITt	*S. schlumbergeri*	24	1	0.04			0.59			x				R		600	1000-1500
300	ITt	*S. schlumbergeri*	50	2	0.04			0.53			x				R		600	1000-1500
310	ITt	Top Gm-PK =Tukemokihi Coiling Zone (TCZ), *C. neoperforatus*	15	5	0.25			0.54	x						R		200	1000-1500
320	ITt	*Hr. panda* s.l. (0S:2D), *S. schlumbergeri*	32	30	0.48			0.57			x				R		600	1000-1500
330	ITt	*Notorotalia*	11	21	0.66			0.56							R	R	400	1000-1500
340	ITt	*Hr. panda s.l. (0S:1D), K. cylindrica*	3	22	0.88			0.61		x							400	1000-1500
350	ITt	*V. pennatula*	5	19	0.79			0.57				x			R		800	1000-1500
360	ITt	*S. schlumbergeri*	19	31	0.62			0.43			x				R		600	1000-1500
370	ITt	*O. bengalensis*	5	11	0.69			0.52			x						600	1000-1500
380	ITt	*S. schlumbergeri, E. bradyi*	10	18	0.64			0.65			x						600	1000-1500
390	ITt	*Hr. scitula* (1S:5D), *E. bradyi, H. mioindex?*	62	75	0.55			0.64			x		?				600	1000-1500
400	ITt	*H. mioindex, T. zealandica?*	34	38	0.53			0.66					x		R		1500	1000-1500
410	ITt	*S. schlumbergeri*	12	5	0.29			0.68			x				A	x	600	1000-1500
420	ITt	*Hr. panda* s.l. (0S:1D), *Hr. scitula* (1S:0D), *S. schlumbergeri, E. bradyi, O. culter,* (Lenticulina facies)	5	8	0.62			0.68			x				F	x	600	1000-1500
430	ITt	*S. schlumbergeri, O. culter,* (Lenticulina facies)	6	7	0.54			0.55			x				F	R	600	1000-1500
440	ITt	*H. mioindex,* (Lenticulina facies)	8	13	0.62			0.52					x		F		1000	1000-1500
450	ITt	*E. bradyi,* (Lenticulina facies)	8	11	0.58			0.26			x				F	R	600	1000-1500
460	ITt	*Hr.* cf. *scitula* (inflated, sinistral), *E. bradyi,* (Lenticulina facies)	7	4	0.36			0.54			x				F		600	1000-1500
470	ITt	*C. molestus,* (Lenticulina facies)	7	4	0.36			0.58	x						F		200	1000-1500
480	ITt	*Hr. scitula* (sinistral), *S. notohispida,* (Lenticulina facies)	9	7	0.44			0.32					x		F		1000	1000-1500
490	ITt	*C. molestus,* (Lenticulina facies)	3	1	0.25			0.09	x						F		200	1000-1500
500	ITt	*H. mioindex,* (Haeuslerella facies)	6	3	0.33			0.14					x		F		1000	1000-1500
510	ITt	*E. bradyi,* (Haeuslerella facies)	1	2	0.67			0.12			x				F		600	1000-1500
520	ITt	*C. molestus,* (Lenticulina facies)	8	2	0.20			0.06	x						C		200	1000-1500
530	ITt	*C. molestus*	5	6	0.55			0.10	x						F		200	1000-1500
540	ITt	*C. molestus*	8	1	0.11			0.12	x						F		200	1000-1500
550	ITt	*C. molestus* [silty]	2	6	0.75			0.11	x						F		200	1000-1500
560	ITt	*H. elegans* [silty]	3	8	0.73			0.30	?						F		200	1000-1500
570	ITt	*C. molestus*	1	1	0.50			0.07	x						R		200	1000-1500
580	ITt	*C. molestus*	1	2	0.67			0.07	x						R		200	1000-1500
590	ITt	*G. medwayensis*	8	8	0.50			0.11				x			F		800	1000-1500
600	ITt	*C. molestus, C. neoperforatus*	8	11	0.58			0.16	x						F	x	200	1000-1500
610	ITt	*O. culter*	19	43	0.69			0.21			x				F		600	1000-1500
620	ITt	*O. culter*	35	57	0.62			0.17			x				F		600	1000-1500
630	ITt	*O. culter*	14	29	0.67			0.21			x				F		600	1000-1500
640	ITt	*Mn. limbata* (1S:0D), *O. culter*	19	23	0.55			0.24			x				F		600	1000-1500
650	ITt	*O. culter*	14	16	0.53			0.16			x				F		600	1000-1500

Appendix 7.6 – Pukearuhe-1, North Taranaki, biostratigraphic data (Page 2 of 3)

Depth (m BKB)		Important taxa and notes on collection	*Gc. miotumida* Sin (n)	*Gc. miotumida* Dex (n)	*Gc. miotumida* Dex (Pi)	Planktics (n)	Benthics (n)	Planktic (Pi)	>200	>400	>600	>800	>1000	>1500	Mollusc fragments	Downslope	Minimum depth (m)	Depth zone depth (m)
660	ITt	*O. culter*	5	16	0.76			0.15			x				F		600	1000-1500
670	ITt	*C. molestus*	5	11	0.69			0.15	x						F		200	1000-1500
680	ITt	*S. notohispida*	7	8	0.53			0.13					x		C		1000	1000-1500
690	ITt	*C. neoperforatus*	1	6	0.86			0.21	x						C		200	1000-1500
700	ITt	*C. molestus*	0	0				0.06	x						F		200	1000-1500
710	ITt	*H. mioindex*	1	1	0.50			0.27					x		F		1000	1000-1500
720	ITt	*O. culter*	1	1	0.50			0.18			x				F		600	1000-1500
730	ITt	*Hr. scitula* (0S:1D), *C. neoperforatus, Z. parri* (downslope)	5	4	0.44			0.18	x						F		200	1000-1500
740	ITt	*E. bradyi, Z. parri* (downslope)	7	1	0.13			0.15			x				F		600	1000-1500
750	ITt	*C. neoperforatus*	2	9	0.82			0.19	x						F		200	1000-1500
760	ITt	*E. bradyi*	5	4	0.44			0.28			x				F		600	1000-1500
770	ITt	*C. neoperforatus*	2	1	0.33			0.21	x						F		200	1000-1500
780	ITt	*C. neoperforatus*	2	2	0.50			0.13	x						F		200	1000-1500
790	ITt	*C. molestus, Gavelinopsis* sp. (downslope)	6	7	0.54			0.20	x						F		200	1000-1500
800	ITt	*C. molestus*	3	8	0.73			0.20	x						F		200	1000-1500
810	ITt	*C. neoperforatus, Z. parri* (downslope)	3	5	0.63			0.21	x						F		200	1000-1500
820	ITt	*C. neoperforatus, Z. parri* (downslope)	4	1	0.20			0.19	x						F		200	1000-1500
830	ITt	Base Gm-PK =Tukemokihi Coiling Zone (TCZ), *S. schlumbergeri, O. culter, Z. parri* (downslope)	16	4	0.20	65	114	0.36			x				F		600	1000-1500
840	ITt	*Nq. pachyderma* (6S:42D), *S. notohispida* [Disrupted Interval]	85	7	0.08	135	175	0.44					x		F		1000	1000-1500
850	ITt	*Nq. pachyderma* (1S:1D), *H. mioindex* [Disrupted Interval]	197	14	0.07	153	84	0.65					x		F		1000	1000-1500
860	ITt	*B. subfragoris* s.l., *Nq. pachyderma* (2S:3D), *H. mioindex*, [Disrupted Interval]	53	5	0.09	122	68	0.64					x		F		1000	1000-1500
870	ITt	*B. pentaspinosa, Nq. pachyderma* (4S:0D), *H. mioindex, S. notohispida, Z. parri* (rare), [Disrupted Interval]	45	2	0.04	340	172	0.66					x				1000	1000-1500
880	ITt	*Nq. pachyderma* (0S:1D), *S. notohispida, Z. parri* (rare), [Disrupted Interval]	46	4	0.08	164	72	0.69					x				1000	1000-1500
890	ITt	*B. subfragoris* s.l., *Nq. pachyderma* (3S:0D), *S. notohispida*, [Disrupted Interval]	32	3	0.09	167	55	0.75					x				1000	1000-1500
900	ITt	*B. pentaspinosa, Nq. pachyderma* (4S:5D), *S. notohispida*, [Disrupted Interval]	48	1	0.02	137	32	0.81					x				1000	1000-1500
910	ITt	*Nq. pachyderma* (1S:5D), *S. notohispida*	28	3	0.10	176	33	0.84					x				1000	1000-1500
920	ITt	*Nq. pachyderma* (1S:3D), *H. mioindex*	36	0	0.00	224	41	0.85					x				1000	1000-1500
930	ITt	*E. bradyi*	23	0	0.00	183	41	0.82			x						600	1000-1500
940	ITt	*H. mioindex*	29	2	0.06	297	57	0.84					x		R		1000	1000-1500
950	ITt	*S. notohispida*	26	0	0.00	48	7	0.87					x		R		1000	1000-1500
960	ITt	*V. pennatula*	34	0	0.00	75	9	0.89				x					800	1000-1500
970	ITt	*S. schlumbergeri, E. bradyi*	7	0	0.00	61	16	0.79			x						600	1000-1500
980	ITt	*Bolivinita, Nq. pachyderma* s.l. (0S:1D), *Nq. mayeri* s.l. (0S:1D), *H. mioindex*	27	1	0.04	147	32	0.82					x				1000	1000-1500
990	ITt	*S. schlumbergeri*	11	1	0.08	65	14	0.82			x				R		600	1000-1500
1000	ITt	*S. schlumbergeri*	16	0	0.00	51	15	0.77			x						600	1000-1500
1010	ITt	*S. schlumbergeri, K. bradyi*	11	1	0.08	105	30	0.78			x						600	1000-1500
1020	ITt	*B. gruetzmacheri, Nq. mayeri* s.l. (1S:0D), *Hr. panda* s.l.? (0S:2D), *H. mioindex*	80	3	0.04	515	51	0.91					x				600	1000-1500
1030	ITt	*Nq. mayeri* s.l. (8S:4D) lower-GCZ?, *S. notohispida, H. mioindex*	77	2	0.03	105	20	0.84					x				1000	1000-1500
1040	ITt	*Nq. mayeri s.l. (1S:0D) S. notohispida, H. mioindex*	19	1	0.05	54	5	0.92					x				1000	1000-1500
1050	ITt	*B. subfragoris* s.l., *Nq. mayeri* s.l. (44S:9D), *T. zealandica*	53	0	0.00	553	12	0.98						x			1500	1500-2000
1060	ITt	*Nq. mayeri* s.l. (37S:13D) lower-GCZ?, *H. mioindex*	52	1	0.02	154	7	0.96					x				1000	1500-2000
1070	Sw	*Nq. mayeri* s.l.? (36S:2D), *O. culter?*	51	1	0.02	204	32	0.86			x						600	1500-2000
1080	Sw	*Nq. mayeri* s.l.? (34S:3D), *H. mioindex*	18	0	0.00	203	34	0.86					x				1000	1500-2000
1090	Sw	*Nq. mayeri* s.l. (21S:1D), *H. mioindex*	20	2	0.09	84	22	0.79					x				1000	1500-2000

Appendix 7.6 – Pukearuhe-1, North Taranaki, biostratigraphic data (Page 3 of 3)

Depth (m BKB)		Important taxa and notes on collection	*Gc. miotumida* Sin (n)	*Gc. miotumida* Dex (n)	*Gc. miotumida* Dex (Pi)	Planktics (n)	Benthics (n)	Planktic (Pi)	>200	>400	>600	>800	>1000	>1500	Mollusc fragments	Downslope	Minimum depth (m)	Depth zone depth (m)
1100	Sw	*Nq. mayeri* s.l. (28S:3D), *Fohsella?, S. notohispida*	28	2	0.07	208	32	0.87					x				1000	1500-2000
1110	Sw	*Nq. mayeri* s.l. (26S:1D), *Fh. peripheroacuta?, S. notohispida*	9	1	0.10	203	20	0.91					x				1000	1500-2000
1120	Sw	*Nq. mayeri* s.l. (44S:6), *S. notohispida*	18	1	0.05	250	13	0.95					x				1000	1500-2000
1130	Sw	*Nq. mayeri* s.l. (13S:0D), *Nq. partimlabiata?, Gc. conica?, Mn. paremenardii?, V. pennatula, Amphistegina* (rare)	41	2	0.05	112	13	0.90				x			R		800	1500-2000
1140	Sw	*Nq. mayeri s.l.* (42S:1D), *T. zealandica*	4	0	0.00	50	5	0.91							R		1500	1500-2000
1150	Sw	*Fohsella?, Nq. mayeri* s.l. (8S:0D), *V. pennatula*	7	0	0.00	166	8	0.95									800	1500-2000
1160	Sw	*Mn. paremenardii?, Nq. mayeri* s.l. (50S:4D), *S. notohispida, H. mioindex, C. kullenbergi, Amphistegina* (rare)	112	2	0.02	293	27	0.92					x				1000	1500-2000
1170	Sw	*Nq. mayeri* s.l. (5S:0D), *Bolivinita pohana, S. notohispida*	5	0	0.00	196	23	0.89					x				1000	1500-2000
1180	Sw	*Gc. conica?, Nq. mayeri* s.l. (48S:2D), *L. truncatum, T. zealandica, Amphistegina* (rare)	38	3	0.07	393	28	0.93						x			1500	1500-2000
1190	Sw	*Nq. mayeri* s.l. (2S:0D), *H. mioindex*	3	0	0.00	166	26	0.86					x				1000	1500-2000
1200	Sw	*Gc. conica?, Nq. mayeri* s.l. (23S:2D), *T. zealandica, Amphistegina* (rare), *Z. parri* (rare)	38	0	0.00	183	40	0.82						x			1500	1500-2000
1210	Sw	*Mn. praemenardii?, Nq. mayeri* s.l. (48S:10D), *T. zealandica*	55	1	0.02	254	21	0.92						x			1500	1500-2000
1220	Sw	*Fh. peripheroronda?, Nq. mayeri* s.l. (53S:10D), *H. mioindex, Amphistegina* (rare)	19	3	0.14	251	36	0.87					x		R		1000	1500-2000
1230	uSl	*Fh. peripheroronda, Gc. amuria, Gc. conica?, Mn. praemenardii?, V. pennatula*	163	3	0.02	395	47	0.89				x			R		800	1500-2000
1240	uSl	*Fh. peripheroronda, Gc. conica, Nq. Partimlabiata, V. pennatula*	10	0	0.00	289	38	0.88				x					800	1500-2000

Synopsis

A synopsis of New Zealand late Miocene biostratigraphy and biochronology, and stage correlations

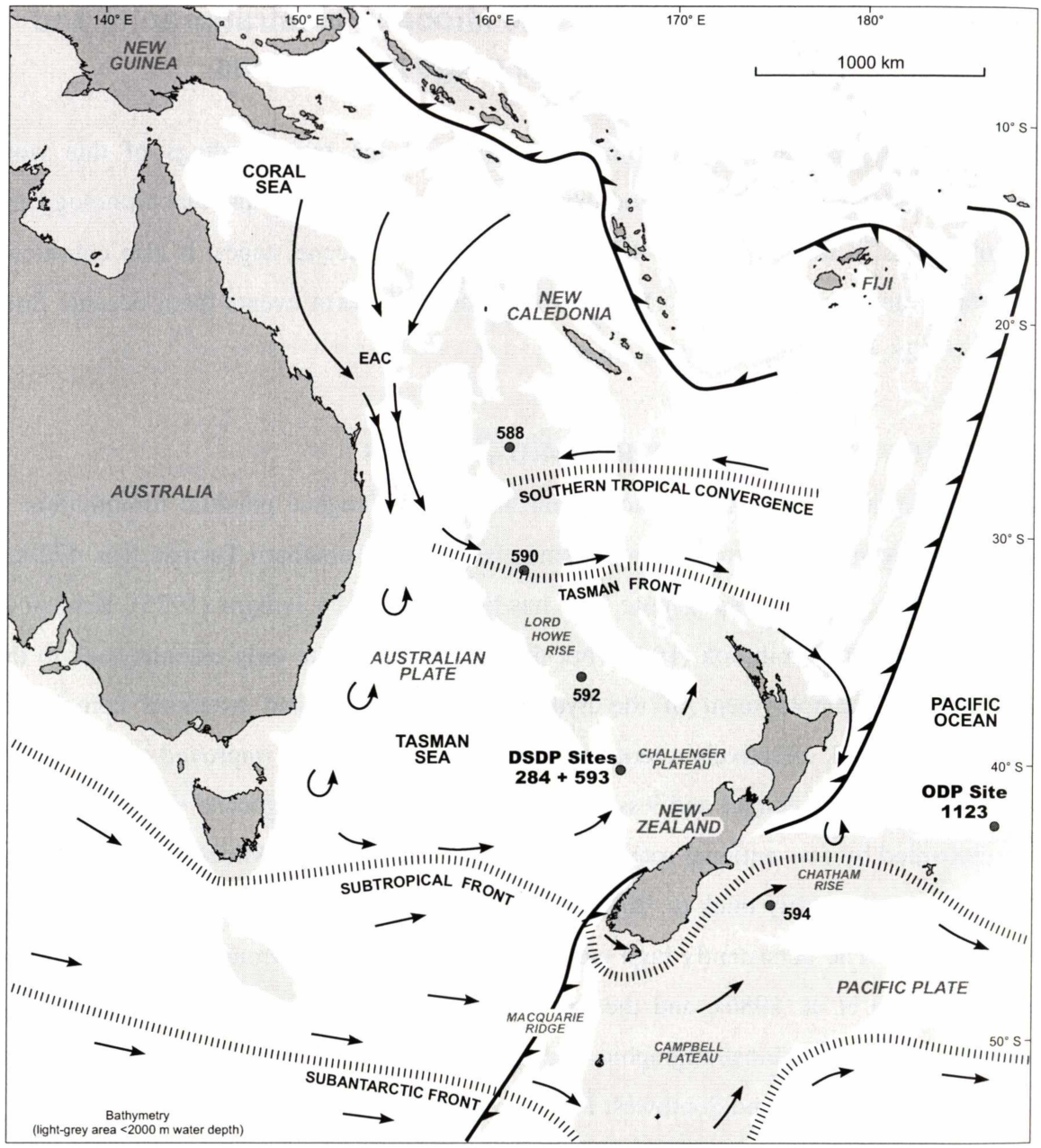
A synopsis of New Zealand late Miocene biostratigraphy and biochronology, and stage correlations

This synopsis summarizes and interrelates some of the main findings of this work concerning advances in New Zealand late Miocene biostratigraphy and biochronology and improvements in the correlation of New Zealand late Miocene stages. It also chronicles important late Miocene planktic foraminiferal and bolboform events from oceanic Sites 593 and 1123, including many that are new.

PLANKTIC FORAMINIFERAL RECORD – SITE 593

The biostratigraphic and paleoceanographic history of Neogene planktic foraminifers at Site 284 between the Subtropical and Tasman fronts in the southern Tasman Sea, 470 km west of central New Zealand (Figure 8.1), has been studied by Jenkins (1975), Kennett & Vella (1975), and Hornibrook (1982), but the record at this site only extends back to the latest Miocene. Employment of the hydraulic piston corer and extended core barrel systems at Site 593, effectively a reoccupation of Site 284, greatly improved core recovery and provided a much longer and less disturbed Quaternary to Oligocene section than had been recovered by conventional rotary coring at Site 284. The late Miocene section at Site 593 involves a relatively thick (c. 200 m) and uninterrupted sequence of calcareous oozes (Nelson 1986). The persistently high carbonate content (>90%) through the late Miocene section (Mycke et al. 1986), and the excellent preservation of calcareous microfossils, make it an important biostratigraphic and paleoceanographic reference section for the temperate New Zealand and Southwest Pacific regions.

The distribution of late Miocene planktic foraminifers at this site is documented in Study 1 in a high-resolution census from the base of core 593-36X to the top of 593-14X (from upper Waiauan to lower Opoitian, c. 11.6-5.2 Ma), using an average sample spacing of c. 7 k.y. Previous planktic foraminiferal studies from this interval have only been of a reconnaissance nature (Jenkins & Srinivasan 1986; Scott 1992), except near the Miocene-Pliocene boundary where morphometric and isotopic studies have focused on evolutionary development of the planktic foraminiferal clade *Globoconella* (Wei 1992; Schneider & Kennett 1996). The census identifies the appearances and disappearances of taxa, relative abundances of taxa, and coiling changes that are potentially useful for the correlation of late Miocene sequences in the New Zealand region. These data form the basis of a robust



Modern oceanic fronts and surface water masses after Cooke (2002)	Abbreviation	Neogene biogeography Kennett & Srinivasan (1983)		Late Miocene biogeography (THIS STUDY)	Example
		Subtropical		Subtropical	Site 588
SOUTHERN TROPICAL CONVERGENCE	**- STC -**	**- STC -**	┐	**- STC -**	**- STC -**
Warm Subtropical Water	WSTW	Transitional	Cool		Site 590
TASMAN FRONT	**- TF -**	**- TF -**	subtropical	Temperate	**- TF -**
Cool Subtropical Water	CSTW	Temperate	assemblage		Sites 592, 593, 1123
SUBTROPICAL FRONT	**- STF -**	**- STF -**	┘	**- STF -**	**- STF -**
Subantarctic Surface Water	SASW				Site 594
SUBANTARCTIC FRONT	**- SAF -**	Subantarctic		Subantarctic	**- SAF -**
Circumpolar Surface Water	CSW				Site 278 (56°33.7'S; 160°04.5'E)

Figure 8.1 – Modern bathymetry, locations of DSDP and ODP Sites, oceanic fronts and general circulation of surface water in the Tasman Sea region (after Heath 1985). EAC = East Australian Current. The relationships between modern oceanic fronts, surface water masses, and biogeography are given in the table beneath the location map.

biostratigraphic framework that is developed in Study 2. The taxonomy of planktic foraminifers that is utilized in the census and in subsequent biostratigraphic studies follows the phylogenetic scheme of Kennett & Srinivasan (1983), except subgenera are raised in status to genera and the clade *Globigerina* is informally subdivided into two groups: *Gg. bulloides* gp and *Gg. quinqueloba* gp (Table 8.1). The taxonomic assignments of some taxa have also been emended: *Globorotalia (Globoconella) panda* is reassigned to *Hirsutella, Globorotalia (Hirsutella) cibaoensis – sensu* Kennett & Srinivasan (1983) – is included in *Truncorotalia juanai,* all species of *Globorotalia (Jenkinsella)* are reassigned to *Neogloboquadrina,* and *Globigerinopsis* is separated from *Globigerinella.* Species concepts are largely based on Hornibrook (1981, 1982), Hornibrook et al. (1989), and Scott et al. (1990), although some have been emended to facilitate their use in regional biostratigraphy. In this respect, some species concepts may differ from those employed by other biostratigraphers and stratigraphic ranges may vary accordingly.

Table 8.1 – Taxonomic classification of important late Miocene planktic foraminiferal genera/subgenera and groups from the New Zealand region.

Kennett & Srinivasan (1983)	This study	Species
Catapsydrax	*Catapsydrax*	*Cs. parvulus*
Globigerina (Globigerina)	*Globigerina bulloides* group	*Gg. bulloides, Gg. falconensis*
	Globigerina quinqueloba group	*Gg. angustiumbilicata, Gg. quinqueloba*
Globigerina (Zeaglobigerina)	*Zeaglobigerina*	*Zg. druryi, Zg. woodi apertura, Zg. woodi decoraperta, Zg. woodi* s.s. *Zg,. nepenthes*
Globigerinoides	*Globigerinoides*	*Gs. obliquus, Gs. quadrilobatus immaturus, Gs. quadrilobatus* s.s., *Gs. quadrilobatus trilobus, Gs. sacculifer*
Orbulina	*Orbulina*	*Or. bilobata, Or. universa*
Globorotalia (Globoconella)	*Globoconella*	*Gc. conomiozea, Gc. explications, Gc. miotumida, Gc. mons, Gc. pliozea, Gc. puncticulata, Gc. sphericomiozea*
Globorotalia (Menardella)	*Menardella*	*Mn.* cf. *limbata*
Globorotalia (Hirsutella)	*Hirsutella*	*Hr.* cf. *ichinosekiensis, Hr. margaritae, Hr. panda, Hr. scitula*
Globorotalia (Truncorotalia)	*Truncorotalia*	*Tr.* aff. *crassaconica, Tr. crassaformis, Tr. juanai, Tr. neojuanai* n.sp.
Globorotalia (Globorotalia)	*Globorotalia*	*Gr. lenguaensis*
Globorotalia (Jenkinsella)	– included in *Neogloboquadrina*	
Globoquadrina	*Globoquadrina*	*Gq. dehiscens, Gq. venezuelana*
Neogloboquadrina	*Neogloboquadrina*	*Nq. dutertrei, Nq. mayeri continuosa, Nq. mayeri* s.s., *Nq. mayeri nympha, Nq. pachyderma*
Sphaeroidinellopsis	*Sphaeroidinellopsis*	*Ss. paenedehiscens, Ss. seminulina*
Globorotaloides	*Globorotaloides*	*Gd. hexagona*
Globigerinita	*Globigerinita*	*Gt. glutinata, Gt. uvula*
Globigerinella	*Globigerinella*	*Ge. aequilateralis*
	Globigerinopsis	*Gp. obesa*

PLANKTIC FORAMINIFERAL BIOSTRATIGRAPHY – SITE 593

A high-resolution census of late Miocene (upper Waiauan to lower Opoitian) planktic foraminifers at DSDP Site 593 (Study 1) has led to a nine-fold improvement in biostratigraphic resolution over the existing land based stage classification. At least 37 well defined bioevents, including lowest and highest occurrences and changes in coiling and abundance, have been identified, many of which are new (Figure 8.2, and Plates 8.1–8.6).

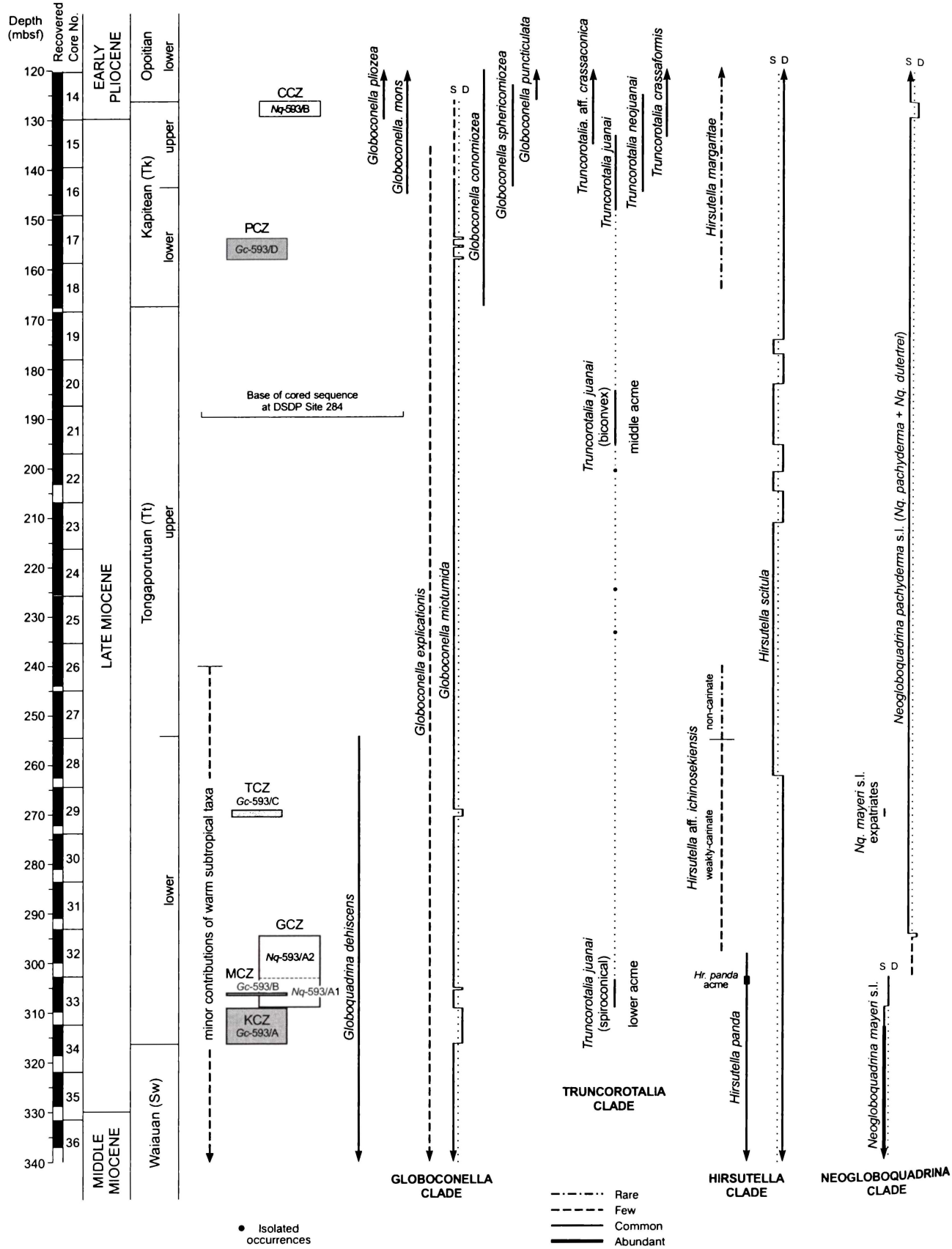


Figure 8.2 – Distribution of important late Miocene planktic foraminifers associated with the clades *Globoconella* (*Gc.*), *Truncorotalia* (*Tr.*), *Hirsutella* (*Hr.*), and *Neogloboquadrina* (*Nq.*), *Globoquadrina dehiscens,* and Coiling Zones: KCZ (Kaiti) *Gc*-593/A, MCZ (Mapiri) *Gc*-593/B, TCZ (Tukemokihi) *Gc*-593/C, PCZ (Palliser) *Gc*-593/D, GCZ (Glomar) *Nq*-593/A1 and *Nq*-593/A2, CCZ (Challenger) *Nq*-593/B. Minor contributions of warm subtropical taxa are a distinctive feature of early late Miocene assemblages, but they largely disappear in the lowermost upper Tongaporutuan. This is followed by a paucity of well-defined bioevents in the upper Tongaporutuan, and the subsequent onset of rapid evolution and divergence in the clades *Globoconella* and *Truncorotalia* in the Kapitean. S = Sinistral, D = Dextral.

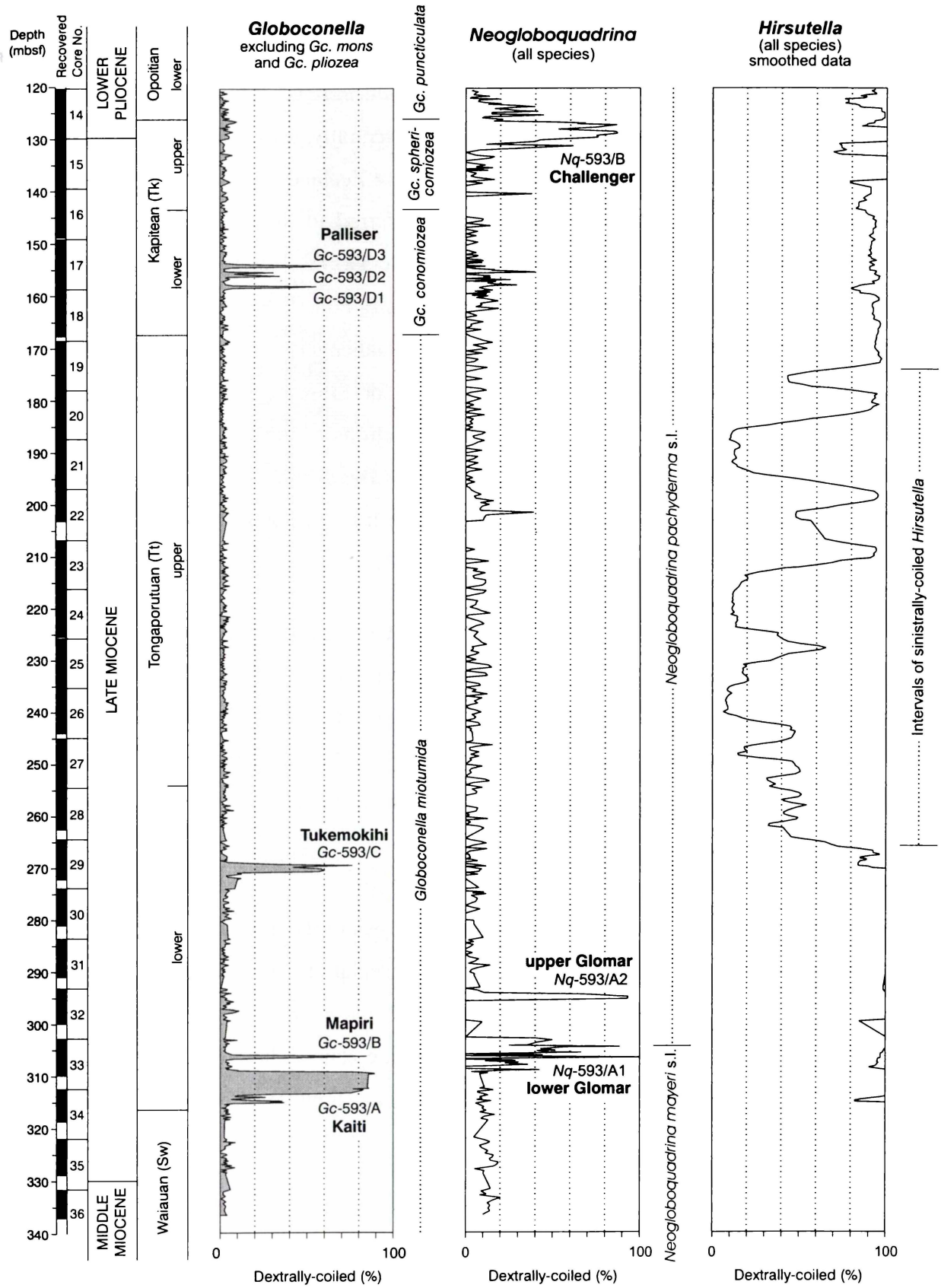


Figure 8.3 – Late Miocene coiling excursions. Coiling signatures associated with the planktic foraminiferal clades *Globoconella*, *Neogloboquadrina*, and *Hirsutella*. Narrow intervals with significant contributions of dextrally-coiled shells (*Gc*-593/A–D and *Nq*-593/A and B) are potentially useful for correlation. Intervals of sinistrally-coiled *Hirsutella* may also be useful for correlation.

Coiling excursions

Distinctive coiling excursions, where the long Miocene history of sinistral coiling in populations of *Globoconella* and *Neogloboquadrina* is interrupted by significant representations of dextrally-coiled shells, are potentially useful for the correlation and subdivision of late Miocene sequences in the New Zealand region (Figure 8.3). Narrow intervals of dextrally-coiled *Globoconella* are referred to as the *Gc*-593/A (Kaiti), *Gc*-593/B (Mapiri), *Gc*-593/C (Tukemokihi), and *Gc*-593/D1, *Gc*-593/D2, and *Gc*-593/D3 (Palliser) Coiling Zones; and intervals of dextrally-coiled *Neogloboquadrina*, the *Nq*-593/A1, *Nq*-593/A2 (Glomar), and *Nq*-593/B (Challenger) Coiling Zones. Intervals of sinistrally-coiled *Hirsutella* may also be useful for biostratigraphic subdivision of the upper Tongaporutuan. Although the coiling directions of planktic foraminifers can be determined with negligible error, even from shell fragments, coiling excursions are not unique biostratigraphic events and they should be used in conjunction with other faunal events to avoid possible miscorrelations.

The causes of coiling changes are poorly understood, although a biological model that links the reproductive success of sinistral and dextral subpopulations to the depth of the thermocline (Lohmann & Schweitzer 1990; Lohmann 1992) appears to apply to late Miocene populations of *Globoconella* at Site 593 (Cooke 2002). Similar biological relationships may also account for coiling excursions in *Neogloboquadrina* and *Hirsutella.*

Changes in abundance

The census at Site 593 identifies well defined changes in the abundance of some planktic foraminifers that are potentially useful for correlation, including acme zones of *Truncorotalia juanai* and *Hirsutella panda,* and the highest common occurrence of *Neogloboquadrina mayeri* s.l. (Figure 8.4). The acme zones relate to deep-dwelling forms and document changes within subsurface water masses (Southern Component Intermediate Water and Southern Component Mode Water), and the decrease in the abundance of *Nq. mayeri* s.l. relates to the species biogeographic withdrawal from the southern Tasman Sea region in the earliest late Miocene.

Appearances and disappearances

A succession of highest and lowest occurrences of planktic foraminifers, including biogeographic and evolutionary events, is identified at Site 593, although these are not

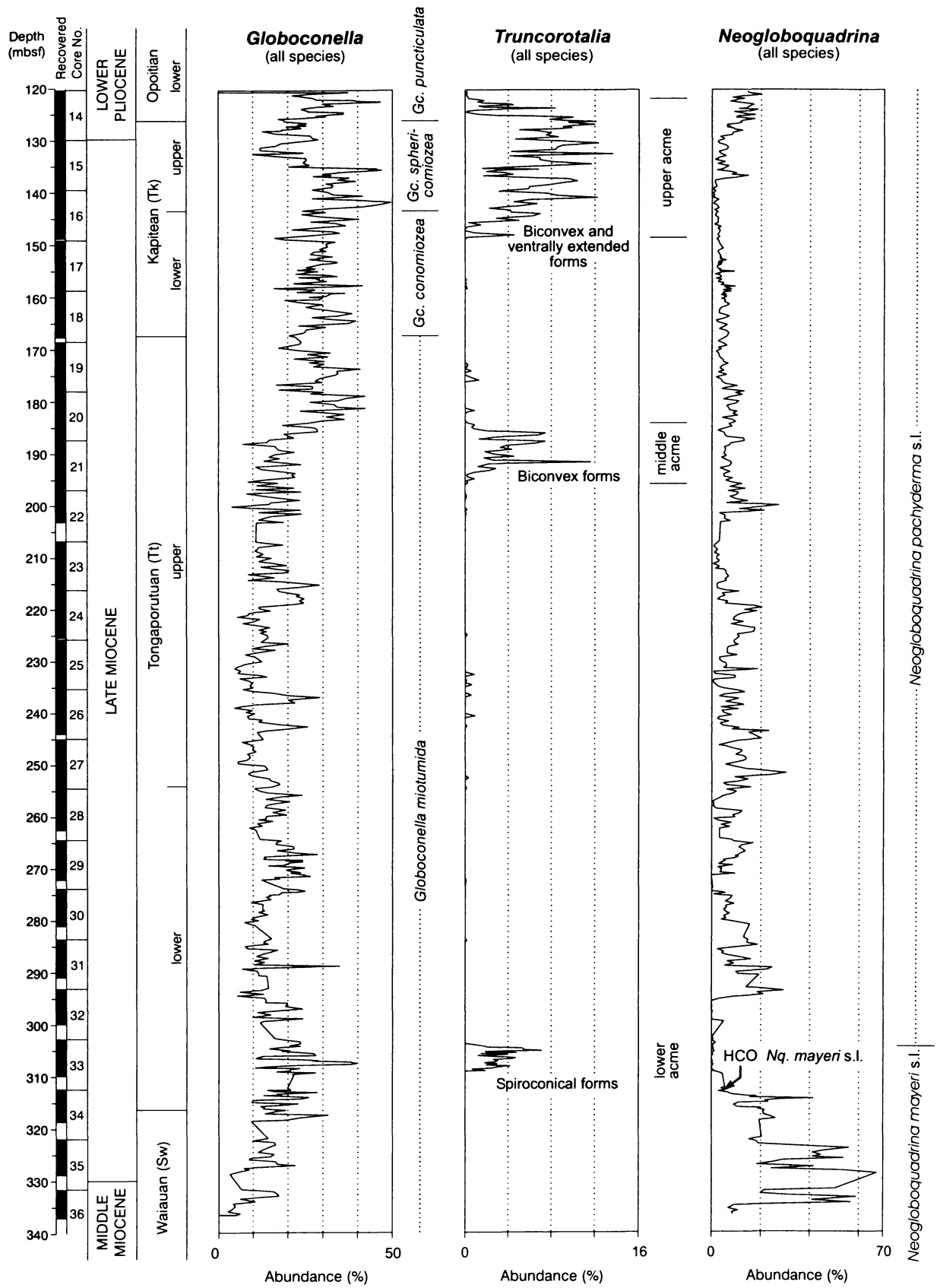


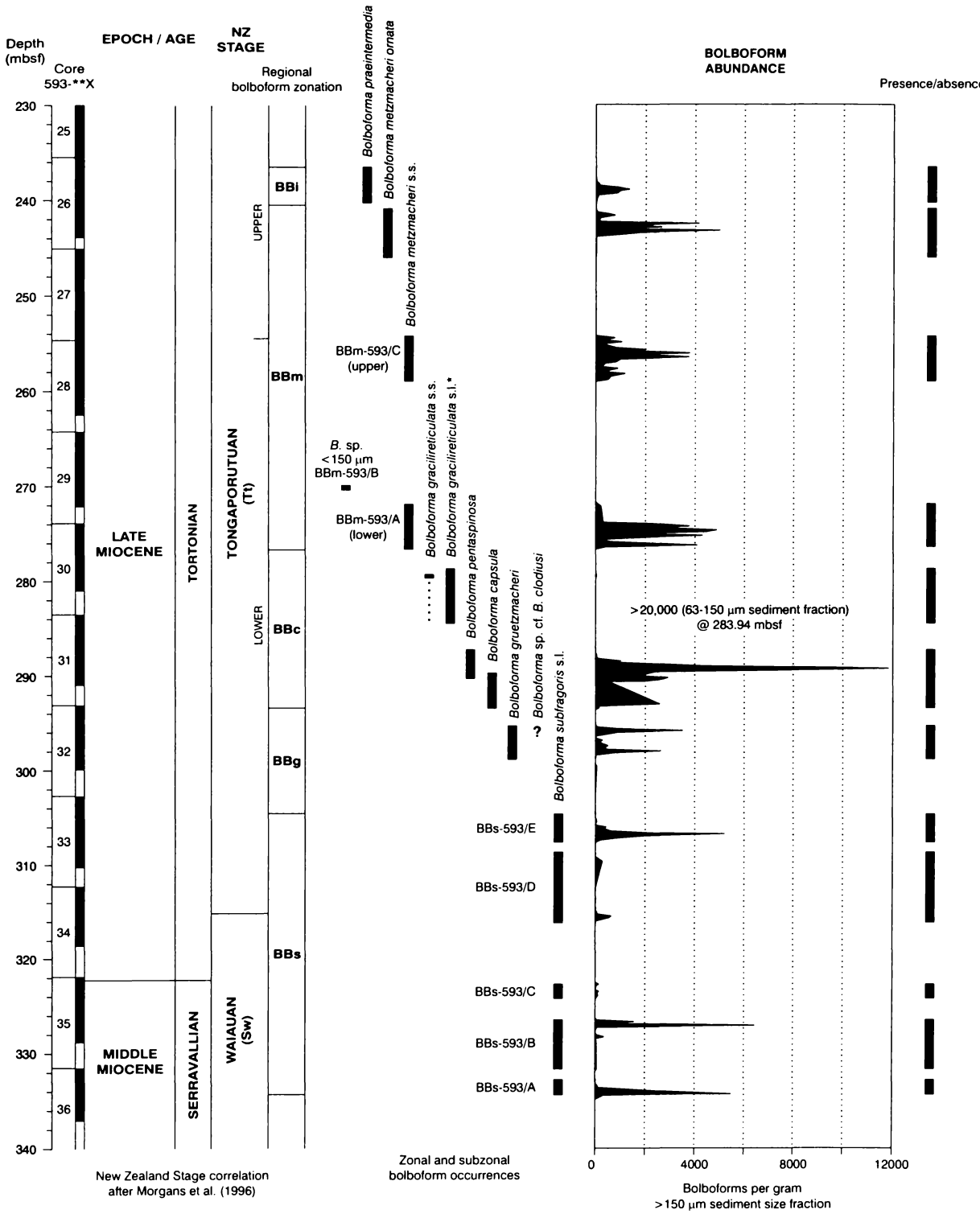
Figure 8.4 – Late Miocene changes in the abundance of the planktic foraminiferal clades *Globoconella, Truncorotalia,* and *Neogloboquadrina*. The onset of rapid evolution and divergence in *Globoconella* follows a marked increase in the clades abundance in the uppermost Tongaporutuan. Rapid evolutionary changes in *Truncorotalia* occur during the clades third regional invasion, when it successfully colonizes the New Zealand region. The disappearance of *Neogloboquadrina mayeri* s.l. and appearance of *Nq. pachyderma* occurs in an interval where the clade is relatively rare, the same interval where there are significant representations of dextrally-coiled shells (Figure 8.3).

evenly distributed through the late Miocene section (Figure 8.2). Biogeographic events including the highest common occurrence of *Neogloboquadrina mayeri* s.l., the highest occurrences of *Neogloboquadrina mayeri* s.l., *Globoquadrina dehiscens,* and *Hirsutella* cf. *ichinosekiensis* (weakly keeled), and the lowest occurrence of *Neogloboquadrina pachyderma,* largely occur in the lower Tongaporutuan. Evolutionary events including the lowest occurrences of *Globoconella conomiozea, Globoconella mons, Globoconella sphericomiozea, Globoconella pliozea, Globoconella puncticulata, Truncorotalia neojuanai* n. sp., *Truncorotalia* aff. *crassaconica,* and *Truncorotalia crassaformis* occur in the Kapitean. The intervening upper Tongaporutuan interval has a paucity of well defined planktic foraminiferal events.

The lower Tongaporutuan bioevents occur within the context of a staged withdrawal of warm-water taxa from the southern Tasman Sea region, including the disappearances of *Neogloboquadrina mayeri* s.l. and *Globoquadrina dehiscens,* and the subsequent withdrawal of most shallow-dwelling warm-water taxa in the lower upper Tongaporutuan (Figure 8.2). The following upper Tongaporutuan interval includes distinctive sinistrally-coiled populations of *Hirsutella scitula* that are not seen at any other time in the late Miocene (Figure 8.3). Coiling excursions in this taxon may be useful for subdivision of the upper Tongaporutuan, but increased coiling counts are needed to improve the reliability of the data. The onset of rapid evolution and divergence in *Globoconella* follows a marked increase in the abundance of the clade in the uppermost Tongaporutuan (Figure 8.4), and evolutionary changes in *Truncorotalia* occur during the youngest of three regional influxes of *Tr. juanai* (Figure 8.4) when the clade successfully colonized the New Zealand region.

BOLBOFORM RECORD – SITE 593

The unexpected discovery of bolboforms at Site 593, an enigmatic group of marine calcareous protophytes that have not been recognized in New Zealand before (Crundwell et al. 1997), supplements the record of planktic foraminifers and has led in Study 3 to a significant improvement in biostratigraphic resolution. Bolboform test sizes range from 70 to 240 μm and they resemble simple unilocular benthic foraminifers (Plate 8.7). They are comprised of a single hollow chamber or two embracing chambers with an imperforate monocrystalline calcite wall, and have a conical or tubular neck with a simple terminal aperture. Surface morphology ranges from smooth to highly ornamented, with spines, flanges, knobs, ridges, and reticulations.

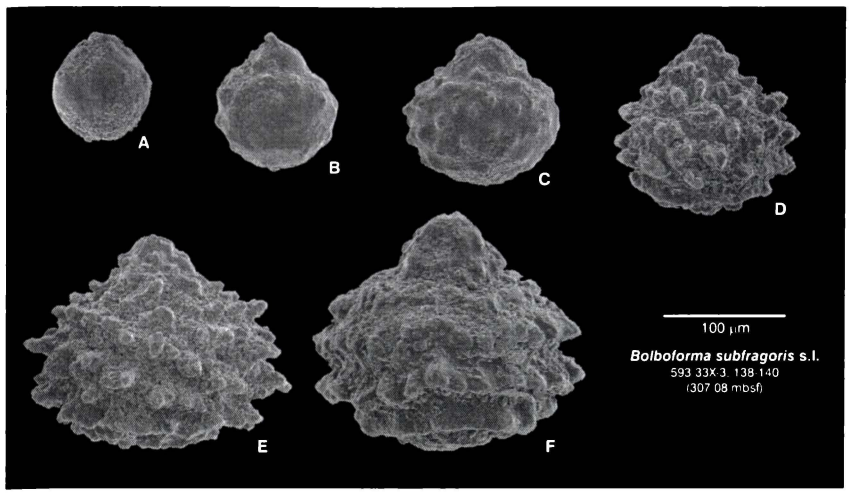


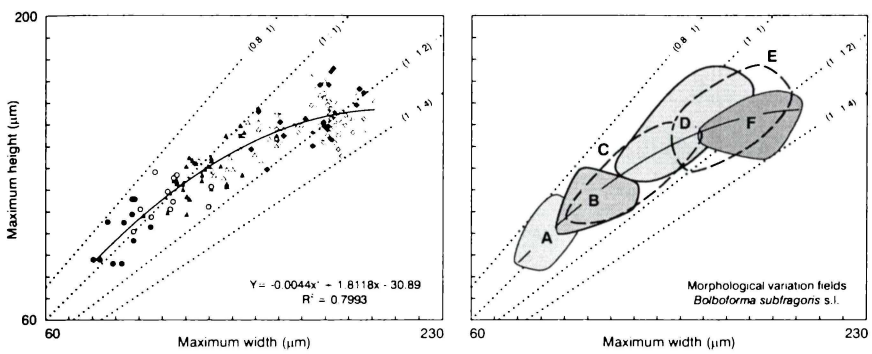
Species	Age(Ma)	Maximum abundance	Species	Age (Ma)	Maximum abundance
Bolboforma praeintermedia	236.52 - 240.32	1333	*Bolboform capsula*	289.73 - 293.51	2879
Bolboforma metzmacheri ornata	240.92 - 246.06	5000	*Bolboforma gruetzmacheri*	295.33 - 298.93	3068
Bolboforma metzmacheri s.s.			*Bolboforma subfragoris* s.l.		
- upper subzone	254.27 - 259.07	3793	BBs-593/E	304.66 - 307.70	5214
- lower subzone	271.94 - 277.55	4884	BBS-593/D	308.99 - 316.27	645
Bolboforma gracilireticulata s.l.	278.72 - 284.55	*>20000	BBs-593/C	322.72 - 324.30	136
Bolboforma gracilireticulata s.s.	279.33 - 279.75	28	BBs-593/B	326.50 - 331.69	6452
Bolboforma pentaspinosa	287.32 - 290.33	11840	BBs-593/A	332.80 - 334.43	5489

Figure 8.5 – Bolboform distribution, abundance, zonation, and stage correlation at Site 593. Maximum abundances normalized as specimens per gram of sediment (>150 µm sediment size fraction). **Bolboforma gracilireticulata* s.l. is a small species and is poorly represented in the >150 µm sediment size fraction, but reaches a maximum abundance of >20000 in the 125-150 µm sediment size fraction. The highest occurrence of *B. praeintermedia* marks the disappearance of bolboforms in the Southwest Pacific – younger occurrences are noted in the Indian Ocean and North Atlantic (Mackensen 1992; Spiegler 1999).

The Neogene record of bolboforms at Site 593 is largely confined to the latest middle and early late Miocene and it consists of a sequence of narrow bolboform subzones punctuated by intervals without bolboforms (Figure 8.5). The lower part of the sequence includes five subzones with heterogenous overlapping morphotypic populations of *Bolboforma subfragoris* s.l. which are described in open nomenclature, and the upper part includes eight subzones with a well defined succession of largely single species associations. In ascending species order, this succession includes *Bolboforma gruetzmacheri* n. sp., *B. capsula, B. pentaspinosa, B. gracilireticulata* s.l., *B. metzmacheri* (subzones BBm-593/A and C), *B. metzmacheri ornata,* and *B. praeintermedia.* Another subzone, BBm-593/B, comprising small smooth-walled phases of uncertain affinity, occurs between subzones BBm-593/A and C.

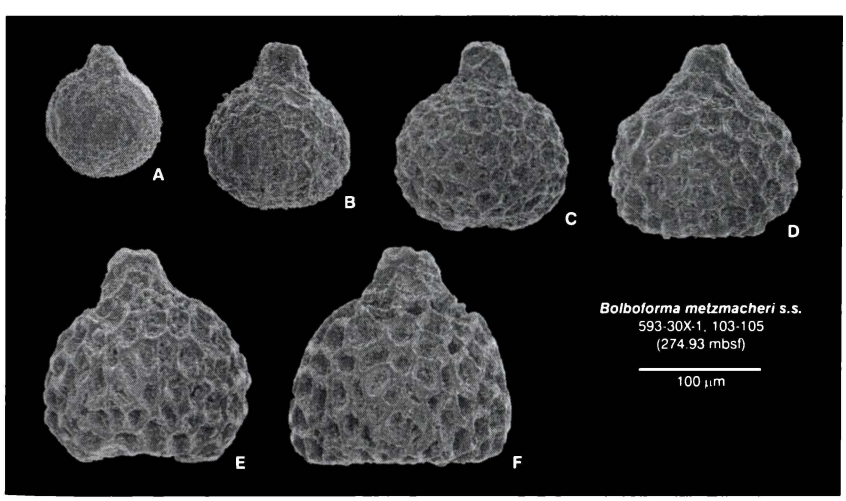
In a global context, the greatest number of bolboform species occurs during the late Eocene to early Oligocene, and the middle to late Miocene (Spiegler 1991). Their distribution is broadly bipolar and they occur most commonly in sediments interpreted to have originated in temperate waters at mid to high latitudes (Poag & Karowe 1986; Kennett & Kennett 1990; Spiegler 1991; Cooke et al. 2002). Their wide geographic distribution, combined with their distinctive morphology, their short ranges, and their resistance to dissolution, make them potentially useful biostratigraphic, paleobiogeographic, and paleoceanographic markers (Rögl & Hochuli 1976; Murray 1979; Müller et al. 1985; Poag & Karowe 1986). Bolboforms have generally been interpreted as phytoplanktic organisms (Rögl & Hochuli 1976; Tappan 1980; Poag & Karowe 1986; Spiegler & von Daniels 1991), although comparative oxygen isotope data from the analysis of bolboform shells (Poag & Karowe 1986; Spiegler & Erlenkeuser 2001) suggest they spent at least part of their life cycle below the photic zone, in the mid to lower levels of the water column. Darling et al. (2000) have recently demonstrated that upwelling systems and subsurface boundary currents are important factors in maintaining the bipolar distribution of cool-water genotypes in some modern planktic foraminifers. It is speculated that a similar scenario may account for the bipolar distribution of bolboforms in the fossil record. This suggests their entrainment in subsurface water masses may have been part of a strategy for reproduction and dispersal.

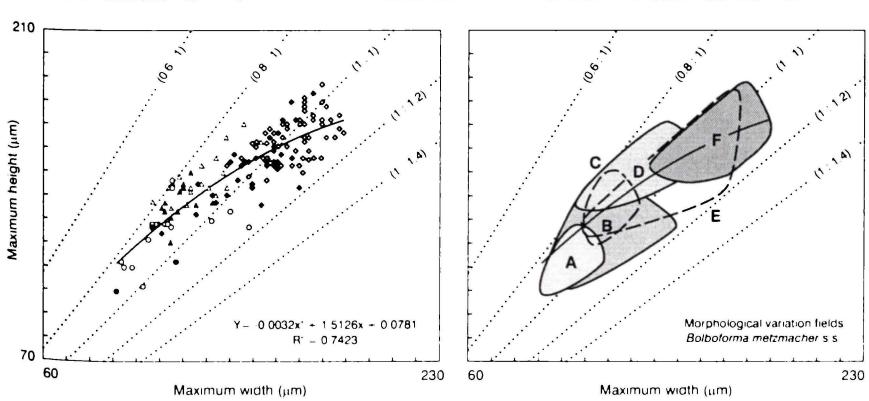




Bolboforma subfragoris s.l.

A	•	small, smooth-walled
B	○	small, rudimentary ornament
C	▲	intermediate, nodular ornament
D	△	intermediate, spinose ornament
E	◆	large ornate, spirospinose ornament
F	◇	large ornate, partially fused ornament

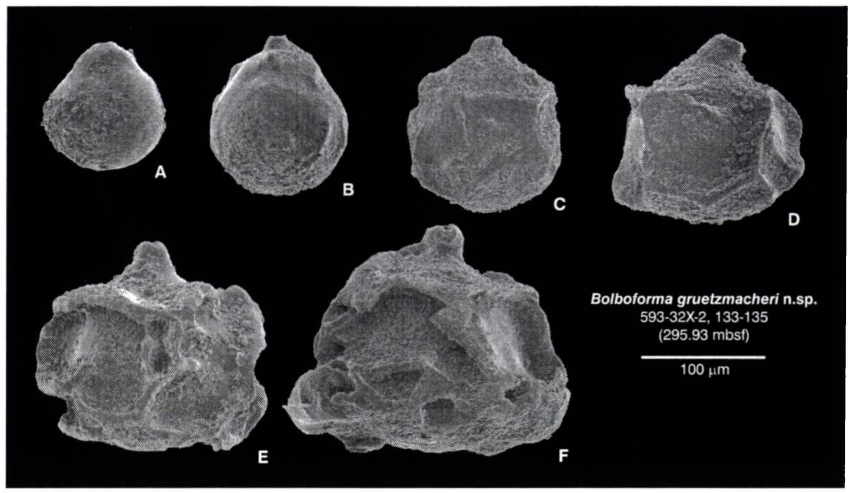


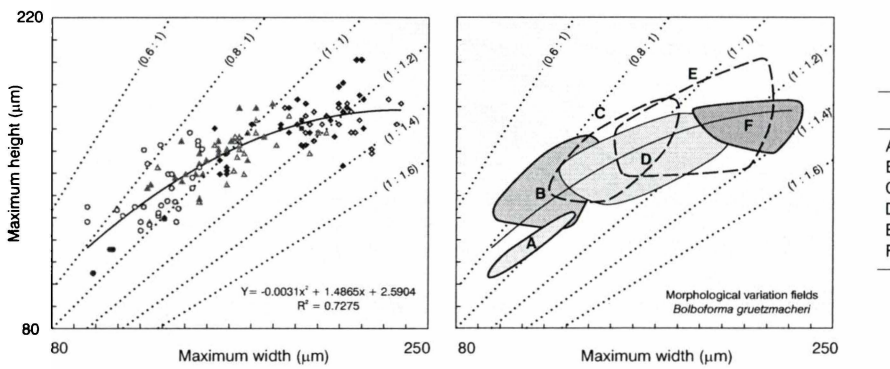


Bolboforma metzmacheri s.s.

A	•	small, smooth-walled
B	○	small, rudimentary ornament
C	▲	intermediate, weakly-ridged ornament
D	△	intermediate, cancellate ornament
E	◆	large ornate, cancellate ornament
F	◇	large ornate, flattened aboral surface

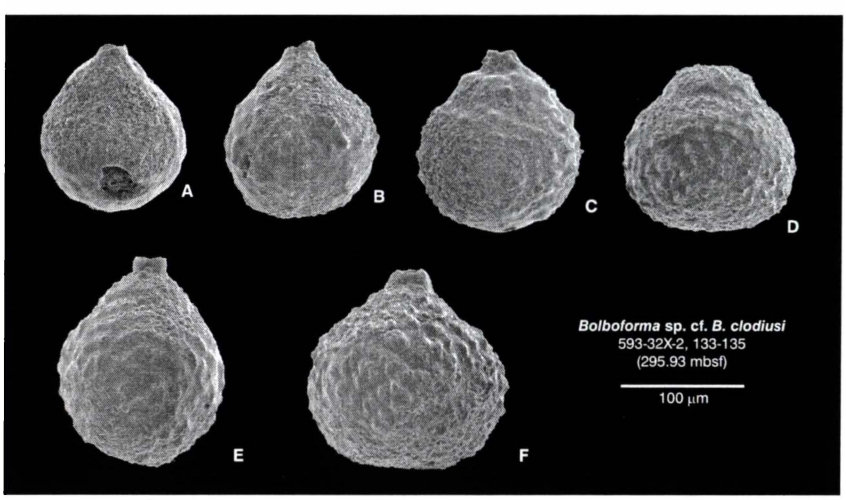
Figure 8.6 – Size related intraspecific morphological variation in large, well preserved populations of *Bolboforma subfragoris* s.l. and *B. metzmacheri* s.s. from DSDP Site 593. Cross plots of maximum meridional diameter (width) versus maximum axial length (height) showing the variation fields associated with visually assigned morphological classes (A–F). The morphological trend of each population is highlighted by polynomial curves fitted to the data (solid line). Linear trend-lines (dotted lines) are shown for comparison.

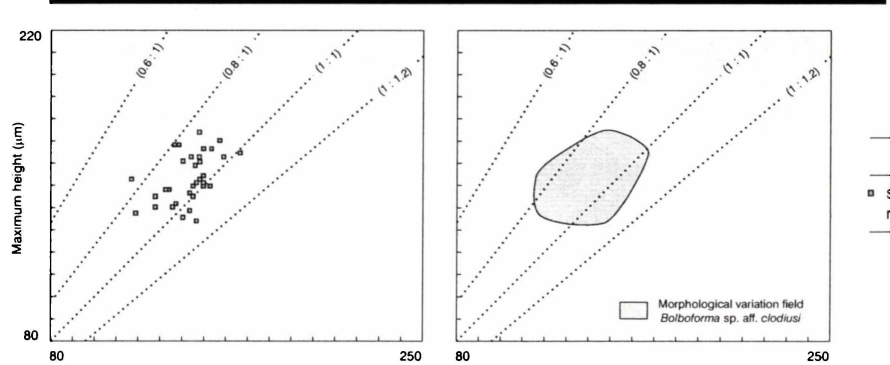




Bolboforma gruetzmacheri n.sp.

A ● small, smooth-walled
B ○ small, rudimentary ornament
C ▲ intermediate, weak ornament
D △ intermediate, ridged ornament
E ◆ large, irregularly-ridged ornament
F ◇ large, partially embracing ornament





Bolboforma sp. aff. *clodiusi*

▫ small and intermediate phases with rudimentary and weakly spinose onaments

Figure 8.7 – Size related intraspecific morphological variation in large, well preserved populations of *Bolboforma gruetzmacheri* n. sp. and *B.* sp. aff. *clodiusi* from the same sample. This is one of the few examples at DSDP Site 593 where two bolboform species occur together. Cross plots of maximum meridional diameter (width) versus maximum axial length (height) showing the variation fields associated with visually assigned morphological classes (A–F). The morphological trend associated with increasingly larger tests of *B. gruetzmacheri* is shown by the polynomial curve fitted to the data (solid line). Linear trend-lines (dotted lines) are shown for comparison.

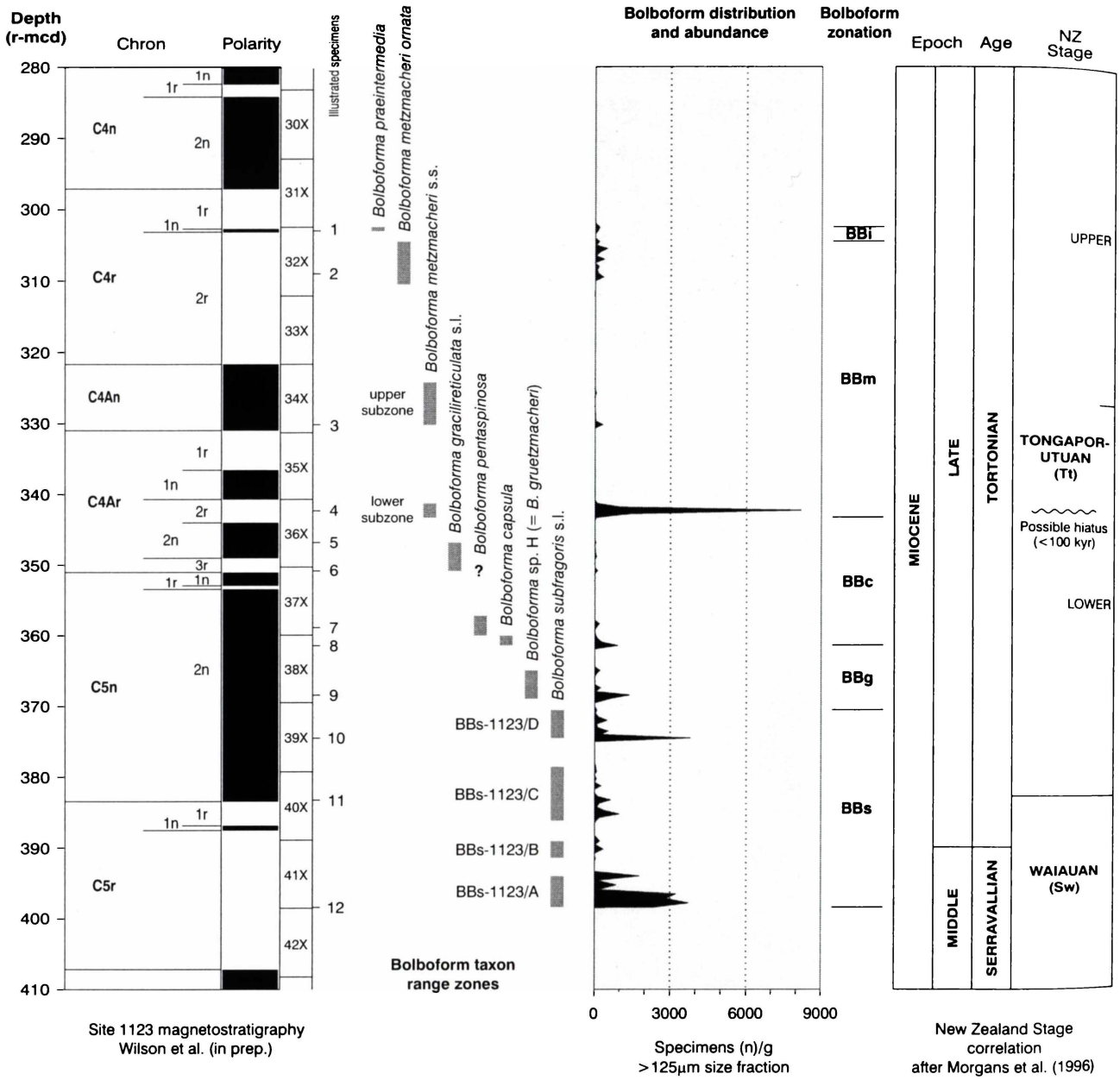
MORPHOLOGICAL VARIATION IN BOLBOFORMS

A population approach to the study of bolboforms at Site 593 has identified in Study 4 a similar pattern of size-related morphological variation in at least three monocamerate species that have contrasting surface ornaments: *Bolboforma subfragoris* s.l., *B. gruetzmacheri,* and *B. metzmacheri* s.s. This involves a gradual transformation in test shape and surface ornamentation, beginning with small, smooth, thin-walled, subspheroidal-shaped tests and ending with large, thick-walled, highly ornate, squat lagenoid-shaped tests (Figures 8.6 and 8.7). Because different morphological phases in the transformation have contrasting test shapes and ornaments they have the potential to be interpreted as different species. Taxonomic confusion is further compounded by the similarity of many small, smooth-walled and weakly ornamented phases. These features are common in bolboform populations and have contributed to the misinterpretation of some species and their assigned ranges.

The morphological transformation in the studied populations involves the addition of calcite to the outer surface of the test wall. This is interpreted to have occurred while the bolboforms were entrained in subsurface flows of Southern Component Intermediate Water. In this respect the increased complexity of ornamention may have been a morphological adaptation to counter the loss of buoyancy as calcite was added to the outer surface of the test wall. This would have presumably contributed to the entrainment and dispersal of bolboforms in the flow of subsurface water masses, and it suggests that the tests of some bolboforms at least may represent a disseminal phase in the life cycle of this enigmatic group of microfossils.

BIOMAGNETOCHRONOLOGY – SITE 1123

In Study 5, the documentation of high-resolution bolboform and planktic foraminiferal distribution data from the late Miocene section at ODP Site 1123 on Chatham Rise (41.8°S, 171.5°W; 3290 m water depth) has enabled these data to be integrated with the magnetostratigraphic record from the same site (Wilson et al. in prep.) and age calibrated in terms of the geomagnetic polarity time scale (GPTS-95). This represents a major advance in New Zealand late Miocene magnetobiochronology, although the calibration of bioevents at this deep oceanic site is confined to species and morphotypes that have a high resistance to dissolution (Figures 8.8 and 8.9). These include bolboform subzones *B. subfragoris* s.l. (11.56-10.61 Ma), *Bolboforma* sp. H (10.46-10.31 Ma), *B. capsula* (10.20-



Species	Depth (r-mcd)	Max abundance	Species	Depth (r-mcd)	Max abundance
Bolboforma praeintermedia	302.50 - 303.00	171	*Bolboforma capsula*	360.00 - 361.40	918
Bolboforma metzmacheri ornata	304.50 - 310.50	480	*Bolboforma* sp. H	364.90 - 368.90	1385
Bolboforma metzmacheri s.s.			*Bolboforma subfragoris* s.l.		
– upper subzone	324.20 - 330.20	310	– D (upper subzone)	370.50 - 374.50	3791
– lower subzone	341.30 - 343.30	8189	– C (small cyst-like phases)	378.50 - 386.20	978
Bolboforma gracilireticulata s.l.	346.80 - 350.80	109	– B (small cyst-like phases)	389.02 - 391.43	341
Bolboforma pentaspinosa	358.30 - 360.00	188	– A (lower subzone)	393.97 - 398.42	2836

Figure 8.8 – Bolboform distribution and abundance at ODP Site 1123 (data are given in Appendix 5.2). Max abundance = specimens (n) /g in the >125 µm sediment size fraction. Bolboform zonation based on Spiegler & Daniels (1991), Grützmacher (1993), and Study 3. BBi = *Bolboforma intermedia* Zone, BBm = *B. metzmacheri* Zone, BBc = *B. capsula* Zone, BBg = *B. gruetzmacheri* Zone (Study 3), BBs = *B. subfragoris* s.l. Zone.

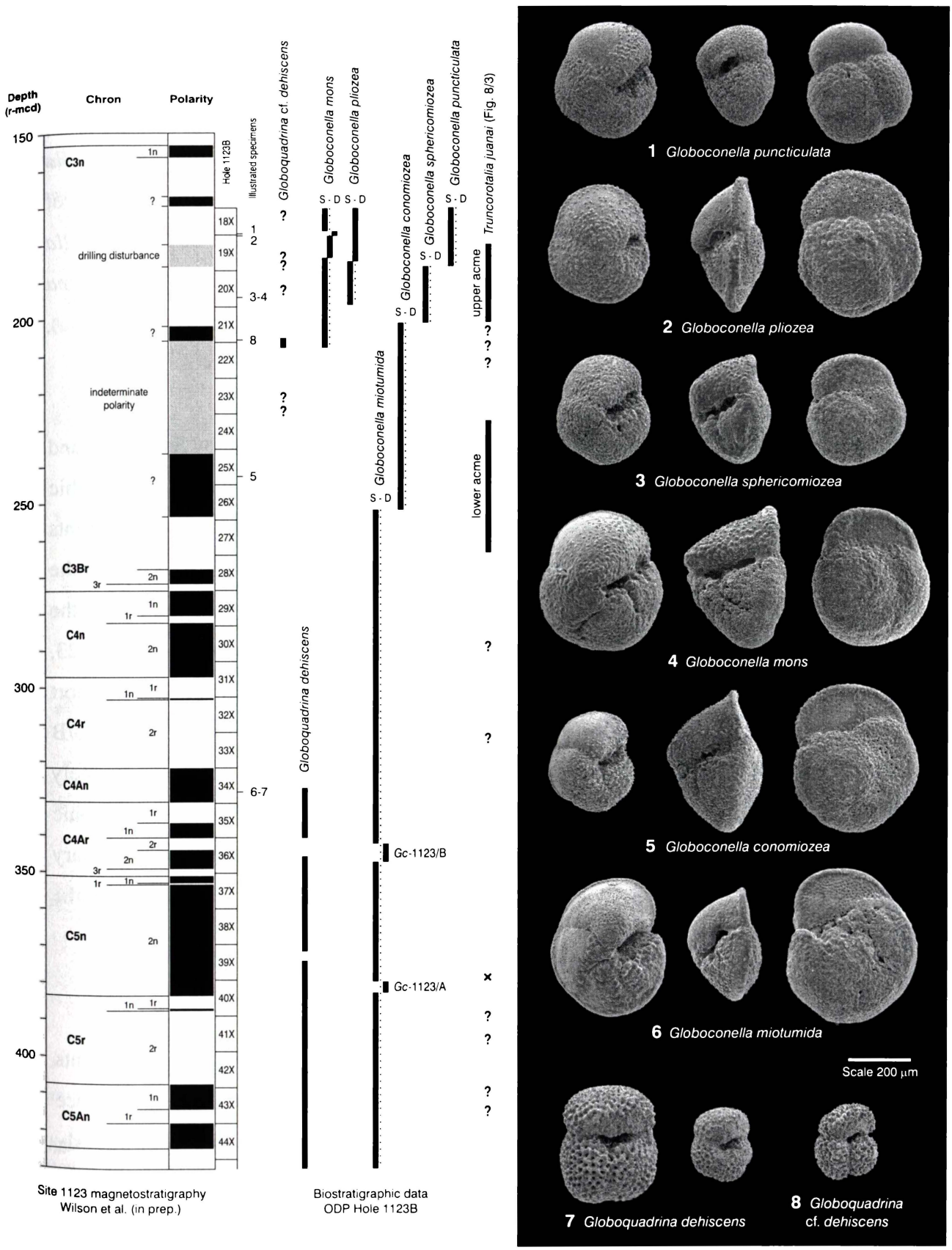


Figure 8.9 – Distribution of important dissolution-resistant planktic foraminifers 1123B-18X to 44X. The numbered horizons of illustrated specimens (1–7) correspond to the adjacent SEM images. All images are shown to the same scale. S = sinistral-coiled, D = dextral-coiled.

10.13 Ma), *B. pentaspinosa* (10.15-10.08 Ma), *B. gracilireticulata* s.l. (9.75-9.61 Ma), *B. metzmacheri* s.s. (lower subzone 9.54-9.34 Ma, upper subzone 9.01-8.78 Ma), *B. metzmacheri ornata* (8.45-8.28 Ma), and *B. praeintermedia* (8.25-8.21 Ma); abundance spikes associated with the uppermost *B. subfragoris* s.l. subzone (10.61 Ma) and the lower *B. metzmacheri* s.s. subzone (9.54 Ma); dextral-coiling excursions in *Globoconella miotumida* (10.93-10.82 Ma and 9.62-9.42 Ma); the regional disappearance of *Globoquadrina dehiscens* (8.88 Ma); and the evolutionary appearances of *Globoconella conomiozea* (c. 6.87 Ma), *Globoconella mons* (c. 5.72 Ma), *Globoconella sphericomiozea* (c. 5.53 Ma), *Globoconella pliozea* (c. 5.39 Ma), *Truncorotalia crassaformis* (c. 5.15 Ma), and *Globoconella puncticulata* (c. 5.11 Ma).

A scatter plot based on the stratigraphic positions of 33 bioevents shared by Sites 1123 and 593 approximates a linear line of correlation. The tight grouping of the biostratigraphic data around the line of correlation, and the consistency of their order, suggest most events are reliable homotaxial criteria and are synchronous or near-synchronous, even though the sites are off opposite sides of New Zealand. This affirms the regional utility of the biostratigraphic framework and it also attests to the continuity of the sequence at Site 1123, relative to Site 593. The only break in the late Miocene sequence at Site 1123 is a short hiatus of less than 100 k.y. within Chron C4Ar.2r, which corresponds to the BBm-1123/B subzone. The calibration of bioevents in the lower part of the late Miocene is extremely robust, although uncertainty concerning the interpretation of the magnetostratigraphic sequence between Chron C3Br.2r and C3n.1n (Wilson et al. in prep.) places a cautionary caveat on the reliability of the chronology through this part of the section and the calibration of bioevents near the Miocene-Pliocene boundary.

AGE MODELS – SITE 593

The late Miocene magnetobiochronology of bolboform and planktic foraminiferal events at Site 1123 is extended in Study 6 to the well preserved calcareous microfossil sequence of the same age at Site 593, which includes bioevents that are missing or poorly represented in the dissolution affected late Miocene section at Site 1123. A linear age (L-Age) model for site 593, constrained by 33 shared bioevents between Sites 1123 and 593, provides a close fit to the biostratigraphic data, but it does not take into account hiatuses and short-term sedimentary variations (Figure 8.10). An alternative segmented age (S-Age) model accommodates these sedimentary variations, at least in the older part of the

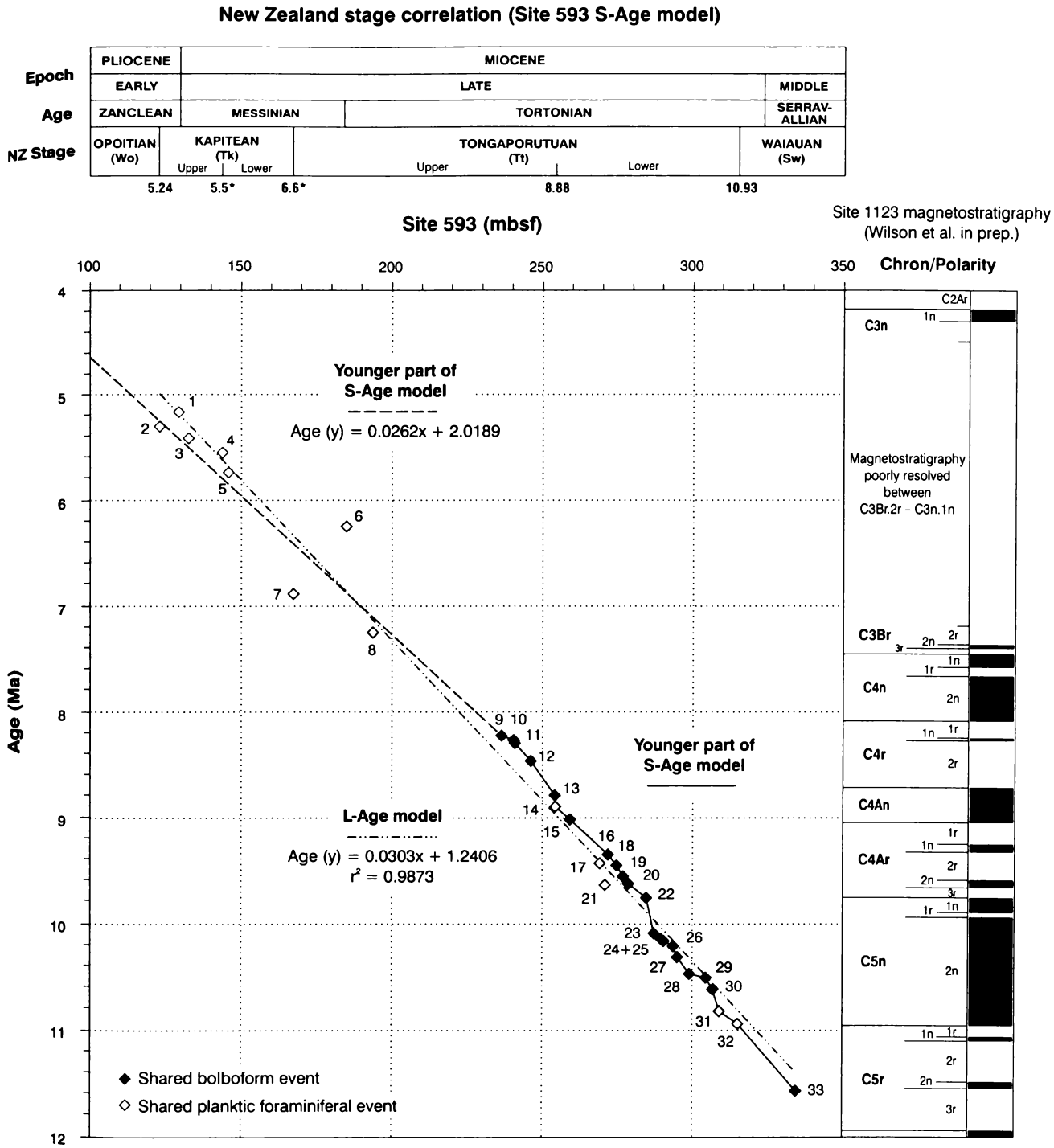


Figure 8.10 – Late Miocene age models for Site 593. Linear age (L-Age) model, based on computed regression through all biostratigraphic data shared between Sites 593 and 1123 (bioevents 1–33). The older part of the segmented age (S-Age) model, is based on computed regression between pairs of shared bioevents (excluding bioevents 21 and 17). The younger part of the S-Age model is based on a regression line between bioevent 9 and the base of Chron C2An.3n (excluding bioevents 1–8). Numbered bioevents, biostratigraphic, and magnetochronologic data are given in Table 8.2. *Ages for lower and upper Kapitean Stage boundaries follow Morgans et al. (1996), other stage boundaries are dated on the basis of the S-Age model.

sequence (11.56-8.21 Ma) where the model is robustly constrained by 22-pairs of closely spaced bioevents. The younger part of the S-Age model (8.21-3.58 Ma) is constrained by only two chronostratigraphic tie-points – the highest occurrence of *Bolboforma praeintermedia* and the base of Chron C2An.3n. There are no bolboforms and relatively few reliable planktic foraminiferal bioevents in the latest Miocene at Sites 1123 and 593, particularly in the upper Tongaporutuan and lower Kapitean.

The S-Age model is important as it establishes, for the first time, a robust late Miocene chronology for Site 593, based entirely on local magnetobiochronologic data. Previous late Miocene age models for the site have relied on a small number of tenuous paleontological, magnetostratigraphic, and stable isotope correlations with dated horizons from onland New Zealand and from outside the region (Wei 1992; Head & Nelson 1994; Schneider & Kennett 1996), and entirely non-local biochronostratigraphic data (Lazarus et al. 1995; Spence-Cervato 1999). The S-Age model which is constrained by magnetochronologic data from Site 1123 enables interpolated ages to be assigned to another 36 bioevents for which there are no reliable age data. This brings the total number of locally age-calibrated late Miocene bolboform and planktic foraminiferal events to 69 – a major advance in chronostratigraphic resolution of New Zealand late Miocene sequences.

CORRELATION OF IMPORTANT LATE MIOCENE SEQUENCES

Biostratigraphic reviews of important late Miocene sections in onland New Zealand: Kaiti Beach, Gisborne; Tukemokihi Stream, northern Hawkes Bay; North Taranaki coast; and Pukearuhe-1 (Figures 8.11), enable robust biostratigraphic correlations to be made in Study 7 with oceanic Sites 593 and 1123 (Figures 8.12). These data demonstrate that the Kaiti Beach section spans a relatively short period of time (c. 0.2 m.y.) and that the c. 2000 m thick Tukemokihi Stream section is interrupted by at least three or possibly four major unconformities. The similarly thick North Taranaki coastal section, which includes the Tongaporutuan stratotype, is shown to represent less than half of all Tongaporutuan time. This coastal section includes a disrupted interval near the base of the stratotype, and rocks of lowermost Tongaporutuan age are missing. Pukearuhe-1 also has a disrupted lower Tongaporutuan interval and is missing lowermost Tongaporutuan rocks.

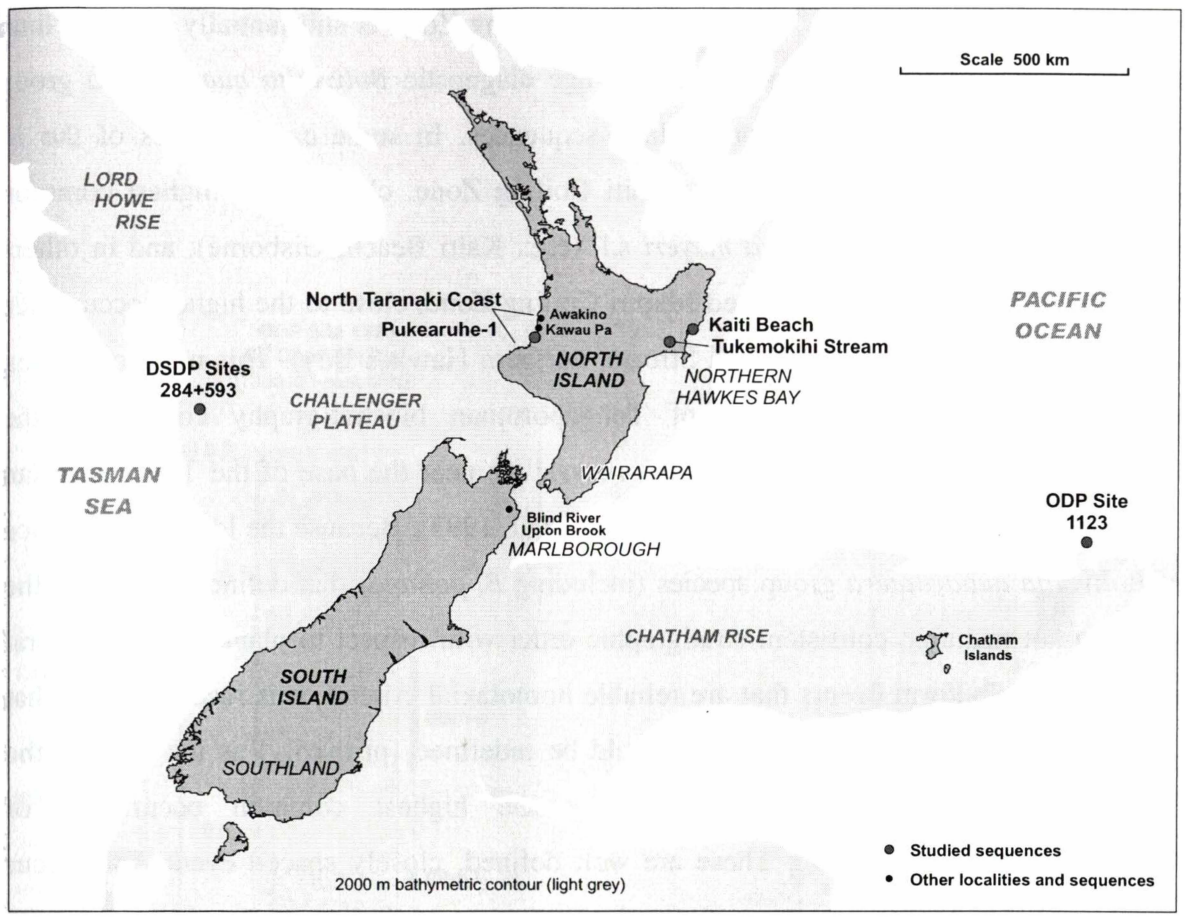


Figure 8.11 – Locality map of New Zealand region showing important late Miocene sequences in onland New Zealand and oceanic Sites 593 and 1123.

ADVANCES IN NEW ZEALAND LATE MIOCENE STAGE CORRELATIONS

The following sections, not tied directly to the numbered thesis studies, expand upon the correlation and dating of late Miocene stages in onland New Zealand.

Lower Tongaporutuan

Since the Tongaporutuan Stage was introduced by Finlay & Marwick (1940), most biostratigraphers have used the presence of distinctive benthic foraminiferal species of the *Bolivinita quadrilatera* group (*B. quadrilatera, B. pohana, B.* cf. *pohana*, *B. pliozea* and related forms) as the primary faunal criterion to distinguish between rocks of Waiauan and Tongaporutuan age. However, the recognition of the Tongaporutuan Stage in deep-water sequences lacking age diagnostic benthic foraminifers has continued to be a problem (Scott 1992). An interval of dextrally-coiled *Globoconella miotumida* that occurs just above the biostratigraphically defined base of the Tongaporutuan stratotype (Scott 1992; King et al. 1993), and has been used to correlate Tongaporutuan sequences (Scott 1995), is shown in Study 7 to be the newly named Tukemokihi Coiling Zone and not the Kaiti Coiling Zone

as reported by Scott (1995). The Tukemokihi Coiling Zone is substantially younger than the stratigraphic level where species of the age diagnostic *Bolivinita quadrilatera* group first appear in some eastern North Island sequences. In some cases species of the *B. quadrilatera* group appear below the Kaiti Coiling Zone, close to the highest common occurrence of *Neogloboquadrina mayeri* s.l. (e.g., Kaiti Beach, Gisborne); and in others they appear below the newly named Mapiri Coiling Zone, close to the highest occurrence of *Nq. mayeri* s.l. (e.g., Tukemokihi Stream, northern Hawkes Bay). This new correlation resolves a long-standing enigma of Tongaporutuan biostratigraphy concerning the anomalous absence of *Neogloboquadrina mayeri* s.l. near the base of the Tongaporutuan stratotype in North Taranaki (Scott 1992; King et al. 1993). Because the lowest occurrence of *Bolivinita quadrilatera* group species (including *B. pohana*) that define the base of the stage do not maintain consistent stratigraphic order with respect to planktic foraminiferal events, nor bolboform events that are reliable homotaxial criteria, it is recommended that the base of the Tongaporutuan Stage should be redefined (primarily) as the base of the Kaiti Coiling Zone and, secondarily, by the highest common occurrence of *Neogloboquadrina mayeri* s.l. These are well defined, closely spaced events that occur near to some of the earliest New Zealand occurrences of *Bolivinita quadrilatera* group species. The emended faunal criteria locate the stage boundary near the base of Chron C5n.2n (10.93 Ma) – 0.37 m.y. younger than Morgans et al. (1996) report for the stage boundary, and 0.27 m.y. younger than the international middle-late Miocene boundary (Berggren et al. 1995). The older part of the late Miocene coastal section in North Taranaki, between Awakino and the base of the stratotype at Kawau Pa (Figure 8.11), does not include the Kaiti Coiling Zone or the highest common occurrence of *Nq. mayeri* s.l. A suitable boundary section for the base of the Tongaporutuan Stage is unlikely to be found in North Taranaki because of a widespread regional unconformity (King et al. 1993; King & Thrasher 1996), but there are sections in the eastern North Island and Southland that are potentially uninterrupted across the lower boundary and are worthy of investigation as standard reference sections for the base of the stage.

Upper Tongaporutuan

The sudden disappearance of *Globoquadrina dehiscens* is one of the most readily recognizable planktic foraminiferal events within the Tongaporutuan and it is used to subdivide the stage into lower and upper parts (Scott 1992). Its disappearance from New Zealand is poorly understood, but has been attributed to a contraction in the species

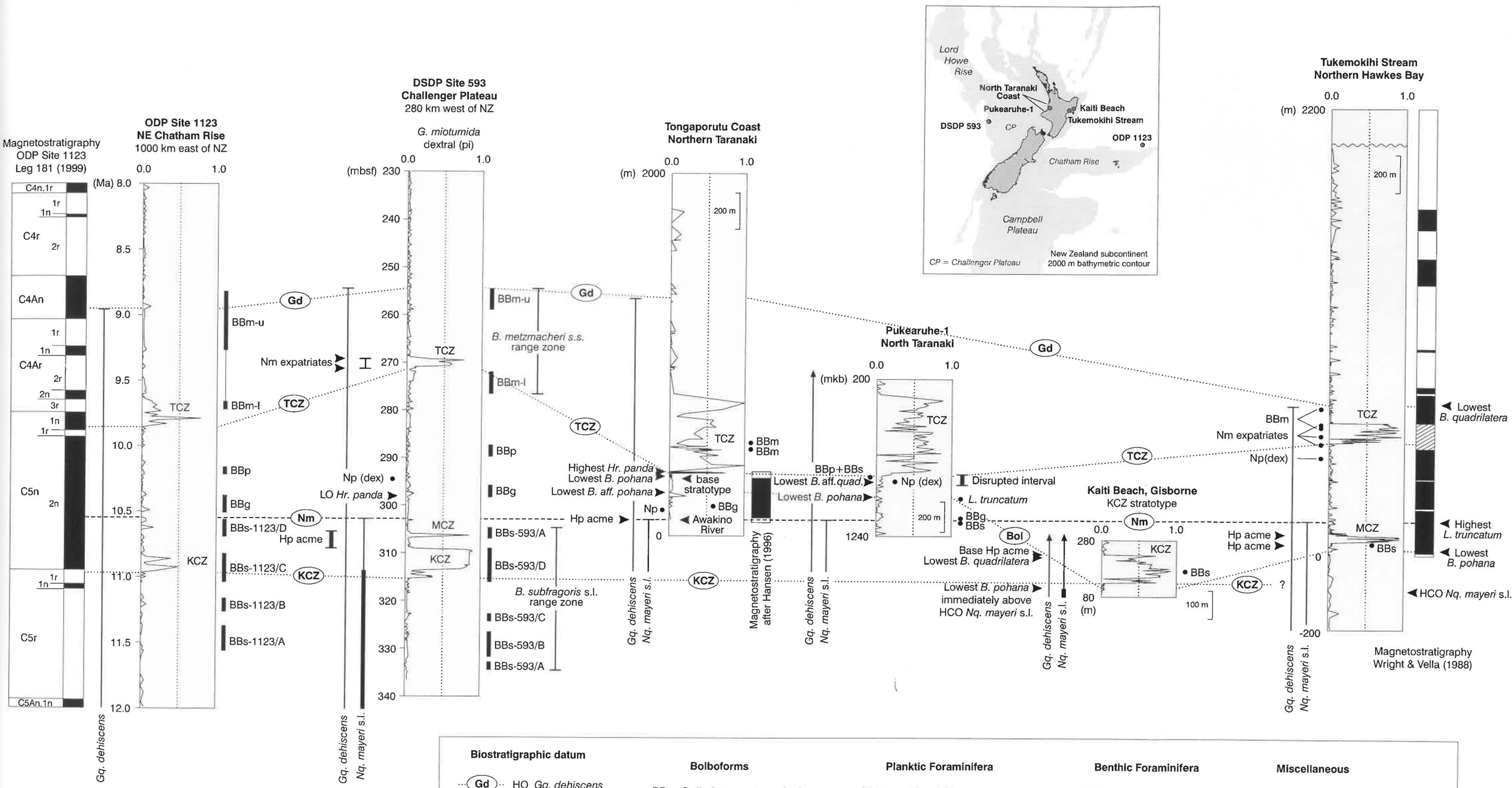


Figure 8.12 – Correlation of late Miocene oceanic sequences from Sites 593 and 1123, and uplifted marine sequences from onland New Zealand.

biogeographic range as it retreated towards lower latitudes (Edwards 1987; Jenkins 1992), where it extinction occurs near the Miocene-Pliocene boundary (Kennett & Srinivasan 1975, 1983; Hodell & Kennett 1986).

The highest occurrence of *Gq. dehiscens* is dated at 8.88 Ma on the basis of the magnetostratigraphy of Site 1123 (Study 5). This is substantially younger than the 10.1 Ma magnetochronologic age that is reported by Morgans et al. (1996) from Tukemokihi Stream in northern Hawkes Bay (Wright & Vella 1988). A review of the biostratigraphy of Tukemokihi Stream and new zircon-fission track dates on tephra layers above the highest occurrence of *Gq. dehiscens* (Peter Kamp pers. comm. 1998) suggest the magnetostratigraphic sequence is interrupted near the highest occurrence of *Gq. dehiscens*. This bioevent is interpreted to occur within Chron C4An, which is considered to be juxtaposed over Chron C5n.2n (Figure 8.12). The revised age for the top of the lower Tongaporutuan Stage results in a more-or-less equal subdivision of the stage, whereas previously the upper Tongaporutuan was considered to be of much longer duration than the lower Tongaporutuan.

The sudden disappearance of *Gq. dehiscens* is a well defined and possibly synchronous event in most late Miocene oceanic and neritic sequences in New Zealand, although rare early Pliocene occurrences of *Gq. dehiscens* have been noted in some eastern North Island sequences (Edwards 1987). Rare occurrences of *Gq.* cf. *dehiscens* have also been recorded in the vicinity of the Miocene-Pliocene boundary at Site 1123 (Study 5). These younger occurrences are interpreted as expatriates that have been transported to the New Zealand region during periods of invigorated flows associated with the East Australian Current and Tasman Front. The presence of these specimens places a cautionary caveat on the use of highest occurrence of *Gq. dehiscens* for the top of the lower Tongaporutuan Stage, but does not detract too much from the use of the species sudden disappearance as a boundary event.

Lower Kapitean

The base of the Kapitean Stage is defined in terms of molluscan criteria, and has an age of 6.6 Ma (Morgans et al. 1996) based on the magnetostratigraphic sequence at Upton Brook, Marlborough (Roberts et al. 1994). However, the consistent recognition of the stage in sequences lacking age diagnostic molluscs continues to be a problem. There are few

reliable planktic foraminiferal criteria in the vicinity of the stage boundary, although the lowest occurrence of *Globoconella conomiozea* has been used as a low-level proxy event, even though it has not been reliably correlated with the entry of Kapitean molluscs. The planktic foraminiferal datum is also problematic, as it is subject to taxonomic confusion (Kennett 1966; Chaproniere 1973; Malmgren & Kennett 1981) and there are conflicting views concerning the species taxonomic status (Scott et al. 1990). Changes to taxonomic concepts and the interpretation of globoconellid populations have also resulted in conflicting correlations concerning the use of the lowest occurrence of *Gc. conomiozea*. In order to stabilize Kapitean Stage correlations in sequences lacking age diagnostic molluscs, the lowest occurrence of *Gc. conomiozea* is redefined as the horizon where 10% or more of fully grown specimens in anagenetic populations of *Gc. miotumida* and *Gc. conomiozea* have more than four and one-half chambers in the outer whorl (Study 2). The emended datum occurs at Site 1123, within an interval of indeterminate polarity and it has an interpolated age of 6.87 Ma. A Shaw-plot of biostratigraphic data from Sites 1123 and 593 suggests the datum may be located too low in the magnetostratigraphic sequence at Site 1123 and an alternative age of 6.40 Ma has been assigned to the datum based on the S-Age for Site 593 (Study 6). Neither age agrees precisely with the age determination for the base of the stage at Upton Brook, but the datum is still useful as a low-level proxy event. More work is needed on the Kapitean stratotype at Kapitea Creek, Westland, and the magnetostratigraphic sequences at Upton Brook and Blind River, Marlborough, to determine more precisely the stratigraphic relationships between the appearance of Kapitean molluscs and the emended definition for the lowest occurrence of *Gc. conomiozea.*

Upper Kapitean

The base of the upper Kapitean Stage is defined in terms of the lowest occurrence of *Globoconella sphericomiozea*, an event that was originally used by Scott (1980) as an option for the boundary between the Kapitean and Opoitian Stages. The entry of the species follows the emended criteria of Scott (1980) and is defined as the horizon where mixed adult populations of *Gc. conomiozea* and *Gc. sphericomiozea* contain 5% or more of unkeeled specimens. Where good planktic assemblages are available this has proven to be a very reliable datum, and in onland New Zealand it has been assigned an age of 5.5 Ma (Morgans et al. 1996) based on the revised magnetostratigraphy of Blind River, Marlborough (Roberts et al. 1994). This agrees closely with the interpolated age of 5.53

Ma for the datum at Site 1123, which occurs in an interval of indeterminate polarity. At Site 593 where the datum is reliably located in large, moderately well preserved globoconellid populations, it is assigned an age of 5.87 Ma based on the S-Age model for the site (Study 6). These data suggest the lowest occurrence of *Gc. sphericomiozea,* which defines the base of the Kapitean Stage, is reliably correlated in New Zealand with the middle of Chron C3r, a horizon that is slightly older than the international Miocene-Pliocene boundary, which occurs towards the younger end of Chron C3r (Berggren et al. 1995). The slightly older age for the stage datum at Site 593 is attributed to uncertainty in the upper part of the S-Age model.

Lower Opoitian

The lowest occurrence of *Globoconella puncticulata* was introduced by Scott (1980) as one of two possible options for the boundary between the Kapitean and Opoitian Stages. The alternative option, the lowest occurrence of *Gc. sphericomiozea,* has subsequently been adopted as the primary faunal criterion for the base of the upper Kapitean Stage (see earlier). The first appearance of *Gc. puncticulata* was originally defined by Scott (1980) as the level where populations in the anagenetic morphological transformation between *Gc. sphericomiozea* and *Gc. puncticulata* contained no keeled specimens. This was qualified by Scott (1980) with the proviso that the lowest occurrence of *Gc. puncticulata* may not be applied consistently by biostratigraphers and that its joint appearance with *Truncorotalia crassaformis* may offer a more satisfactory boundary. This definition has proven unsatisfactory and it is proposed that the lowest occurrence of *Globoconella puncticulata* is redefined as the horizon where mixed adult populations of weakly keeled *Gc. sphericomiozea* and unkeeled *Gc. puncticulata* morphotypes contain 5% or less of keeled specimens (Study 2). The emended criterion for the base of the Opoitian Stage locates the stage boundary at a slightly lower stratigraphic horizon than before, although it is expected to improve the consistency with which biostratigraphers recognize the stage boundary.

The emended datum for the base of the Opoitian Stage occurs in an interval of indeterminate polarity at Site 1123, and it has an interpolated age of 5.28 Ma (Study 5). At Site 593 where populations of *Globoconella* are better preserved and the datum is located more reliably, it is assigned an age of 5.24 Ma based on the S-Age model that has been developed for the site (Study 6). The constraints on the dating are relatively poor at both sites, although the ages agree closely with the magnetochronologic age of 5.2 Ma that

Morgans et al. (1996) cite for the stage boundary. The latter age is based on the entry of *Gc. puncticulata* at Blind River, Marlborough – *sensu* Scott (1980) (Roberts et al. 1994). A review of the Blind River sequence is needed to locate the position of the emended stage datum and reliably date the base of the Opoitian Stage. In the interim, an age of 5.24 Ma is adopted for the lower stage boundary.

SUMMARY OF LATE MIOCENE BIOEVENTS

The identification and age calibration of at least 69 bolboform and planktic foraminiferal and bolboform events at Sites 593 and 1123, and their correlation with the New Zealand onland stage classification, represent a major advance in New Zealand late Miocene biostratigraphy and chronology (Table 8.2). These bioevents, however, are not evenly distributed through the late Miocene, nor are they tightly clustered, except in the lowermost Tongaporutuan where there are 16 bioevents in the interval 10.93-10.48 Ma. Bolboform events are confined to the upper Waiauan to lowermost upper Tongaporutuan (11.56-8.21 Ma) and there are few well defined planktic foraminiferal events in the upper Tongaporutuan (8.88-6.40 Ma). Rapid evolutionary changes are also noted in the planktic foraminiferal clades *Globoconella* and *Truncorotalia* near the Miocene-Pliocene boundary (6.40-5.24 Ma). These bioevents and some paleoceanographic information are included in Figure 8.13, and are summarized below along with their interpreted ages based on the S-Age model for Site 593:

Lower Tongaporutuan (10.93-8.88 Ma)

- **Withdrawal of warm-subtropical taxa:** General reduction in the diversity of warm-subtropical taxa through the lower Tongaporutuan following the sequential withdrawal of common *Neogloboquadrina mayeri* s.l. (10.88 Ma); HO *Nq. mayeri* s.l. (10.48 Ma); HO *Hirsutella panda,* strongly keeled morphotype (10.42 Ma); and HO *Globoquadrina dehiscens* (8.88 Ma).

- **Turn-over in *Neogloboquadrina*:** Sudden appearance of *Nq. pachyderma* following the regional withdrawal of *Nq. mayeri* s.l. (10.48 Ma). This occurs near the middle of the Glomar Coiling Zone (10.82-10.25 Ma) – an interval where *Neogloboquadrina* is extremely rare and the long Miocene history of sinistral coiling in *Neogloboquadrina* (>80% sinistral) is interrupted for the first time by populations with significant contributions of dextrally-coiled shells.

Table 8.2 – Age calibrated bolboform and planktic foraminiferal events from ODP Site 1123 and DSDP Site 593. New Zealand stages and international correlation emended after M-96 (Morgans et al. 1996) and bolboform zonation (Study 3).

Ref.	Bolboform and planktic foraminiferal events	GPTS-95 correlation	1123 (Ma)	S-Age (Ma)	M-96 (Ma)	NZ Stage (This Study)	Bolboform zonation
	Top upper *Truncorotalia juanai* acme			5.24		lower Opoitian (lWo)	unzoned
	Top Challenger Coiling Zone (CCZ) = top *Nq*-593/B			5.24			
2	LO *Gc. puncticulata* s.s. (<5% weakly carinate) **Wo/Tk proxy**	reversed	5.28	5.24	5.2	5.28	
1	LO *Truncorotalia crassaformis*	indeterminate	5.15	5.41		upper Kapitean (uTk)	
	Base Challenger Coiling Zone (CCZ) = base *Nq*-593/B			5.47			
3	LO *Globoconella pliozea*	reversed	5.39	5.49			
	LO *Truncorotalia* aff. *crassaconica*			5.57			
4	LO *Gc. sphericomiozea* s.s. **upper-lower Tk proxy**	reversed	5.53	5.78	5.5	5.5	
	LO *Truncorotalia neojuanai*			5.84			
5	LO *Globoconella mons*	indeterminate	5.72	5.84			
	Base upper *Truncorotalia juanai* acme			5.91			
	Top Palliser Coiling Zone (PCZ) = Top subzone *Gc*-593/D3			6.05		lower Kapitean (lTk)	
	Palliser Coiling Zone (Base subzone *Gc*-593/D3)			6.06			
	Palliser Coiling Zone (Top subzone *Gc*-593/D2)			6.08			
	Palliser Coiling Zone (Base subzone *Gc*-593/D2)			6.11			
	Palliser Coiling Zone (Top subzone *Gc*-593/D1)			6.15			
	Base Palliser Coiling Zone (PCZ) = Base subzone Gc-593/D1			6.16			
7	LO *Globoconella conomiozea* **Tk/Tt proxy**	indeterminate	6.87	6.40	6.6	6.6	
6	Top middle *Truncorotalia juanai* acme	indeterminate	6.23	6.86			
8	Base middle *Truncorotalia juanai* acme	C3Br.2n	7.23	7.09			
9	HO *Bolboforma praeintermedia*	C4r.1r(0.81)	8.21	8.21		upper Tongaporutuan (uTt)	B. intermedia (BBi)
	HO *Hirsutella* cf. *ichinosekiensis* (non-carinate)			8.24			
10	LO *Bolboforma praeintermedia*	base C4n.1n	8.25	8.25			
11	HO *Bolboforma metzmacheri ornata*	C4r.2r(0.06)	8.28	8.28			B. metzmacheri (BBm)
12	LO *Bolboforma metzmacheri ornata*	C4r.2r(0.44)	8.45	8.45			
13	HO *Bolboforma metzmacheri* s.s. (upper subzone) BBm-593/C	C4An(0.25)	8.78	8.78			
14	HO *Globoquadrina dehiscens* **upper-lower Tt proxy**	C4An(0.57)	8.88	8.88	10.1	8.88	
	HO *Hirsutella* cf. *ichinosekiensis* (weakly carinate)			8.90			
15	LO *Bolboforma metzmacheri* s.s. (upper subzone) BBm-593/C			9.01			
17	Top Tukemokihi Coiling Zone (TCZ) >20% Dex	C4Ar.2r(0.41)	9.42	9.27			
	Top subzone BBm-593/B (small smooth-walled phases)			9.29			
	Base subzone BBm-593/B (small smooth-walled phases)			9.31			
21	Base Tukemokihi Coiling Zone (TCZ)	C4Ar.2n(0.71)	9.62	9.31			
16	HO *Bolboforma metzmacheri* s.s. (lower subzone) BBm-593/A			9.34			
18	*B. metzmacheri* s.s. abundance spike (lower subzone) BBm-593/A	C4Ar.2r(0.48)	9.44	9.44			
19	LO *Bolboforma metzmacheri* s.s. (lower subzone)	C4Ar.2r(0.86)	9.54	9.54			
20	HO *Bolboforma gracilireticulata* s.l.	C4Ar.2n(0.51)	9.61	9.61			B. capsula (BBc)
22	LO *Bolboforma gracilireticulata* s.l.	base C4Ar.3r	9.75	9.75			
23	HO *Bolboforma pentaspinosa*	C5n.2n(0.16)	10.08	10.08			
24	HO *Bolboforma capsula*	C5n.2n(0.21)	10.13	10.13			
25	LO *Bolboforma pentaspinosa*	C5n.2n(0.22)	10.15	10.15			
26	LO *Bolboforma capsula*	C5n.2n(0.27)	10.20	10.20			
	Top Glomar Coiling Zone (GCZ)			10.25		lower Tongaporutuan (lTt)	B. gruetzmacheri (BBg)
27	HO *Bolboforma gruetzmacheri*	C5n.2n(0.38)	10.31	10.31			
	HO *Hirsutella panda* (strongly keeled morphotypes)			10.42			
28	LO *Bolboforma gruetzmacheri*	C5n.2n(0.53)	10.46	10.46			
	LO *Neogloboquadrina pachyderma* s.l.			10.48			
	HO *Neogloboquadrina mayeri* s.l.			10.48			
	Top lower *Truncorotalia juanai* acme			10.50			
29	HO *Bolboforma subfragoris* s.l. = Top subzone BBs-593/E	C5n.2n(0.56)	10.50	10.50			B. subfragoris (BBs)
	Top *Hirsutella panda* acme (>10%)			10.56			
	Top Mapiri Coiling Zone (MCZ)			10.57			
	Base Mapiri Coiling Zone (MCZ)			10.60			
30	*B. subfragoris* s.l. abundance spike (subzone BBs-593/E)	C5n.2n(0.71)	10.61	10.61			
	Base *Bolboforma subfragoris* s.l. subzone BBs-593/E			10.70			
	Top *Bolboforma subfragoris* s.l. subzone BBs-593/D			10.80			
	LO *Truncorotalia juanai* (base lower *Tr. juanai* acme)*			10.82			
	Base Glomar Coiling Zone (GCZ)			10.82			
31	Top Kaiti Coiling Zone (KCZ)	C5n.2n(0.87)	10.82	10.82			
	Base *Hirsutella panda* acme (>10%)			10.82			
	HCO *Neogloboquadrina mayeri* s.l. (>5%)			10.88			
32	Base Kaiti Coiling Zone (KCZ) **Tt/Sw proxy**	C5n.2n(0.98)	10.93	10.93	11.3	10.93	
	Base *Bolboforma subfragoris* s.l. subzone BBs-593/D			10.97		Waiauan (Sw)	
	Top *Bolboforma subfragoris* s.l. subzone BBs-593/C			11.17			
	Base *Bolboforma subfragoris* s.l. subzone BBs-593/C			11.23			
	Top *Bolboforma subfragoris* s.l. subzone BBs-593/B			11.29			
	Base *Bolboforma subfragoris* s.l. subzone BBs-593/B			11.47			
	Top *Bolboforma subfragoris* s.l. subzone BBs-593/A			11.50			
33	FO *Bolboforma subfragoris* s.l. = Base subzone BBs-593/A	C5r.2r(0.55)	11.56*	11.56*			

- **Coiling excursions:** Distinctive intervals with significant contributions of dextrally-coiled *Globoconella miotumida* (>20% dextral): Kaiti (10.93-10.82 Ma); Mapiri (10.60-10.57 Ma); and Tukemokihi (9.31-9.27 Ma) Coiling Zones. Related to changes in the permanent thermocline during periods of significant Subantarctic Surface Water cooling and Southern Component Mode Water (SCMW) formation (Cooke 2002).

- **Bolboform influxes:** BBs-593/D (10.97-10.80 Ma); BBs-593/E (10.70-10.61 Ma); *Bolboforma gruetzmacheri* (10.46-10.31 Ma); *B. capsula* (10.20-10.13 Ma); *B. pentaspinosa* (10.15-10.08 Ma); *B. gracilireticulata* s.l. (9.75-9.61 Ma); *B. metzmacheri,* lower subzone (9.54-9.34 Ma); BBm-593/B (9.31-9.29 Ma); *B. metzmacheri,* upper subzone (9.01-8.78 Ma). Linked to periods of Southern Component Intermediate Water (SCIW) formation at the Antarctic Front and invigorated subsurface flow over the seafloor at Site 593 (Cooke 2002; Cooke et al. 2002).

- ***Hirsutella* influx:** *Hirsutella panda* forms a minor component of lower Tongaporutuan assemblages up to the level of its disappearance (10.56 Ma), except for a short interval (10.82-10.56 Ma) where the species reaches abundances of c. 10-20%. The closely related extant species *Hr. hirsuta* is a "Deep-Water" form that lives predominantly below 100 m (Berger 1969; Bé 1977; Vincent & Berger 1981) – possibly a thermocline or SCMW signal?

- ***Truncorotalia* influx:** Distinctive influx of *Tr. juanai* (10.82-10.50 Ma) where it forms a small but persistent part of lower Tongaporutuan assemblages before virtually disappearing. Modern truncorotalids are "Deep-Water" forms whose adult stages occur predominantly below 100 m (Berger 1969; Bé 1977; Vincent & Berger 1981) – possibly a thermocline or SCMW signal?

Upper Tongaporutuan (8.88-6.40 Ma)

- **Bolboform influxes:** *Bolboforma metzmacheri ornata* (8.45-8.28 Ma); *B. praeintermedia* (8.25-8.21 Ma). Regional disappearance of bolboforms (8.21 Ma) corresponding to a culmination of invigorated SCIW-flow over the seafloor at Site 593 (Cooke 2002).

- **Warm-subtropical taxa:** Marked reduction in the abundance and diversity of warm-subtropical planktic foraminifers (8.04 Ma) – possibly signifying a northward shift in

the position of the Tasman Front relative to New Zealand. It is speculated that this may relate to a weaker East Australian Current and a reduction in the size of the West Pacific Warm Pool in the western equatorial Pacific – a counter situation to that which Wei (1998) notes for the southward shift of the Tasman Front in the early Pliocene.

- **Paucity of bioevents:** Paucity of well defined bioevents suitable for biostratigraphic correlation (8.88-6.40 Ma). This is a feature of regional biostratigraphic units within the late Miocene, which typically have rather long durations (Berggren et al. 1995).

- **Coiling excursions:** Distinctive sinistral-coiling excursions in *Hirsutella scitula* – a species that forms a minor component of planktic foraminiferal assemblages and rarely exceeds abundances of 10%. Such populations are not seen in the southern Tasman Sea region at any other time in the late Miocene.

Lower Kapitean (6.40-5.87 Ma)

- **Rapid evolution:** Onset of rapid evolution and divergence in the planktic foraminiferal clades *Globoconella*: LO *Gc. conomiozea* (6.40 Ma); LO *Gc. mons* (5.84 Ma); and *Truncorotalia*: reappearance of *Tr. juanai* (5.91 Ma); and LO *Tr. neojuanai* (5.84 Ma). Related to increased vertical thermal gradients and stratification within the thermocline (Norris 1994; Schneider & Kennett 1996, 1999).

- **Coiling excursions:** Distinctive intervals with significant contributions of dextrally-coiled *Globoconella conomiozea* (>20% dextral), Palliser Coiling Zone: *Gc*-593/D1 (6.16-6.15 Ma); *Gc*-593/D2 (6.11-6.08 Ma); and *Gc*-593/D3 (6.06-6.05 Ma).

Upper Kapitean (5.87-5.24 Ma)

- **Rapid evolution:** Continuation of rapid evolution and divergence in the planktic foraminiferal clades *Globoconella*: LO *Gc. sphericomiozea* (5.78 Ma); and LO *Gc. pliozea* (5.49 Ma); and *Truncorotalia*: LO *Tr.* aff. *crassaconica* (5.57 Ma); and LO *Tr. crassaformis* (5.41 Ma).

- **Coiling excursion:** Well defined appearance of significant contributions of dextrally-coiled *Neogloboquadrina pachyderma* (>30%) base of Challenger Coiling Zone (5.47 Ma). The first significant departure to dextral coiling in late Miocene populations of *Neogloboquadrina* since the Glomar Coiling Zone (10.82-10.25 Ma).

Lower Opoitian (5.24-5.17 Ma and younger)

- **Rapid evolution:** Continued evolution and morphological change in the planktic foraminiferal clade *Globoconella*: LO *Gc. puncticulata* (5.24 Ma).
- **Coiling excursion:** Distinctive interval with increased contributions of dextrally-coiled *Neogloboquadrina pachyderma* (>30% dextral): Challenger Coiling Zone (5.47-5.24 Ma). The first significant coiling excursion in the clade following the Glomar Coiling Zone (10.82-10.25 Ma).

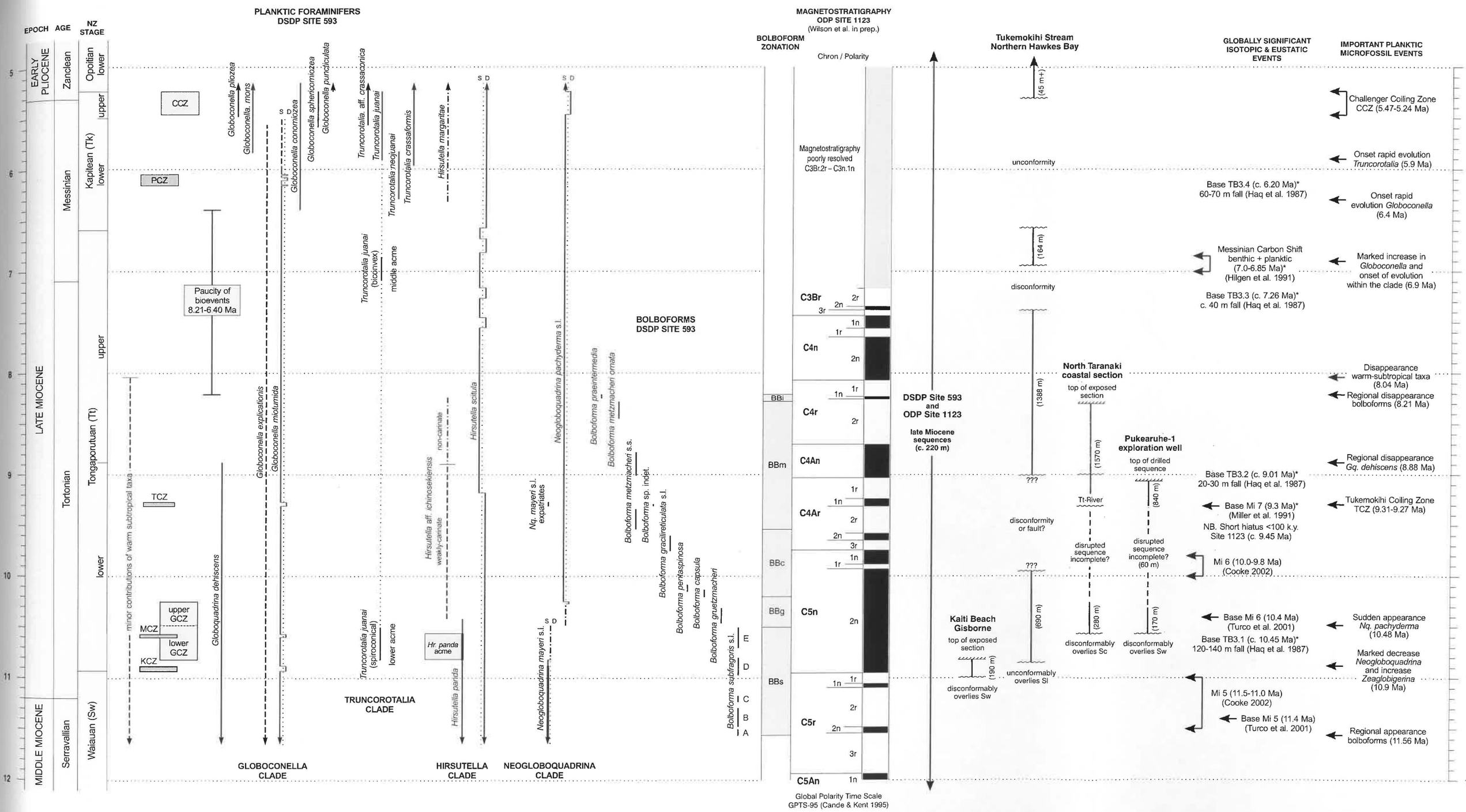


Figure 8.13 – Distribution of important late Miocene taxa associated with the clades *Globoconella* (*Gc.*), *Truncorotalia* (*Tr.*), *Hirsutella* (*Hr.*), *Neogloboquadrina* (*Nq.*), and *Globoquadrina* (*Gq.*), and intervals of dextrally-coiled *Globoconella* (*Gc*-593/A–D) and *Neogloboquadrina* (Nq-593/A–B). S = sinistral, D = dextral; Coiling Zones, GCZ = Glomar (*Nq*-593/A1 and *Nq*-593/A2), CCZ = Challenger (*Nq*-593/B). The paucity of upper Tongaporutuan planktic foraminiferal events (8.88-6.40 Ma) is a distinctive feature of the late Miocene sequence at Site 593. The adopted ages of bioevents and stage boundaries are based on the S-Age model for Site 593, except for the Kapitean, where the ages of stage boundaries follow Morgans et al. (1996).

Correlation and age calibration of important late Miocene sequences exposed on land in New Zealand, Miocene isotope events (Miller et al. 1991), 3rd-order eustatic cycles (Haq et al. 1987), and important planktic foraminiferal and bolboform events. All events are dated with respect to the GPTS-95 time scale (Cande & Kent 1995). *Published ages that are reported in terms of other time scales have been converted to GPTS-95 using the conversion application posted on the Ocean Drilling Stratigraphic Network (ODSN) website: http://www.odsn.de/odsn/services/conv_ts/conv_ts.html

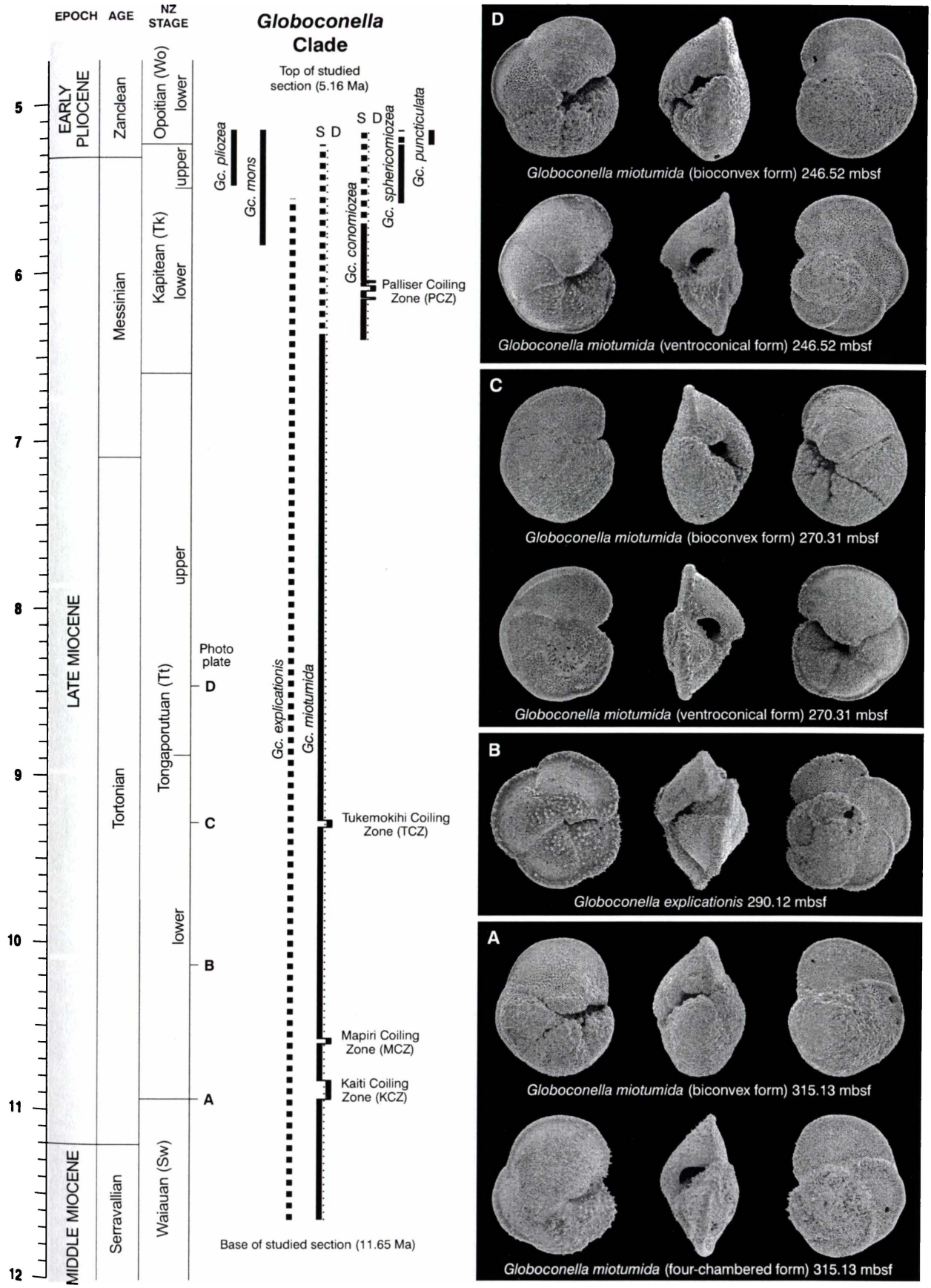


Plate 8.1 – Early late Miocene (lower Tongaporutuan) species of the planktic foraminiferal clade *Globoconella*. Includes the *Gc. miotumida* bioseries, which involves a morphological transformation from carinate forms with five chambers in the outer whorl to non-carinate four chambered forms (*Gc. miotumida* – *Gc. conomiozea* – *Gc. sphericomiozea* – *Gc. puncticulata*). The most rapid evolutionary phase occurs in the vicinity of the Miocene-Pliocene boundary, where modern non-carinate forms first appear. The Kaiti, and newly named Mapiri, Tukemokihi, and Palliser Coiling Zones are defined on the basis of having 20% or more dextrally-coiled specimens.

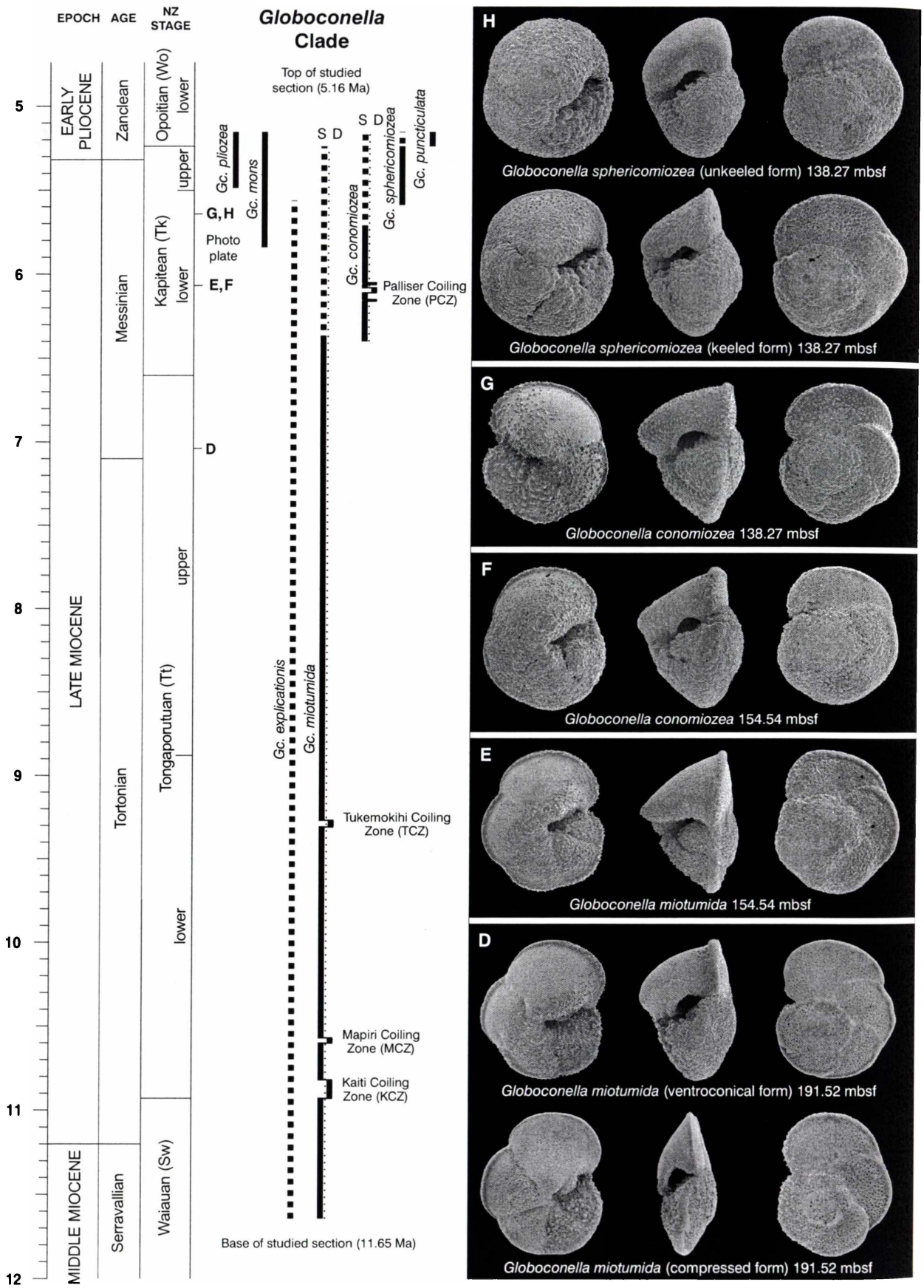


Plate 8.2 – Latest Miocene (upper Tongaporutuan to Kapitean) species of the planktic foraminiferal clade *Globoconella*. For further explanation see Figure 8.91 caption.

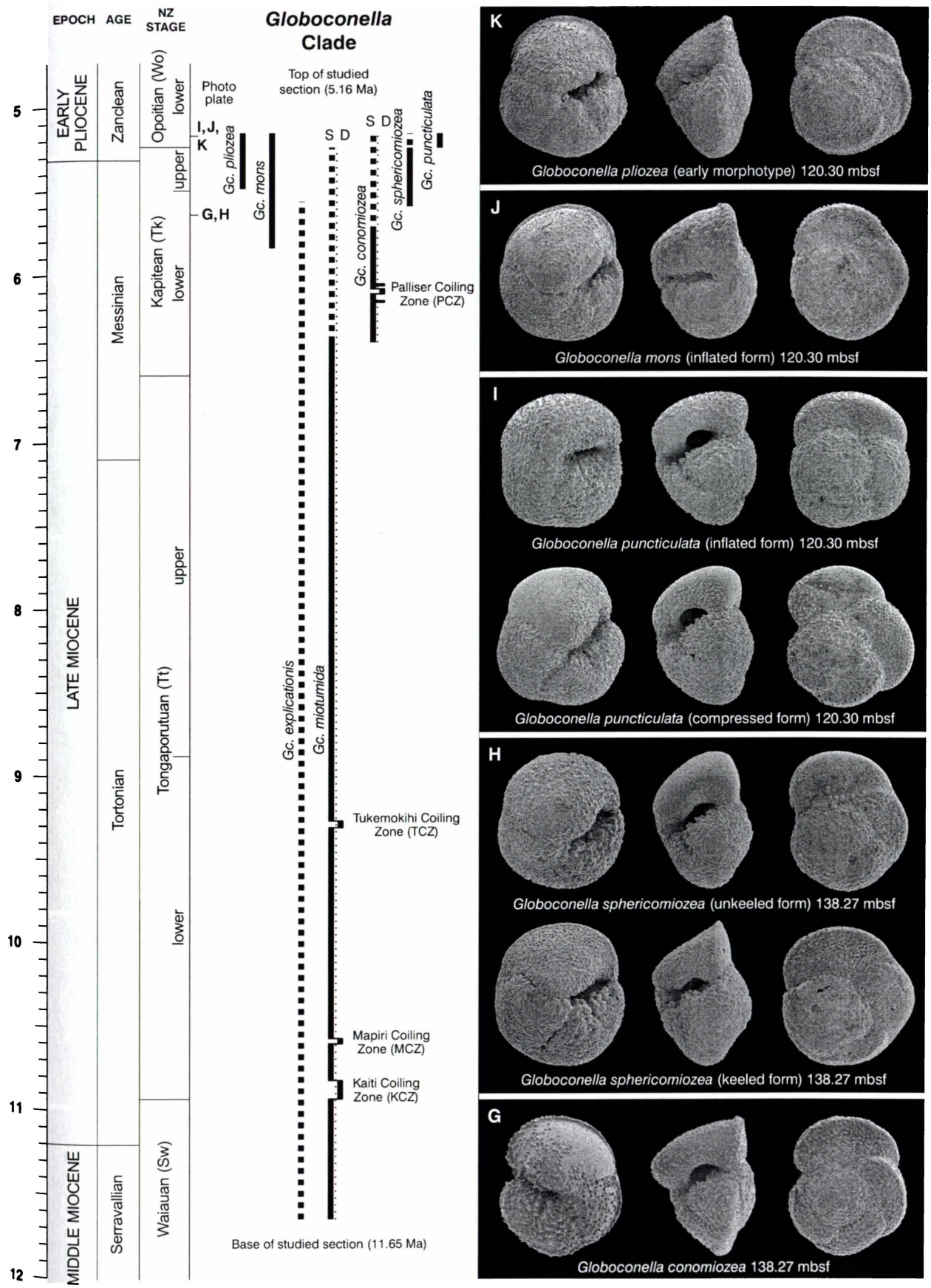


Plate 8.3 – Latest Miocene (upper Tongaporutuan to Kapitean) species of the planktic foraminiferal clade *Globoconella*. For further explanation see Figure 8.91 caption.

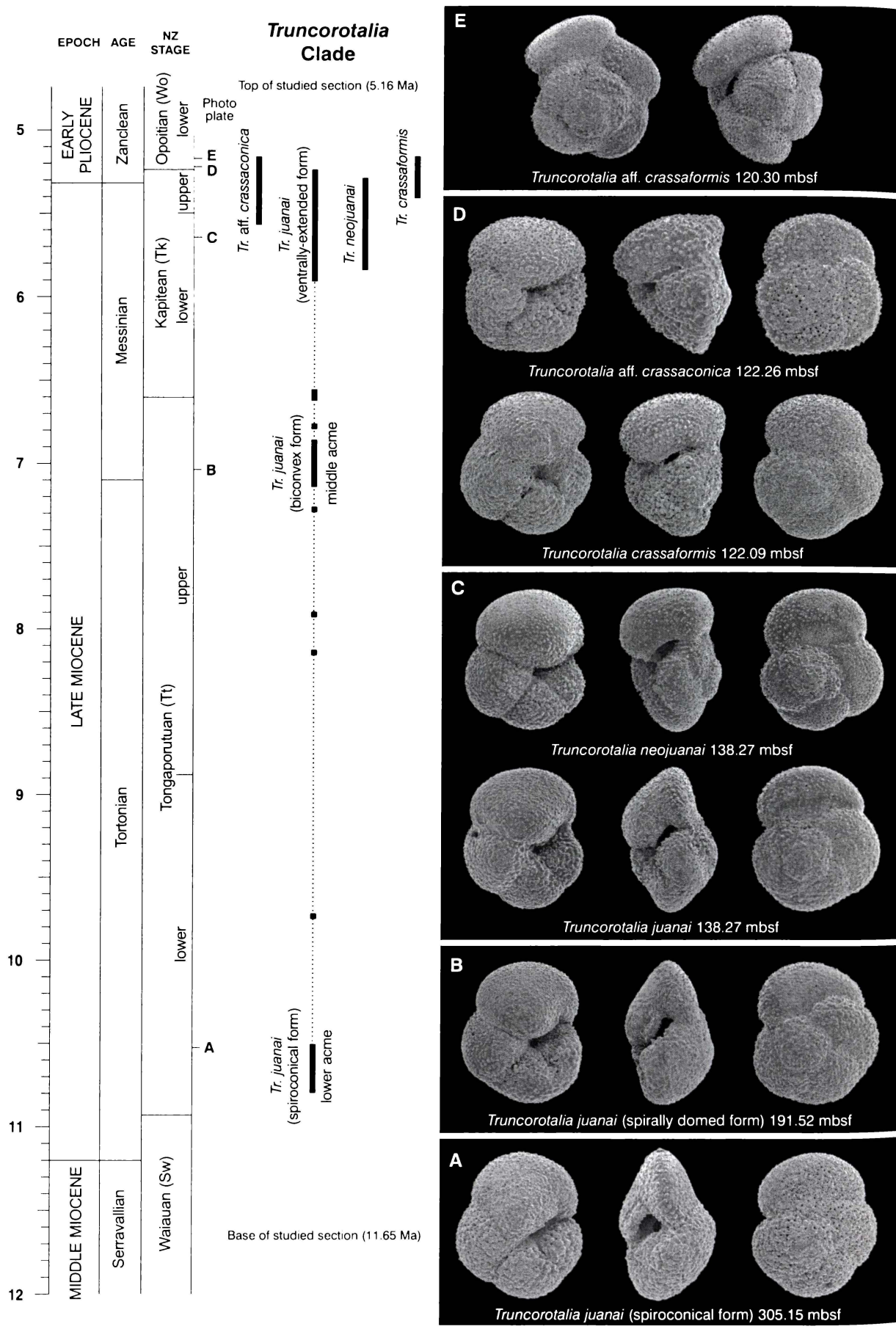


Plate 8.4 – Late Miocene species associated with the clade *Truncorotalia*. The main changes within the clade include a morphological transformation from spiroconical to ventrally-extended and conicotruncate forms. The most rapid evolutionary phase occurs in the vicinity of the Miocene-Pliocene boundary, where modern conicotruncate forms first appear.

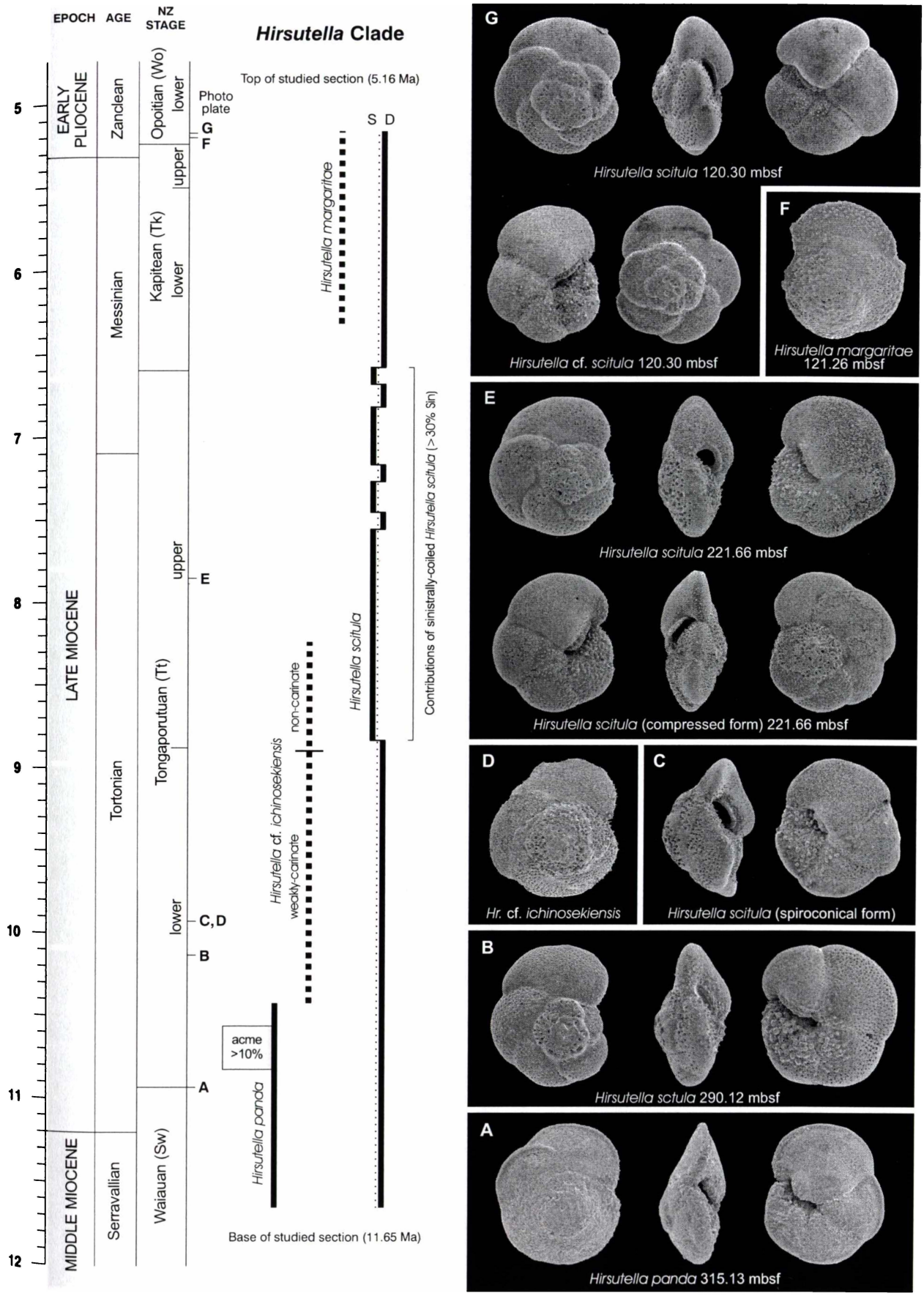


Plate 8.5 – Late Miocene elements of the planktic foraminiferal clade *Hirsutella*: *Hr. panda; Hr.* cf. *ichinosekiensis; Hr. margaritae* (early elements of the *Hr. hirsuta* group) which are poorly represented at Site 593; *Hr. scitula* is also included in the clade on the basis of its smooth, densely perforate surface-ultrastructure. Distinctive events include an acme of *Hr. panda* in the lowermost Tongaporutuan and significant contributions of sinistrally-coiled *Hr. scitula* in the upper Tongaporutuan. The highest occurrence of *Hr. panda* is also a well-defined event. S = sinistral; D = dextral.

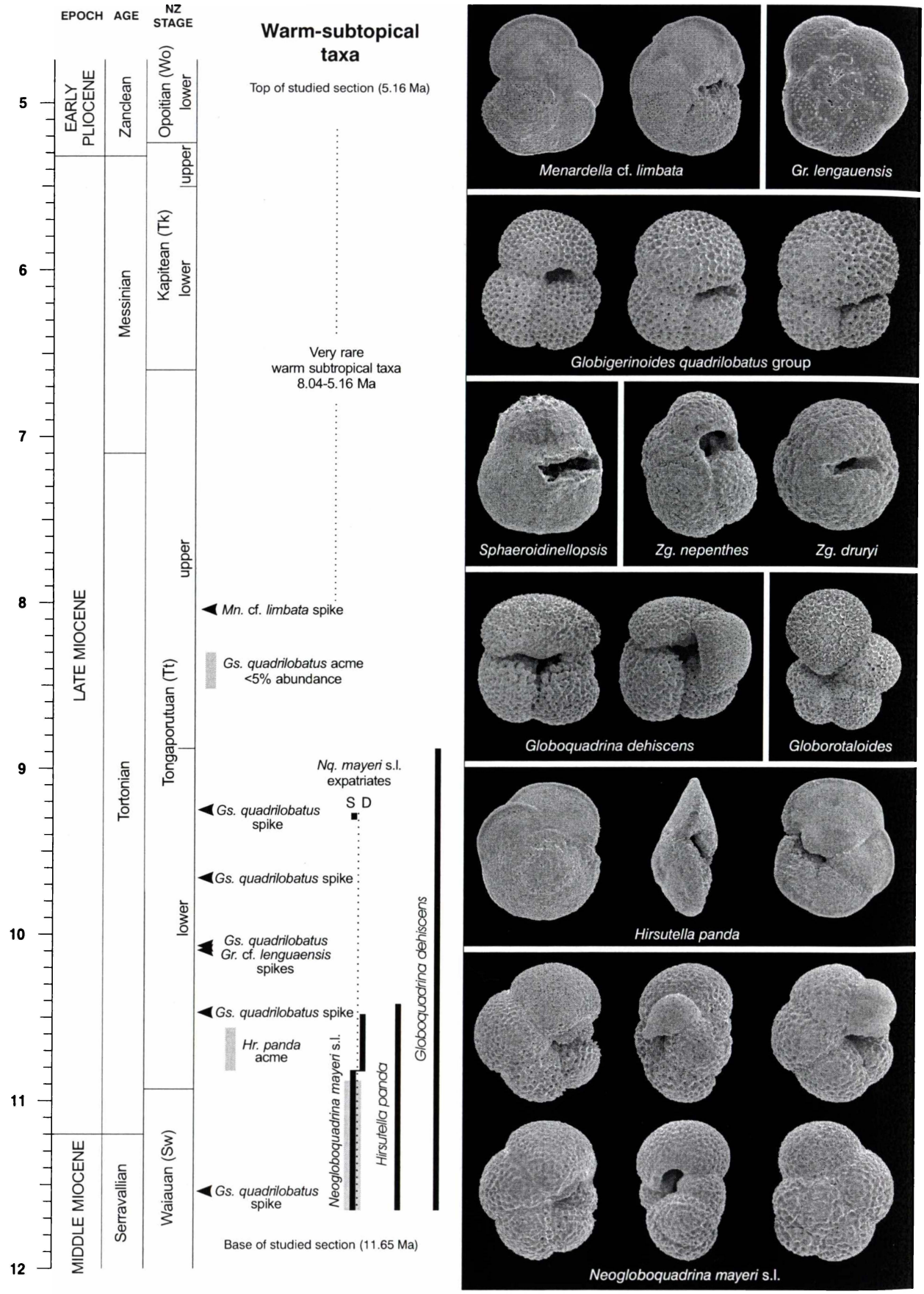


Plate 8.6 – Distinctive abundance spikes, acme zones, coiling and highest occurrences associated with late Miocene warm-subtropical taxa. Abundance spikes and acmes associated with *Menardella* cf. *limbata*, *Globorotalia lenguaensis*, and *Globigerinoides quadrilobatus* are poorly defined events with maximum abundances of <5%, but are potentially useful for biostratigraphic refinement, particularly when used in conjunction with other bioevents.

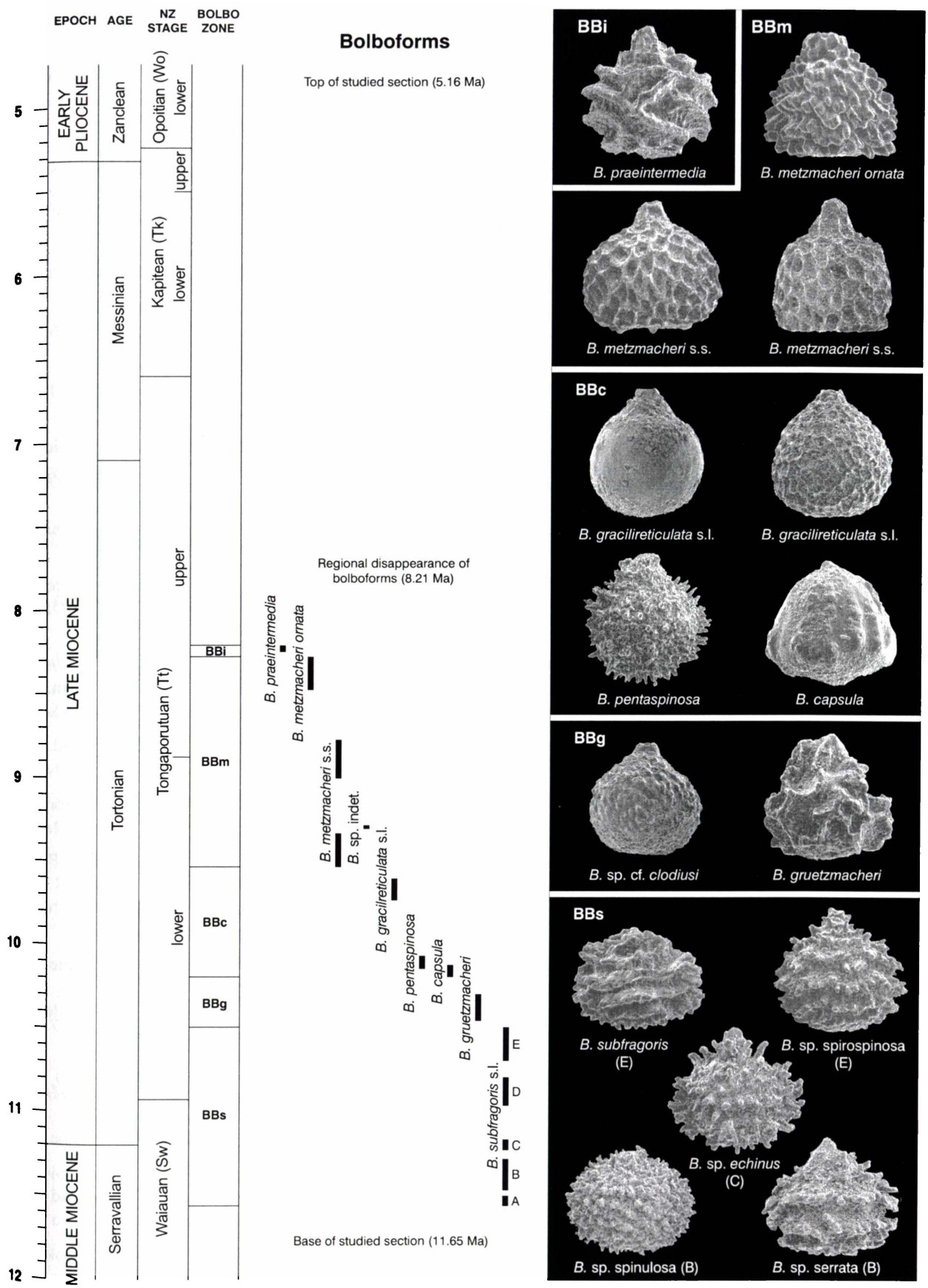


Plate 8.7 – Late Miocene bolboform species and distinctive morphotypes (large ornate phases) identified at Site 593. All specimens are shown in axial orientation (not to scale). BBs (*Bolboforma subfragoris* s.l. Range Zone) subdivided into five subzones BBs-593/A to BBs-593/E that include several distinctive morphotypes (described in open nomenclature); BBg (*B. gruetzmacheri* Partial Range Zone); BBc (*B. capsula* Partial Range Zone); BBm (*B. metzmacheri* Range Zone); BBi (*B. intermedia* Partial Range Zone) – zonation described in Study 3.

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Data Appendices, Site 593

DA–1.1
Census data

DA–1.2
Planktic foraminiferal distribution and abundance data

DA–1.3
Globoconellid coiling data

DA–1.4
Neogloboquadrinid coiling data

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globigerina bulloides*	*Globigerina eamesi*	*Globigerina falconensis*	*Globigerina* sp.	*Globigerina* cf. *angustiumbilicata*	*Globigerina quinqueloba*	*Globigerinella aequilateralis*	*Globigerinella aequilateralis?*	*Globigerinita glutinata*	*Globigerinita uvula*	*Globigerinita uvula?*	*Globigerinoides obliquus*	*Globigerinoides obliquus?*	*Globigerinoides quadrilobatus immaturus*	*Globigerinoides quadrilobatus quadrilobatus*	*Globigerinoides quadrilobatus quadrilobatus?*	*Globigerinoides quadrilobatus trilobus*	*Globigerinoides sacculifer*	*Globigerinopsis obesa*	*Globigerinopsis obesa?*	*Globigerinopsis sp.?*	*Globoconella conomiozea* [crust-free] dex	*Globoconella conomiozea* [crust-free] sin	*Globoconella conomiozea* [encrusted] dex	*Globoconella conomiozea* [encrusted] sin	*Globoconella conomiozea* s.l. [crust-free] dex
120.30	120.33	14/1/0-3	lower Wo	5		3	34					7																	
120.51	120.54	14/1/21-24	lower Wo	12		4	47					7																	1
120.69	120.72	14/1/39-42	lower Wo	2		6	64		1			6			1								1						
120.90	120.93	14/1/60-63	lower Wo	25		6	52		1			5			11									3					1
121.11	121.14	14/1/81-84	lower Wo	17		8	69		1		1	3			1									6					1
121.26	121.29	14/1/96-99	lower Wo	18		8	43		1			2			1								2	2					
121.49	121.52	14/1/119-122	lower Wo	7		5	53					4			1								3	5					
121.69	121.72	14/1/139-142	lower Wo	7		3	56					8											1	1					1
121.90	121.93	14/2/10-13	lower Wo	12		2	58					7										1		1					2
122.09	122.12	14/2/29-32	lower Wo	14		2	52					5			1														1
122.26	122.29	14/2/46-49	lower Wo	13		6	34					3												3					1
122.51	122.55	14/2/71-75	lower Wo	4		4	47		2			4												3					
122.71	122.74	14/2/91-94	lower Wo	15		5	58					7											2	5					
122.92	122.95	14/2/112-115	lower Wo	5		2	38					4			1								1						
123.10	123.13	14/2/130-133	upper Tk	15		3	77			1		7																	
123.30	123.33	14/3/0-3	upper Tk	6		8	79					2											2						1
123.53	123.56	14/3/23-26	upper Tk	8		2	59		2			8												2					
123.69	123.72	14/3/39-42	upper Tk	4		9	56					3												2					
123.88	123.91	14/3/58-61	upper Tk	8		3	48					9											1	5					3
124.11	124.14	14/3/81-84	upper Tk	5		4	71					4											1	4					1
124.30	124.33	14/3/100-103	upper Tk	14		9	81					2												2					
124.50	124.53	14/3/120-123	upper Tk	6		3	60					3												4					
124.68	124.71	14/3/138-141	upper Tk	4		1	61					4												2					
124.90	124.93	14/4/10-13	upper Tk	6		9	74					6												2					2
125.10	125.13	14/4/30-33	upper Tk	6		5	67					10												2					
125.30	125.33	14/4/50-53	upper Tk	12		7	56					12												6					
125.48	125.51	14/4/68-71	upper Tk	8		4	52					6											1	1					1
125.71	125.74	14/4/91-94	upper Tk	8		4	33					5												3					1
125.91	125.94	14/4/111-114	upper Tk	18		7	109					6												1					
126.10	126.13	14/4/130-133	upper Tk	8		3	60					1											1	4					3
126.30	126.33	14/5/0-3	upper Tk	5		4	40		1			1																	
126.56	126.59	14/5/26-29	upper Tk	15		3	60					4												5					
126.70	126.73	14/5/40-43	upper Tk	10		4	47				1	6												1					1
126.90	126.93	14/5/60-63	upper Tk	27		6	57					12		3	1														
127.12	127.15	14/5/82-85	upper Tk	10		2	80					11			4								2						
127.30	127.33	14/5/100-103	upper Tk	12		1	75					5												1					
127.51	127.54	14/5/121-124	upper Tk	10		5	98		3			3																	
127.70	127.73	14/5/140-143	upper Tk	10		7	129					7												1					
127.90	127.93	14/6/10-13	upper Tk	9		9	131					12			2							3		2					
128.29	128.32	14/6/49-52	upper Tk	13		2	95					2										2		1					
128.72	128.75	14/6/92-95	upper Tk	10		1	76					10												3					
129.10	129.13	14/6/130-133	upper Tk	6			72					4										1		2					1
129.50	129.53	14/7/20-23	upper Tk	12		2	124					10												2					2
129.90	129.93	15/1/0-3	upper Tk	3		1	55																1						
130.29	130.32	15/1/39-42	upper Tk	3		2	62					4											2	2					
130.69	130.72	15/1/79-82	upper Tk	5		3	74																	1					
131.10	131.13	15/1/120-123	upper Tk	15		3	74					2	1											1					
131.51	131.54	15/2/11-14	upper Tk	8			83					4																	
131.91	131.93	15/2/51-53	upper Tk	3		4	83					5										2		1					
132.33	132.36	15/2/93-96	upper Tk	4			75					1												3					
132.74	132.76	15/2/134-136	upper Tk	6		1	48					2												1					1
133.07	133.10	15/3/17-20	upper Tk	3		2	54					3												3					
133.46	133.49	15/3/56-59	upper Tk	13		1	74					5												1					1
133.89	133.92	15/3/99-102	upper Tk	3			61					3																	
134.30	134.33	15/3/140-143	upper Tk	16		1	74					3																	
134.70	134.73	15/4/30-33	upper Tk	7		2	71					2												1					
135.10	135.13	15/4/70-73	upper Tk	3			42																	1					
135.30	135.33	15/4/90-93	upper Tk	12			68					3																	
135.50	135.53	15/4/110-113	upper Tk	6		4	52					2																	
135.70	135.73	15/4/130-133	upper Tk	6		2	74					3																	
135.90	135.93	15/5/0-3	upper Tk	10		2	61					2												3					
136.06	136.09	15/5/16-19	upper Tk	10		1	48																						1
136.32	136.35	15/5/42-45	upper Tk	8		3	57					2												8					
136.51	136.53	15/5/61-63	upper Tk	11		3	91					2																	
136.92	136.95	15/5/102-105	upper Tk	7		2	44				1	5											1						
137.13	137.16	15/5/123-126	upper Tk	3		1	43					2																	
137.52	137.55	15/6/12-15	upper Tk	5			65					1																	
137.91	137.94	15/6/51-54	upper Tk	5			71																						2
138.27	138.30	15/6/87-90	upper Tk	3		1	53					1												2					
138.66	138.69	15/6/126-129	upper Tk	2		2	66					5			1														
139.07	139.10	15/7/17-20	upper Tk	9		4	97					2																	
139.50	139.53	16/1/0-3	upper Tk	5			58		1			1																	1

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globigerina bulloides*	*Globigerina eamesi*	*Globigerina falconensis*	*Globigerina* sp.	*Globigerina* cf. *angustiumbilicata*	*Globigerina quinqueloba*	*Globigerinella aequilateralis*	*Globigerinella aequilateralis?*	*Globigerinita glutinata*	*Globigerinita uvula*	*Globigerinita uvula?*	*Globigerinoides obliquus*	*Globigerinoides obliquus?*	*Globigerinoides quadrilobatus immaturus*	*Globigerinoides quadrilobatus quadrilobatus*	*Globigerinoides quadrilobatus quadrilobatus?*	*Globigerinoides quadrilobatus trilobus*	*Globigerinoides sacculifer*	*Globigerinopsis obesa*	*Globigerinopsis obesa?*	*Globigerinopsis* sp. ?	*Globoconella conomiozea* [crust-free] dex	*Globoconella conomiozea* [crust-free] sin	*Globoconella conomiozea* [encrusted] dex	*Globoconella conomiozea* [encrusted] sin	*Globoconella conomiozea* s.l. [crust-free] dex
139.93	139.96	16/1/43-46	upper Tk	5		2	89					3																	1
140.34	140.37	16/1/84-87	upper Tk	3		2	60					1																	
140.73	140.76	16/1/123-126	upper Tk	1		4	60					3												3					1
141.13	141.15	16/2/13-16	upper Tk			1	40					2																	2
141.54	141.57	16/2/54-57	upper Tk	15		1	49						1											2					
141.92	141.95	16/2/92-95	upper Tk	7			37					1											1	2					
142.32	142.35	16/2/132-135	upper Tk	4		1	51					4											1						1
142.75	142.78	16/3/25-28	upper Tk	7			69		1			2											1	1					1
143.15	143.18	16/3/65-68	upper Tk	7		7	98					2											2	3					
143.53	143.56	16/3/103-106	upper Tk	9		1	99					4												2					2
143.84	143.87	16/3/134-137	lower Tk	4		1	75					5												3	1	24	1	59	
144.26	144.29	16/4/26-29	lower Tk	6		6	64					1										1		15	1	23	1	83	
144.67	144.70	16/4/67-70	lower Tk	3		2	39					1											1	3		10	3	63	
145.13	145.16	16/4/113-116	lower Tk	10		7	61					4												4		25	1	76	
145.50	145.53	16/5/0-3	lower Tk	8		4	50																		1	35	1	88	
145.93	145.96	16/5/43-46	lower Tk	7		3	62					2										3		4	2	27	3	85	
146.36	146.38	16/5/86-88	lower Tk	10		3	53					4												7	1	18	3	85	
146.71	146.74	16/5/121-124	lower Tk	10		1	40					1											1	8		11		56	
147.06	147.09	16/6/6-9	lower Tk	5			37					2											2	3		14		76	
147.47	147.50	16/6/47-50	lower Tk	8		3	79					2												4		22	2	132	
147.93	147.96	16/6/93-96	lower Tk	7		3	67																	2		25		70	
148.33	148.36	16/6/133-136	lower Tk	6		12	128					1											1		2	17	2	63	
148.67	148.69	16/7/17-19	lower Tk	7		10	84					3										1				13		55	
149.10	149.13	17/1/0-3	lower Tk	8		2	74		1			3												1		21	2	98	
149.52	149.55	17/1/42-45	lower Tk	10			69					3														24		93	
150.11	150.14	17/1/101-104	lower Tk	3		2	49					1														23	2	69	
150.51	150.54	17/1/141-144	lower Tk	8			61					1											1			29	2	56	
150.87	150.90	17/2/27-30	lower Tk	11		4	106					6										1		1	1	36		92	
151.07	151.10	17/2/47-50	lower Tk	9		7	62					2			2									1		20		74	
151.52	151.55	17/2/92-95	lower Tk	9		2	85					3														16	4	117	
151.96	151.98	17/2/136-138	lower Tk	6			44					3												2		27	4	62	
152.10	152.13	17/3/0-3	lower Tk	13			80					3												2	5	32	1	78	
152.25	152.28	17/3/15-18	lower Tk	6			56					1												3	2	31	2	76	
152.47	152.50	17/3/37-40	lower Tk	3			43					2												1		21		49	
152.75	152.77	17/3/65-67	lower Tk	13			50					2												2	1	40	3	71	
152.91	152.94	17/3/81-84	lower Tk	9			39					2													1	30	2	78	
153.12	153.15	17/3/102-105	lower Tk	13		1	61					2												2		21	3	89	
153.26	153.29	17/3/116-119	lower Tk	2			70					1			1									2		23	3	105	
153.45	153.48	17/3/135-138	lower Tk	13			66					3										1				16	3	108	
153.66	153.69	17/4/6-9	lower Tk	3			41																1	1		10	9	53	
153.97	153.99	17/4/37-39	lower Tk	1			52					2												3	9	3	56	28	
154.13	154.16	17/4/53-56	lower Tk	4			51					3										2		4	11	10	31	52	
154.32	154.35	17/4/72-75	lower Tk	1			45					2											2	3	3	21	6	95	
154.54	154.57	17/4/94-97	lower Tk	4		4	48					1											1		1	21	2	89	
154.77	154.79	17/4/117-119	lower Tk	3		3	27					1			1											17	4	89	
154.95	154.98	17/4/135-138	lower Tk	3		4	46					3										1			1	23	3	91	
155.10	155.13	17/5/0-3	lower Tk	4			41					1												3		15	4	92	
155.24	155.27	17/5/14-17	lower Tk	4		1	31					1			2										1	6	21	50	
155.48	155.50	17/5/38-40	lower Tk	10		1	79					3											2		1	21	12	126	
155.67	155.70	17/5/57-60	lower Tk			2	48					4												2	3	7	11	72	
155.94	155.97	17/5/84-87	lower Tk	5		1	72					5												4	3	9	39	56	
156.13	156.16	17/5/103-106	lower Tk	7		2	52					2														11	4	76	
156.27	156.30	17/5/117-120	lower Tk	7			48					3											1	4		19	4	89	
156.47	156.50	17/5/137-140	lower Tk	3			47					2												1		23	5	83	
156.71	156.74	17/6/11-14	lower Tk	3		1	58					5													1	14	1	85	
156.95	156.98	17/6/35-38	lower Tk	7		8	49					5			3											16	1	59	
157.12	157.15	17/6/52-55	lower Tk	9		10	86					5	2		5							1		1		20	2	80	
157.37	157.39	17/6/77-79	lower Tk	3		1	51																	4		14	3	83	
157.52	157.55	17/6/92-95	lower Tk	8		1	23					2												1	1	24	2	104	
157.76	157.79	17/6/116-119	lower Tk	2		3	46					1														11	5	94	
157.93	157.96	17/6/133-136	lower Tk	6		7	55					8	1												1	5	38	34	
158.10	153.13	17/7/0-3	lower Tk	4		1	70					3													1	8	24	56	
158.27	158.30	17/7/17-20	lower Tk	2			46					6												1	2	18	7	93	
158.52	158.55	17CC/6-9	lower Tk	2		5	54					3	1													19		77	
158.70	158.73	18/1/0-3	lower Tk	2		7	80						1												1	14		83	
158.95	158.98	18/1/25-28	lower Tk				41					1													1	13		121	
159.13	159.16	18/1/43-46	lower Tk			2	38					2												1	1	11	2	83	
159.35	159.38	18/1/65-68	lower Tk	5		3	47					3														23	3	112	
159.49	159.52	18/1/79-82	lower Tk	14		4	66				1	7														43	3	140	
159.72	159.75	18/1/102-105	lower Tk	8			59					6												1	2	21		80	
159.86	159.89	18/1/116-119	lower Tk	4			54					6														23		84	
160.11	160.14	18/1/141-144	lower Tk	8		3	54					9														18	3	82	

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globigerina bulloides*	*Globigerina eamesi*	*Globigerina falconensis*	*Globigerina* sp.	*Globigerina* cf. *angustiumbilicata*	*Globigerina quinqueloba*	*Globigerinella aequilateralis*	*Globigerinella aequilateralis?*	*Globigerinita glutinata*	*Globigerinita uvula*	*Globigerinita uvula?*	*Globigerinoides obliquus*	*Globigerinoides obliquus?*	*Globigerinoides quadrilobatus immaturus*	*Globigerinoides quadrilobatus quadrilobatus*	*Globigerinoides quadrilobatus quadrilobatus?*	*Globigerinoides quadrilobatus trilobus*	*Globigerinoides sacculifer*	*Globigerinopsis obesa*	*Globigerinopsis obesa?*	*Globigerinopsis sp. ?*	*Globoconella conomiozea* [crust-free] dex	*Globoconella conomiozea* [crust-free] sin	*Globoconella conomiozea* [encrusted] dex	*Globoconella conomiozea* [encrusted] sin	*Globoconella conomiozea* s.l. [crust-free] dex
160.33	160.36	18/2/13-16	lower Tk	6		1	77					3	1											2	1	9		87	
160.73	160.76	18/2/53-56	lower Tk	11		2	48					4												1		10		66	
161.16	161.19	18/2/96-99	lower Tk	9			58					3	1											2	1	17	5	95	
161.53	161.56	18/2/133-136	lower Tk	9			47					2												1	1	17	3	92	
161.84	161.87	18/3/14-17	lower Tk	8		1	72					6												4	1	21		81	
162.26	162.29	18/3/56-59	lower Tk	1			30					7												2		12	3	97	
162.87	162.90	18/3/117-120	lower Tk	10		3	30					1												10		21		100	
163.33	163.36	18/4/13-16	lower Tk	8		2	44					1												3		12	1	80	
163.56	163.59	18/4/36-39	lower Tk	3		2	74					6			3									2		36	5	117	
163.93	163.96	18/4/73-76	lower Tk	7			32					3											2	2		12	1	78	
164.31	164.33	18/4/111-113	lower Tk	3		1	38		1			3												3	3	27	2	94	
164.70	164.73	18/5/0-3	lower Tk	13		1	33					8											1	1		27	4	108	
165.13	165.16	18/5/43-46	lower Tk	17		4	73		1			3												4	1	23	1	83	
165.50	165.53	18/5/80-83	lower Tk	14		2	66					6			3										2	30	4	127	
165.95	165.97	18/5/125-127	lower Tk	9			65		1			4												6	2	16	1	70	
166.26	166.29	18/6/6-9	lower Tk	4		2	53					9	1											4	2	13		56	
166.66	166.69	18/6/46-49	lower Tk	14		2	37					1												8		15	3	66	
167.06	167.09	18/6/86-89	lower Tk	7			47					6	1											6	1	8	1	78	
167.44	167.47	18/6/124-127	upper Tt	11		3	56					7												5					
168.30	168.33	19/1/0-3	upper Tt	12		2	54					4	1											6					
168.71	168.74	19/1/41-44	upper Tt	8		8	76					6												5					
169.13	169.15	19/1/83-85	upper Tt	8		7	63					4												8					
169.51	169.54	19/1/121-124	upper Tt	12		1	57					7	1											2					
169.85	169.88	19/2/5-8	upper Tt	7		1	51					7												7					
170.32	170.35	19/2/52-55	upper Tt	11		5	62					3																	
170.73	170.76	19/2/93-96	upper Tt	7		8	76					9									1			1					
171.15	171.18	19/2/135-138	upper Tt	17		8	68					5										1		2					
171.57	171.59	19/3/27-29	upper Tt	7		5	64					8										1	3	1					
171.92	171.94	19/3/62-64	upper Tt	6		2	37					4																	
172.32	172.35	19/3/102-105	upper Tt	7			45					10											2	7					
172.66	172.68	19/3/136-138	upper Tt	8		6	57					3	1										4	6					
173.07	173.09	19/4/27-29	upper Tt	10			75					5																	
173.52	173.54	19/4/72-74	upper Tt	5		1	25					5												10					
173.93	173.95	19/4/113-115	upper Tt	5		3	56					5	1									2		6					
174.30	174.33	19/5/0-3	upper Tt	11		5	77					2												14					
174.72	174.75	19/5/42-45	upper Tt	12		6	75					6	1											4					
175.26	175.28	19/5/96-99	upper Tt	5		1	32		2			5												2					
175.71	175.74	19/5/141-144	upper Tt	8			45					2												1					
176.06	176.09	19/6/26-29	upper Tt	5		1	35					6												6					
176.47	176.49	19/6/67-69	upper Tt	2		1	56					2												3					
176.92	176.94	19/6/112-114	upper Tt				30					2												4					
177.30	177.33	19/7/0-3	upper Tt	8		1	48					2												2					
177.52	177.55	19/7/22-25	upper Tt	10		6	150	6			1	16												4					
177.90	177.93	20/1/0-3	upper Tt	8		3	47					5												2					
178.27	178.30	20/1/37-40	upper Tt	14		6	50					5												5					
178.68	178.70	20/1/78-80	upper Tt	5		4	49	1				6												3					
179.08	179.10	20/1/118-120	upper Tt	2			41					5	1											1					
179.45	179.47	20/2/5-7	upper Tt	8		2	50	1				10	1										2	2					
179.86	179.88	20/2/46-48	upper Tt	11		7	58					4	2										2	2					
180.33	180.35	20/2/93-95	upper Tt	8		3	47	6				3												3					
180.73	180.75	20/2/133-135	upper Tt	2		5	30	1				7												1					
181.14	181.16	20/3/24-26	upper Tt	4		2	20					4												1					
181.57	181.59	20/3/67-69	upper Tt	4		1	26	1				14												1					
181.86	181.88	20/3/96-98	upper Tt	3		2	36					7										1		5					
182.23	182.25	20/3/133-135	upper Tt	4		6	39					5	1											3					
182.68	182.70	20/4/28-30	upper Tt	3		1	28					3												1					
183.08	183.10	20/4/68-70	upper Tt	5		1	29	2				2	2																
183.45	183.47	20/4/105-107	upper Tt	5		1	45	2				11																	
183.91	183.93	20/5/1-3	upper Tt	7		4	42	4				15	1									1							
184.32	184.34	20/5/42-44	upper Tt	3		7	51	1				4	1											1					
184.72	184.74	20/5/82-84	upper Tt	8		4	64	3				7	1									1		1					
185.07	185.09	20/5/117-119	upper Tt	9		4	54	5				3	4									1		2					
185.47	185.49	20/6/7-9	upper Tt	3		1	22	4				8																	
185.92	185.94	20/6/52-54	upper Tt	12		6	54	2				11																	
186.32	186.34	20/6/92-94	upper Tt	11		7	45	2				7												2					
186.72	186.74	20/6/132-134	upper Tt	10			46	1				10												2					
187.07	187.09	20/7/17-19	upper Tt	3		1	35	3				12	1											3					
187.51	187.53	21/1/1-3	upper Tt	7		2	40	1	1			16			1									2					
187.93	187.95	21/1/43-45	upper Tt	5		1	50	1				17	3											1					
188.32	188.34	21/182-84	upper Tt	2		1	28	1				4	3									1		2					
188.67	188.69	21/1/117-119	upper Tt	4		4	47	1				9										1		2					
189.08	189.10	21/2/8-10	upper Tt	6		2	29	2				7	2																

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globigerina bulloides*	*Globigerina eamesi*	*Globigerina falconensis*	*Globigerina* sp.	*Globigerina* cf. *angustiumbilicata*	*Globigerina quinqueloba*	*Globigerinella aequilateralis*	*Globigerinella aequilateralis?*	*Globigerinita glutinata*	*Globigerinita uvula*	*Globigerinita uvula?*	*Globigerinoides obliquus*	*Globigerinoides obliquus?*	*Globigerinoides quadrilobatus immaturus*	*Globigerinoides quadrilobatus quadrilobatus*	*Globigerinoides quadrilobatus quadrilobatus?*	*Globigerinoides quadrilobatus trilobus*	*Globigerinoides sacculifer*	*Globigerinopsis obesa*	*Globigerinopsis obesa?*	*Globigerinopsis sp.?*	*Globoconella conomiozea* [crust-free] dex	*Globoconella conomiozea* [crust-free] sin	*Globoconella conomiozea* [encrusted] dex	*Globoconella conomiozea* [encrusted] sin	*Globoconella conomiozea* s.l. [crust-free] dex
189.46	189.48	21/2/46-48	upper Tt	8			49	2				1	1																
189.93	189.96	21/2/93-96	upper Tt	2		3	41	1				5										2		1					
190.42	190.44	21/2/142-144	upper Tt	5			36					6	3									1							
190.66	190.68	21/3/16-18	upper Tt	5		1	38	4				7	3											2					
191.12	191.14	21/3/62-64	upper Tt	25			66	1				11	2											4					
191.52	191.54	21/3/102-104	upper Tt	6		3	54	1				15	1																
191.86	191.89	21/3/136-139	upper Tt	6		6	34	1				5	2											5					
192.36	192.38	21/4/36-38	upper Tt	19		2	54	3				12	3											3					
192.73	193.75	21/4/73-75	upper Tt	10		14	74	1				12	2											3					
193.12	193.14	21/4/112-114	upper Tt	12		3	67					10	1											2					
193.50	193.52	21/5/0-2	upper Tt	16		1	79	1				19																	
193.92	193.94	21/5/42-44	upper Tt	8		1	36					7	3											5					
194.34	194.26	21/5/84-86	upper Tt	6		3	30					3	2											1					
194.72	194.74	21/5/122-124	upper Tt	13			91	1				15	2									1							
195.07	195.09	21/6/7-9	upper Tt	15		6	79	2				8	1											1					
195.49	195.51	21/6/49-51	upper Tt	7			35	3				11																	
195.87	195.89	21/6/87-89	upper Tt	15		5	73	4				7	3																
196.34	196.36	21/6/134-136	upper Tt	12		5	83	2				6	2											1					
196.72	196.74	21/7/22-24	upper Tt	11		5	69					12										1		3					
197.11	197.13	22/1/1-3	upper Tt	1		6	49	1				4																	
197.48	197.50	22/1/38-40	upper Tt	3		1	18					6	1																
197.94	197.96	22/1/84-86	upper Tt	9		7	47	2				7	1											1					
198.32	198.34	22/1/122-124	upper Tt	13		7	69	5				4	1																
198.73	198.75	22/2/13-15	upper Tt	9		2	32	2				3											1						
199.14	199.16	22/2/54-56	upper Tt	4		9	68	1				8												4					
199.53	199.55	22/2/93-95	upper Tt	2		11	62					15	1																
199.93	199.95	22/2/133-135	upper Tt	2		5	38	2				4	1											3					
200.25	200.27	22/3/15-17	upper Tt	4		2	48	1				7	3																
200.66	200.68	22/3/56-58	upper Tt	8		1	33					4	1																
201.05	201.07	22/3/95-97	upper Tt	14		3	65					8	3											2					
201.42	201.44	22/3/132-134	upper Tt	8		6	73	1				10	1		1									8					
201.93	201.95	22/4/33-35	upper Tt	17		2	105					8	1																
202.52	202.55	22/4/92-95	upper Tt	8		1	69					12																	
202.93	202.95	22/4/133-135	upper Tt	3		7	52	1				7	3											3					
203.17	203.20	22CC/7-10	upper Tt	7		4	38					5																	
206.71	206.73	23/1/1-3	upper Tt	9		4	33	1	1			3										1							
207.13	207.15	23/1/43-45	upper Tt	7		7	47					3	1																
207.48	207.50	23/1/78-80	upper Tt	3		5	67	2				3										1		2					
207.88	207.90	23/1/118-120	upper Tt	6		6	78	1				2		1										2					
208.26	208.28	23/2/6-8	upper Tt	5		1	48					2																	
208.52	208.54	23/2/32-34	upper Tt	22		5	57	1				4																	
209.06	209.08	23/2/86-88	upper Tt	4		1	40	1				2		1										2					
209.54	209.56	23/2/134-136	upper Tt	6		3	55					1	1										1						
209.85	209.87	23/3/15-17	upper Tt	3		4	60					3	1											1					
210.33	210.35	23/3/63-65	upper Tt	1		3	52	7				1																	
210.53	210.55	23/3/83-85	upper Tt	15		7	33	5					2																
210.87	210.89	23/3/117-119	upper Tt	9			70	2				3	1											1					
211.27	211.29	23/4/7-9	upper Tt	3		2	76	3				3	1											2					
211.72	211.74	23/4/52-54	upper Tt	1		4	56	3				5																	
212.13	212.15	23/4/93-95	upper Tt	4		2	46	3				1																	
212.32	212.34	23/4/112-114	upper Tt	16		2	44	2				6											1						
212.71	212.73	23/5/1-3	upper Tt	4			21	2				1																	
213.12	213.14	23/5/42-44	upper Tt	13		2	83	2				2												1					
213.72	213.74	23/5/102-104	upper Tt	11		5	25	4																					
214.12	214.14	23/5/142-144	upper Tt	11			34	1				1	2											2					
214.51	214.53	23/6/31-33	upper Tt	17		1	72	15				2																	
215.05	215.07	23/6/85-87	upper Tt	9			54	2				3	2											1					
215.53	215.55	23/6/133-135	upper Tt	11		11	75	1			1	3	3																
215.93	215.95	23/7/23-25	upper Tt	20		2	75	1				2										1							
216.31	216.33	24/1/1-3	upper Tt	7		3	53	2				3																	
216.57	216.59	24/1/27-29	upper Tt	11		6	55	1				1	2											4					
216.94	216.96	24/1/64-66	upper Tt	5		13	75	1	1			1												1					
217.34	217.36	24/1/104-106	upper Tt	9		4	67	2				1																	
217.72	217.74	24/1/142-144	upper Tt	4		3	67	1																2					
218.08	218.10	24/2/28-30	upper Tt	5		3	85	2				2																	
218.52	218.54	24/2/72-74	upper Tt	6		7	54					7																	
218.87	218.89	24/2/107-109	upper Tt	6		7	95	3				4										1							
219.31	219.33	24/3/1-3	upper Tt	6		14	77	1		1		2							1										
219.72	219.74	24/3/42-44	upper Tt	10		15	111	6				7																	
220.12	220.14	24/3/82-84	upper Tt	14		12	89	4				2												1					
220.46	220.48	24/3/116-118	upper Tt	4		2	49	19				12	2																
220.87	220.89	24/4/7-9	upper Tt	16		5	71	13				6											1	3					

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Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globigerina bulloides*	*Globigerina eamesi*	*Globigerina falconensis*	*Globigerina* sp.	*Globigerina* cf. *angustiumbilicata*	*Globigerina quinqueloba*	*Globigerinella aequilateralis*	*Globigerinella aequilateralis?*	*Globigerinita glutinata*	*Globigerinita uvula*	*Globigerinita uvula?*	*Globigerinoides obliquus*	*Globigerinoides obliquus?*	*Globigerinoides quadrilobatus immaturus*	*Globigerinoides quadrilobatus quadrilobatus*	*Globigerinoides quadrilobatus quadrilobatus?*	*Globigerinoides quadrilobatus trilobus*	*Globigerinoides sacculifer*	*Globigerinopsis obesa*	*Globigerinopsis obesa?*	*Globigerinopsis sp. ?*	*Globoconella conomiozea* [crust-free] dex	*Globoconella conomiozea* [crust-free] sin	*Globoconella conomiozea* [encrusted] dex	*Globoconella conomiozea* [encrusted] sin	*Globoconella conomiozea* s.l. [crust-free] dex
221.27	221.29	24/4/47-49	upper Tt	23		8	111	22				4												2					
221.66	221.68	24/4/86-88	upper Tt	10		5	60	10				8												6					
222.13	222.15	24/4/133-135	upper Tt	13		8	65	7				7	1											2					
222.45	222.47	24/5/15-17	upper Tt	5		5	52	11				5		4															
222.93	222.95	24/5/63-65	upper Tt	6		11	49	7				1																	
223.33	223.35	24/5/103-105	upper Tt	8		10	46	3				2	1																
223.72	223.74	24/5/142-144	upper Tt	13		5	59	6				6												2					
224.07	224.09	24/6/27-29	upper Tt	9		3	24	11				3											1	2					
224.47	224.49	24/6/67-69	upper Tt	15	2	5	67	5	1			10												1					
224.87	224.89	24/6/107-109	upper Tt	5		7	27	2				6												2					
225.36	225.38	24CC/9-11	upper Tt	5		10	27	8				5										1		2					
226.13	226.15	25/1/23-25	upper Tt	10		14	57	5				1							1				2						
226.53	226.55	25/1/63-65	upper Tt	18		7	54	20				8	1											2					
226.93	226.95	25/1/103-105	upper Tt	13		11	57					5												1					
227.34	227.36	25/1/144-146	upper Tt	9		11	50					7												1					
227.72	227.74	25/2/-32-34	upper Tt	12		8	40					2																	
228.12	228.14	25/2/72-74	upper Tt	18		26	94	4				1		4															
228.52	228.54	25/2/112-114	upper Tt	23		12	78	13				8						3						1					
228.90	228.92	25/3/0-2	upper Tt	13		7	37	3	1			4										1		1					
229.33	229.35	25/3/43-45	upper Tt	7		20	102	6				3	1					1				2							
229.85	229.87	25/3/95-97	upper Tt	8		12	90	3				5		1				1						1					
230.27	230.29	25/3/137-139	upper Tt	10		19	39	3						4					1										
230.47	230.49	25/4/7-9	upper Tt	17		22	72	14				3	1											2					
230.93	230.95	25/4/53-55	upper Tt	8		18	58					5						1											
231.33	231.35	25/4/93-95	upper Tt	13		31	74	10			1	3	3											2					
231.73	231.75	25/4/133-135	upper Tt	24		10	57	3			1	9	1																
232.06	232.08	25/5/16-18	upper Tt	10		29	64	7				4	1																
232.52	232.54	25/5/62-64	upper Tt	17		9	61	8				4	2					3						2					
232.92	232.94	25/5/102-104	upper Tt	8		13	38	6				1		1				4						5					
233.27	233.29	25/5137-139	upper Tt	10		27	55	9				2	1			1								2					
233.67	233.69	25/6/27-29	upper Tt	8		26	38	10				6	1						1				1	1					
234.15	234.17	25/6/75-77	upper Tt	28		33	73	15				10	1											1					
234.52	234.54	25/6/112-114	upper Tt	28		56	93	9				10				1								7					
234.91	234.93	25/7/1-3	upper Tt	19		27	51	6				5	2											3					
235.26	235.28	25CC/10-22	upper Tt	12		29	52	7				6	1											3					
235.73	235.75	26/1/23-25	upper Tt	24		5	44	3	1		1	5	1										1	5					
236.08	236.10	26/1/58-60	upper Tt	21		14	38	1				5	2											6					
236.52	236.54	26/1/102-104	upper Tt	15		33	36	7			1	5												2					
236.92	236.94	26/1/142-144	upper Tt	7		5	38	6				2	1																
237.32	237.34	26/2/32-34	upper Tt	12			53	3				4	2											9					
237.93	237.95	26/2/93-95	upper Tt	18		6	55	3				4	3											3					
238.33	238.35	26/2/133-135	upper Tt	7		9	81	17				4												7					
238.51	238.53	26/3/1-3	upper Tt	34		6	85	6			1	6	1											1					
238.93	238.95	26/3/43-45	upper Tt	24		10	56	5				5	3									2		8					
239.32	239.34	26/3/82-84	upper Tt	13		3	87	3				4	1											5					
239.67	239.69	26/3/117-119	upper Tt	15		9	41					6	1											4					
240.07	240.09	26/4/7-9	upper Tt	24		16	51	3			2	4	1																
240.52	240.54	26/4/52-54	upper Tt	39		8	93	1				4							1					4					
240.92	240.94	26/4/92-94	upper Tt	8		40	93	3			1	3	1											5					
241.32	241.34	26/4/132-134	upper Tt	13		29	70	6				10	2										2	4					
241.65	241.67	26/5/15-17	upper Tt	21		8	79	1				7	2						1			1		2					
242.13	242.15	26/5/63-65	upper Tt	10		5	40	2				10	1									1		1					
242.52	242.54	26/5/102-104	upper Tt	6		7	57	3				15				2		6		6									
242.92	242.94	26/5/142-144	upper Tt	21		19	74	3				8	1					3		1		2		8					
243.26	243.28	26/6/26-28	upper Tt	12		11	120	2				2						1						1					
243.63	243.65	26/6/63-65	upper Tt	9		14	39	6					1					18		1			1	5					
243.86	243.88	26CC/13-15	upper Tt	11		11	44	6				5		1				6		2									
245.11	245.13	27/1/1-3	upper Tt	20		12	58	2				1						10		2		1		3					
245.53	245.55	27/1/43-45	upper Tt	4		15	75	3				2						1		2									
245.91	245.93	27/1/81-83	upper Tt	17		9	62					3					16	4						2					
246.27	246.29	27/1/117-119	upper Tt	14		16	60	1				1					10	9						2					
246.52	246.54	27/1/142-144	upper Tt	15		21	96	10				5		1			9	9						7					
246.87	246.89	27/2/27-29	upper Tt	20		10	80	4				3					8	10						1					
247.33	247.35	27/2/73-76	upper Tt	9		12	54	6				3					5	1						3					
247.67	247.69	27/2/107-109	upper Tt	11		7	62	11		1	2	4					2	6											
248.11	248.13	27/3/1-3	upper Tt	10		12	47	10				4					1	1						1					
248.47	248.49	27/3/37-39	upper Tt	15		8	70	14				4						1				1							
248.93	248.95	27/3/83-85	upper Tt	9		9	38	7				2						1						1					
249.27	249.27	27/3/117-119	upper Tt	7		10	78	10				2																	
249.67	249.69	27/4/7-9	upper Tt	19		17	118	18				5										1		2					
250.12	250.14	27/4/52-54	upper Tt	11		13	65	10				4						1	1					2					
250.46	250.48	27/4/86-88	upper Tt	3		1	52	2				4								1									

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Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globigerina bulloides*	*Globigerina eamesi*	*Globigerina falconensis*	*Globigerina* sp.	*Globigerina* cf. *angustiumbilicata*	*Globigerina quinqueloba*	*Globigerinella aequilateralis*	*Globigerinella aequilateralis?*	*Globigerinita glutinata*	*Globigerinita uvula*	*Globigerinita uvula?*	*Globigerinoides obliquus*	*Globigerinoides obliquus?*	*Globigerinoides quadrilobatus immaturus*	*Globigerinoides quadrilobatus quadrilobatus*	*Globigerinoides quadrilobatus quadrilobatus?*	*Globigerinoides quadrilobatus trilobus*	*Globigerinoides sacculifer*	*Globigerinopsis obesa*	*Globigerinopsis obesa?*	*Globigerinopsis sp.?*	*Globoconella conomiozea* [crust-free] dex	*Globoconella conomiozea* [crust-free] sin	*Globoconella conomiozea* [encrusted] dex	*Globoconella conomiozea* [encrusted] sin	*Globoconella conomiozea* s.l. [crust-free] dex
250.92	250.94	27/4/132-134	upper Tt	8		6	79	2				4	1					2						1					
251.33	251.36	27/5/23-26	upper Tt	5		11	78	3				5						1				1		4					
251.67	251.69	27/5/57-59	upper Tt	11		6	67	2				1						1				1							
252.13	252.15	27/5/103-105	upper Tt	8		13	60	5				4					1												
252.53	252.55	27/5/143-145	upper Tt	3		22	39					4												3					
252.92	252.94	27/6/32-34	upper Tt	5		16	58	2				1												5					
253.33	253.35	27/6/73-75	upper Tt	12		18	50					3					1					1		1					
253.67	253.69	27/6/107-109	upper Tt	18		12	87	4				5						2						4					
254.10	254.12	27/7/0-2	upper Tt	7		11	84	2				10										1		2					
254.49	254.51	27CC/10-12	lower Tt	8		19	102					13								1									
254.93	254.95	28/4/23-25	lower Tt	9		15	86	2				15	2											1					
255.28	255.30	28/1/58-60	lower Tt	4		31	84	2				3												1					
255.73	255.75	28/1/103-105	lower Tt	4		17	84	3				4					1	1						2					
256.11	256.13	28/1/141-143	lower Tt	4		16	51					9												4					
256.53	256.55	28/2/33-35	lower Tt	5		14	48	2				15																	
257.03	257.05	28/2/83-85	lower Tt	6		9	40	2									1						1	2					
257.33	257.35	28/2/113-115	lower Tt	6		6	48					8																	
257.71	257.73	28/3/1-3	lower Tt	4		8	42					7						1						4					
258.12	258.14	28/3/42-44	lower Tt	4		23	54	1				10											1	1					
258.54	258.56	28/3/84-86	lower Tt	6			40	1				14																	
259.07	259.09	28/3/137-139	lower Tt	2		8	36					12					1	1						1					
259.53	259.55	28/4/33-35	lower Tt	8		13	54	2				12												3					
259.86	259.88	28/4/66-68	lower Tt	10		24	88	1				12										2		5					
260.28	260.30	28/4/108-110	lower Tt	10		27	85	2				8												2					
260.54	260.56	28/4/134-136	lower Tt	11		3	93				1	7							1										
260.86	260.88	28/5/16-18	lower Tt	12		18	44					9				1													
261.31	261.33	28/5/61-63	lower Tt	11		9	94					4												2					
261.72	261.74	28/5/102-104	lower Tt	13		27	75					9												4					
262.11	262.13	28/5/141-143	lower Tt	4		7	49					4		1										1					
262.45	262.47	28CC/8-10	lower Tt	12		12	71					13	1					1						1					
264.30	264.32	29/1/0-2	lower Tt	9		6	35					4						2						1					
264.64	264.66	29/1/34-36	lower Tt	5		8	52					12										1		2					
264.88	264.90	29/1/58-60	lower Tt	6		20	46					2												2					
265.26	265.28	29/1/96-98	lower Tt	9		31	56	1				9												2					
265.72	265.74	29/1/142-144	lower Tt	7		13	79	5				5						1						2					
266.12	266.14	29/2/32-34	lower Tt	6		23	75	6				10										1							
266.44	266.46	29/2/64-66	lower Tt	5		2	57	1				5												3					
266.87	266.89	29/2/107-109	lower Tt	4		12	37					5												2					
267.31	267.33	29/3/1-3	lower Tt	2		12	53	1				5												2					
267.53	267.55	29/3/23-25	lower Tt	5		7	51	4				4		1										1					
267.72	267.74	29/3/42-44	lower Tt	7		21	84	1				8																	
267.87	267.89	29/3/57-59	lower Tt	8		17	66	3				8		2															
268.14	268.16	29/3/84-86	lower Tt	7		29	55	4				5										2							
268.34	268.36	29/3/104-106	lower Tt	6		33	67	5				2		1										3					
268.47	268.49	29/3/117-119	lower Tt	11		39	88	8				10						1						3					
268.68	268.70	29/3/138-140	lower Tt	1		12	27	3				2						4				1		4					
268.86	268.88	29/4/6-8	lower Tt	3		12	21	3				6		2				13				1		1					
269.28	269.30	29/4/48-50	lower Tt	6		19	34	1				4												2					
269.52	269.54	29/4/72-74	lower Tt	7		25	28	1				3						1						2					
269.75	269.77	29/4/95-97	lower Tt	9		28	50	1				5						4		1									
269.87	269.89	29/4/107-109	lower Tt	10		24	60	1				3						3	1										
270.15	270.17	29/4/135-137	lower Tt	6		26	41	1				7												2					
270.31	270.33	29/5/1-3	lower Tt	5		42	37					11		1				1											
270.45	270.47	29/5/15-17	lower Tt	5		9	31					5								2		1		1					
270.72	270.74	29/5/42-44	lower Tt	5		8	30					8												4					
270.91	270.93	29/5/61-63	lower Tt	5		16	68					6												2					
271.15	271.17	29/5/85-87	lower Tt	10		19	44					9						7						1					
271.34	271.36	29/5/104-106	lower Tt	10		16	58					11						4						1					
271.48	271.50	29/5/118-120	lower Tt	13		7	106					2																	
271.72	271.74	29/5/142-144	lower Tt	13		11	45	1				1						1						1					
271.94	271.96	29/6/14-16	lower Tt	14		10	73					5												2					
272.19	272.21	29CC/17-19	lower Tt	24		33	108					11	1											1					
273.91	273.93	30/1/1-A7303	lower Tt	6		17	60					6																	
274.04	274.06	30/1/14-16	lower Tt	11		31	61					5										3		2					
274.32	274.34	30/1/42-44	lower Tt	20		44	65					6												3					
274.48	274.50	30/1/58-60	lower Tt	8		30	35					3												3					
274.72	274.74	30/1/82-84	lower Tt	16		37	51					3												3					
274.93	274.95	30/1/103-105	lower Tt	37		29	75				1	13		1										2					
275.12	275.14	30/1/122-124	lower Tt	11		51	96					10												1					
275.31	275.33	30/1/141-143	lower Tt	18		19	72					3		1										6					
275.45	275.47	30/2/5-7	lower Tt	6		37	65					3						1						2					
275.93	275.95	30/2/53-55	lower Tt	6		8	40					7					1	3				2		3					

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globigerina bulloides*	*Globigerina eamesi*	*Globigerina falconensis*	*Globigerina* sp.	*Globigerina* cf. *angustiumbilicata*	*Globigerina quinqueloba*	*Globigerinella aequilateralis*	*Globigerinella aequilateralis?*	*Globigerinita glutinata*	*Globigerinita uvula*	*Globigerinita uvula?*	*Globigerinoides obliquus*	*Globigerinoides obliquus?*	*Globigerinoides quadrilobatus immaturus*	*Globigerinoides quadrilobatus quadrilobatus*	*Globigerinoides quadrilobatus quadrilobatus?*	*Globigerinoides quadrilobatus trilobus*	*Globigerinoides sacculifer*	*Globigerinopsis obesa*	*Globigerinopsis obesa?*	*Globigerinopsis sp.?*	*Globoconella conomiozea* [crust-free] dex	*Globoconella conomiozea* [crust-free] sin	*Globoconella conomiozea* [encrusted] dex	*Globoconella conomiozea* [encrusted] sin	*Globoconella conomiozea* s.l. [crust-free] dex
276.52	276.54	30/2/112-114	lower Tt	13		28	85					11		2					2			2	1	4					
276.91	276.93	30/3/1-3	lower Tt	11		9	47	1				3										3		2					
277.33	277.35	30/3/43-45	lower Tt	11		48	94					6	1									1		3					
277.74	277.76	30/3/84-86	lower Tt	8		42	97					14												2					
278.07	278.09	30/3/117-119	lower Tt	7		26	78	2				1					1							3					
278.49	278.51	30/4/9-11	lower Tt	14		32	72					6							3					2					
278.88	278.90	30/4/48-50	lower Tt	5		35	62					4		1								1		2					
279.33	279.35	30/4/93-95	lower Tt	1		32	44	1				6						1				1		2					
279.75	279.77	30/4/135-137	lower Tt	3		26	50					8										1		1					
280.05	280.07	30/5/15-17	lower Tt	3		30	54					2						1				1		1					
280.25	280.27	30/5/35-37	lower Tt	15		29	90				1	13						4						3					
280.92	280.94	30/5/102-104	lower Tt	5		31	47					8	2					17		4		3							
283.51	283.53	31/1/1-3	lower Tt	5		19	56					13							1					3					
283.94	283.96	31/1/44-46	lower Tt	3		29	57					6	2											1					
284.33	284.35	31/1/83-85	lower Tt	4		9	43					16	2					1						3					
284.55	284.57	31/1/105-107	lower Tt	5		24	53					19						5						4					
284.88	284.90	31/1/138-140	lower Tt	12		3	53					10										1		2					
285.29	285.31	31/2/29-31	lower Tt	10		15	41					9						5				1		2					
285.73	285.75	31/2/73-75	lower Tt	5		30	64					7						1				1		1					
286.10	286.12	31/2/110-112	lower Tt	5		32	61				1	8	1									3							
286.51	286.53	31/3/1-3	lower Tt	7		48	76				1	7						9	2					1					
286.88	286.90	31/3/38-40	lower Tt	4		32	50					7										1		2					
287.32	287.34	31/3/82-84	lower Tt	1		13	34					6						3				1		1					
287.67	287.69	31/3/117-119	lower Tt	3		19	73				1	13					3	16						1					
288.08	288.10	31/4/8-10	lower Tt	5		35	62					4					3	7											
288.55	288.57	31/4/55-57	lower Tt	6		23	57					7						12				2		3					
288.89	288.91	31/4/89-91	lower Tt	3		13	39					3																	
289.34	289.36	31/4/134-136	lower Tt	15		21	90					12		1								1		2					
289.73	289.75	31/5/23-25	lower Tt	5		31	114				1	5							1					2					
290.12	290.14	31/5/62-64	lower Tt	5		30	56					4										1		2					
290.51	290.53	31/5/101-103	lower Tt	8		44	58					9						5	2										
290.74	290.76	31CC/0-2	lower Tt	8		11	92					4	2					1											
293.11	293.13	32/1/1-3	lower Tt	8		32	46					6						7						2					
293.33	293.35	32/1/23-25	lower Tt	11		31	119					5	1							1				2					
293.71	293.73	32/1/61-63	lower Tt	20		3	77					8																	
294.12	294.14	32/1/102-104	lower Tt	7		22	56					7	1											2					
294.51	294.53	32/1/141-143	lower Tt	12		44	72					9							6										
294.90	294.92	32/2/30-32	lower Tt	23		41	124					6	1											1					
295.33	295.35	32/2/73-75	lower Tt	20		19	108					7												1					
295.73	295.75	32/2/113-115	lower Tt	11		8	71					6												2					
295.93	295.95	32/2/133-135	lower Tt	8		14	50					4								1				3					
296.50	296.52	32/3/40-42	lower Tt	9		33	45					4												2					
296.93	296.95	32/3/83-85	lower Tt	12		17	106					7																	
297.33	297.35	32/3/123-125	lower Tt	18		7	60					1																	
297.70	297.72	32/4/10-12	lower Tt	29		18	117					5																	
298.08	298.10	32/4/48-50	lower Tt	7		19	86					10												1					
298.52	298.54	32/4/92-94	lower Tt	6		52	35				1	5						1											
298.93	298.95	32/4/133-135	lower Tt	25		31	86			1		6																	
299.38	299.40	32/5/28-30	lower Tt	13		26	98					3						16											
299.67	299.69	32CC/2-4	lower Tt	8		49	69					12						12						2					
302.71	302.73	33/1/1-3	lower Tt	1		29	51					4												1					
302.97	302.99	33/1/27-29	lower Tt	7		19	65					13	1											3					
303.29	303.31	33/1/59-61	lower Tt	11		11	78					14						1						3					
303.77	303.79	33/1/107-109	lower Tt	7		10	76					3												1					
304.13	304.15	33/1/143-145	lower Tt	9		19	85					8																	
304.29	304.31	33/2/9-11	lower Tt	9		22	60					4		1										2					
304.47	304.49	33/2/27-29	lower Tt	14		41	102				1	11												1					
304.66	304.68	33/2/46-48	lower Tt	16		24	112					11		3															
305.02	305.04	33/2/82-84	lower Tt	8		17	82					7	3											1					
305.15	305.17	33/2/95-97	lower Tt	7		7	57					11																	
305.34	305.36	33/2/114-116	lower Tt	6		13	66					3						1											
305.55	305.57	33/2/135-137	lower Tt	5		13	53					10		1										1					
305.71	305.73	33/3/1-3	lower Tt	12		27	61	1				6						2						1					
305.93	305.95	33/3/23-25	lower Tt	6		6	25					5						1											
306.11	306.13	33/3/41-43	lower Tt	7		22	53					5	1					7						2					
306.27	306.29	33/3/57-59	lower Tt	6		24	64					3		1				1		1									
306.54	306.56	33/3/84-86	lower Tt	5		7	30					8		1															
306.75	306.77	33/3/105-107	lower Tt	9		34	74					12		2				1						2					
306.86	306.88	33/3/116-118	lower Tt	5		23	61					5																	
307.08	307.10	33/3/138-140	lower Tt	2		12	35					8							1					1					
307.30	307.32	33/4/10-12	lower Tt	10		19	51					2																	
307.49	307.51	33/4/29-31	lower Tt	4		5	12					3		1										1					

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globigerina bulloides*	*Globigerina eamesi*	*Globigerina falconensis*	*Globigerina* sp.	*Globigerina* cf. *angustiumbilicata*	*Globigerina quinqueloba*	*Globigerinella aequilateralis*	*Globigerinella aequilateralis?*	*Globigerinita glutinata*	*Globigerinita uvula*	*Globigerinita uvula?*	*Globigerinoides obliquus*	*Globigerinoides obliquus?*	*Globigerinoides quadrilobatus immaturus*	*Globigerinoides quadrilobatus quadrilobatus*	*Globigerinoides quadrilobatus quadrilobatus?*	*Globigerinoides quadrilobatus trilobus*	*Globigerinoides sacculifer*	*Globigerinopsis obesa*	*Globigerinopsis obesa?*	*Globigerinopsis sp.?*	*Globoconella conomiozea* [crust-free] dex	*Globoconella conomiozea* [crust-free] sin	*Globoconella conomiozea* [encrusted] dex	*Globoconella conomiozea* [encrusted] sin	*Globoconella conomiozea* s.l. [crust-free] dex
307.70	307.72	33/4/50-52	lower Tt	3		12	27					4						1						1					
307.93	307.95	33/4/73-75	lower Tt	4		35	77					11												1					
308.14	308.16	33/4/94-96	lower Tt	11		24	84					5						1						1					
308.30	308.32	33/4/110-112	lower Tt	8		15	67				1	7	1											2					
308.53	308.55	33/4/133-135	lower Tt	3		17	41					3																	
308.71	308.73	33/5/1-3	lower Tt	10		16	53				1		2											1					
308.99	309.01	33/5/29-31	lower Tt	9		13	50					6												1					
309.11	309.13	33/5/41-43	lower Tt	5		15	54					9	1											1					
309.28	309.30	33/5/58-60	lower Tt	6		28	71					9																	
309.54	309.56	33/5/84-86	lower Tt			29	56					9	1																
309.74	309.76	33/5/104-106	lower Tt	7		24	64					9	1																
312.31	312.33	34/1/1-3	lower Tt	4		20	39					8						1											
312.54	312.56	34/1/24-26	lower Tt	4		11	57					1												4					
312.67	312.69	34/1/37-39	lower Tt	2		17	50					6																	
312.87	312.89	34/1/57-59	lower Tt	4		11	37					9																	
313.07	313.09	34/1/77-79	lower Tt	6		24	68					11	1																
313.31	313.33	34/1/101-103	lower Tt	3		19	40					5								1									
313.53	313.55	34/1/123-125	lower Tt	9		6	58					3	2											3					
313.71	313.73	34/1/141-143	lower Tt	17		16	55					10	2											1					
313.90	313.92	34/2/10-12	lower Tt	6		8	52					10	1											1					
314.09	314.11	34/2/29-31	lower Tt	6		8	23	1				5	1											2					
314.29	314.31	34/2/49-51	lower Tt	3		9	17				1	1												2					
314.45	314.47	34/2/65-67	lower Tt	5		9	35	2				1	6											2					
314.69	314.71	34/2/89-91	lower Tt	3		28	57	4				4																	
314.90	314.92	34/2/110-112	lower Tt	9		13	34					4												1					
315.13	315.15	34/2/133-135	lower Tt	2		25	39	5				11																	
315.30	315.32	34/3/0-2	upper Sw	7		12	33	1				7																	
315.52	315.54	34/3/22-24	upper Sw	9		11	56	8				11						1						2					
315.71	315.73	34/3/41-43	upper Sw	13		20	49	3				8	2											1					
316.06	316.08	34/3/76-78	upper Sw	17		15	66	12				7								1				2					
316.27	316.29	34/3/97-99	upper Sw	7		12	43	10				5		3				1											
316.48	316.50	34/3/118-120	upper Sw	2		15	46	3				6	1																
316.67	316.69	34/3/137-139	upper Sw	6		10	58	13				4												1					
317.10	317.12	34/4/30-32	upper Sw	3		20	53	10				11												1					
317.50	317.52	34/4/70-72	upper Sw	3		11	38					10								1		1							
317.90	317.92	34/4/110-112	upper Sw			8	11	1				12										1							
318.35	318.37	34/5/5-7	upper Sw	2		5	17	1				7												5					
318.60	318.62	34/5/30-32	upper Sw	4		23	44	10				4												5					
321.91	321.93	35/1/1-3	upper Sw	1		44	48	2				6												2					
322.33	322.35	35/1/43-45	upper Sw	3		65	112	7				9												2					
322.72	322.74	35/1/82-84	upper Sw	12		11	48	1				8												1					
323.09	323.11	35/1/119-121	upper Sw	3		9	23	3				12												1					
323.48	323.50	35/2/8-10	upper Sw	1			13	9				7	1											1					
323.91	323.93	35/2/51-53	upper Sw	2		7	17	12				8								1				1					
324.50	324.52	35/2/110-112	upper Sw	2		8	21	1				3																	
324.91	324.93	35/3/1-3	upper Sw	2		4	10					2												1					
325.33	325.35	35/3/43-45	upper Sw	7		16	20					16												1					
325.71	325.73	35/3/81-83	upper Sw	5		3	34					9												3					
325.94	325.96	35/3/104-106	upper Sw	2		6	20					18	1																
326.28	326.30	35/3/138-140	upper Sw	5		36	65					13												1					
326.70	326.72	35/4/30-32	upper Sw	6		10	31					3										1		1					
327.09	327.11	35/4/69-71	upper Sw	2		13	19					4												3					
327.50	327.52	35/4/110-112	upper Sw	19		10	46	7				6												1					
327.91	327.93	35/5/1-3	upper Sw	5		54	90	4				3								1				1					
328.27	328.29	35/5/37-39	upper Sw	4		16	41					6	5											3					
328.72	328.74	35/5/82-84	upper Sw	3		19	27					2	1							1									
331.69	331.71	36/1/19-21	upper Sw	3		13	34	1				4												2					
332.11	332.13	36/1/61-63	upper Sw	3		26	45	2				3												3					
332.68	332.70	36/1/118-120	upper Sw	9		12	50	1				1												2					
332.98	333.00	36/1/148-150	upper Sw	5		16	42	1				4	1											2					
333.40	333.42	36/2/40-42	upper Sw	9		29	58					3												5					
334.00	334.02	36/2/100-102	upper Sw	7		23	65	2				5											1						
334.36	334.38	36/2/136-138	upper Sw	7		14	19	1				4							1										
334.87	334.89	36/3/37-39	upper Sw	9		23	42					6												5					
335.47	335.49	36/3/97-99	upper Sw	25		29	84				1	5						13		2				2					
335.88	335.90	36/3/138-140	upper Sw	14		13	46	1				6												1					
336.20	336.22	36/4/20-22	upper Sw	24		42	115	1				1																	
336.60	336.62	36/4/60-62	upper Sw	6		31	107	1				8	2																

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globoconella conomiozea* s.l. [crust-free] sin	*Globoconella explicationis* dex	*Globoconella explicationis* sin	*Globoconella miotumida* [crust-free] dex	*Globoconella miotumida* [crust-free] sin	*Globoconella miotumida* [encrusted] dex	*Globoconella miotumida* [encrusted] sin	*Globoconella miotumida* [weakly carinate] dex	*Globoconella miotumida* [weakly carinate] sin	*Globoconella miotumida* s.l. [crust-free] dex	*Globoconella miotumida* s.l. [crust-free] sin	*Globoconella mons* [crust-free] dex	*Globoconella mons* [crust-free] sin	*Globoconella mons* [encrusted] dex	*Globoconella mons* [encrusted] sin	*Globoconella mons?* [crust-free] dex	*Globoconella mons?* [crust-free] sin	*Globoconella mons?* [encrusted] dex	*Globoconella mons?* [encrusted] sin	*Globoconella pliozea* [crust-free] dex	*Globoconella pliozea* [encrusted] dex	*Globoconella pliozea* [encrusted] sin	*Globoconella pliozea?* [crust-free] dex	*Globoconella pliozea?* [crust-free] sin	*Globoconella pliozea?* [encrusted] dex	*Globoconella pliozea?* [encrusted] sin
120.30	120.33	14/1/0-3	lower Wo	4																1					6		4		
120.51	120.54	14/1/21-24	lower Wo	3											1										2		5		
120.69	120.72	14/1/39-42	lower Wo	9																					11		4		
120.90	120.93	14/1/60-63	lower Wo	10											1									3	26		2		
121.11	121.14	14/1/81-84	lower Wo	16																					22		4		
121.26	121.29	14/1/96-99	lower Wo	12												1									34		3		
121.49	121.52	14/1/119-122	lower Wo	10																2					11				
121.69	121.72	14/1/139-142	lower Wo	8																				2	7				
121.90	121.93	14/2/10-13	lower Wo	14																		1		1	15				
122.09	122.12	14/2/29-32	lower Wo	5																					5				
122.26	122.29	14/2/46-49	lower Wo	6																				1	7				
122.51	122.55	14/2/71-75	lower Wo	4																					6		2	1	
122.71	122.74	14/2/91-94	lower Wo	14															1						4		2		
122.92	122.95	14/2/112-115	lower Wo	4																				5	1		1		
123.10	123.13	14/2/130-133	upper Tk	3																				7	3	10	6		
123.30	123.33	14/3/0-3	upper Tk	6																					1				
123.53	123.56	14/3/23-26	upper Tk	4																						1		3	2
123.69	123.72	14/3/39-42	upper Tk	5																								4	2
123.88	123.91	14/3/58-61	upper Tk	2																								2	5
124.11	124.14	14/3/81-84	upper Tk	11																							3	1	10
124.30	124.33	14/3/100-103	upper Tk	14																							3	2	14
124.50	124.53	14/3/120-123	upper Tk	6																							3	1	9
124.68	124.71	14/3/138-141	upper Tk	6																		2				4			4
124.90	124.93	14/4/10-13	upper Tk	9																							1	2	16
125.10	125.13	14/4/30-33	upper Tk	6																							1	1	12
125.30	125.33	14/4/50-53	upper Tk	9																2		12					3		15
125.48	125.51	14/4/68-71	upper Tk	1																							3	2	10
125.71	125.74	14/4/91-94	upper Tk																							1	2	2	2
125.91	125.94	14/4/111-114	upper Tk	1										1													1	8	
126.10	126.13	14/4/130-133	upper Tk											2														6	
126.30	126.33	14/5/0-3	upper Tk	1									3															1	4
126.56	126.59	14/5/26-29	upper Tk										1					1						1					
126.70	126.73	14/5/40-43	upper Tk															2		3									
126.90	126.93	14/5/60-63	upper Tk										2					3				3		2					
127.12	127.15	14/5/82-85	upper Tk	5									2					1						1					
127.30	127.33	14/5/100-103	upper Tk	4																				1					
127.51	127.54	14/5/121-124	upper Tk																					2					
127.70	127.73	14/5/140-143	upper Tk	3												1						1		2	2				
127.90	127.93	14/6/10-13	upper Tk	3																	1		5	12					
128.29	128.32	14/6/49-52	upper Tk																			2						1	
128.72	128.75	14/6/92-95	upper Tk	4																									
129.10	129.13	14/6/130-133	upper Tk	10																		2							
129.50	129.53	14/7/20-23	upper Tk	13									1									3			6				
129.90	129.93	15/1/0-3	upper Tk	5																		2			2	2		1	
130.29	130.32	15/1/39-42	upper Tk	10																									
130.69	130.72	15/1/79-82	upper Tk	6										1				2											
131.10	131.13	15/1/120-123	upper Tk	2																									
131.51	131.54	15/2/11-14	upper Tk	4																									
131.91	131.93	15/2/51-53	upper Tk	10													1	4											
132.33	132.36	15/2/93-96	upper Tk	3																					1				
132.74	132.76	15/2/134-136	upper Tk	5																									
133.07	133.10	15/3/17-20	upper Tk	16										1															
133.46	133.49	15/3/56-59	upper Tk	5										1						2									
133.89	133.92	15/3/99-102	upper Tk																										
134.30	134.33	15/3/140-143	upper Tk											1															
134.70	134.73	15/4/30-33	upper Tk	20										1			1												
135.10	135.13	15/4/70-73	upper Tk	28									2	9								1							
135.30	135.33	15/4/90-93	upper Tk	28		2								2				4			2								
135.50	135.53	15/4/110-113	upper Tk	11																									
135.70	135.73	15/4/130-133	upper Tk	15										2								1							
135.90	135.93	15/5/0-3	upper Tk	30										5															
136.06	136.09	15/5/16-19	upper Tk	14										2															
136.32	136.35	15/5/42-45	upper Tk	38										5															
136.51	136.53	15/5/61-63	upper Tk	40										2				2											
136.92	136.95	15/5/102-105	upper Tk	16																									
137.13	137.16	15/5/123-126	upper Tk	13										2				3											
137.52	137.55	15/6/12-15	upper Tk	27										15				1											
137.91	137.94	15/6/51-54	upper Tk	28									1	3				1											
138.27	138.30	15/6/87-90	upper Tk	30									1																
138.66	138.69	15/6/126-129	upper Tk	34										6															
139.07	139.10	15/7/17-20	upper Tk	37										10															
139.50	139.53	16/1/0-3	upper Tk	20										8				2											

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globoconella conomiozea* s.l. [crust-free] sin	*Globoconella explicationis* dex	*Globoconella explicationis* sin	*Globoconella miotumida* [crust-free] dex	*Globoconella miotumida* [crust-free] sin	*Globoconella miotumida* [encrusted] dex	*Globoconella miotumida* [encrusted] sin	*Globoconella miotumida* [weakly carinate] dex	*Globoconella miotumida* [weakly carinate] sin	*Globoconella miotumida* s.l. [crust-free] dex	*Globoconella miotumida* s.l. [crust-free] sin	*Globoconella mons* [crust-free] dex	*Globoconella mons* [crust-free] sin	*Globoconella mons* [encrusted] dex	*Globoconella mons* [encrusted] sin	*Globoconella mons?* [crust-free] dex	*Globoconella mons?* [crust-free] sin	*Globoconella mons?* [encrusted] dex	*Globoconella mons?* [encrusted] sin	*Globoconella pliozea* [crust-free] dex	*Globoconella pliozea* [encrusted] dex	*Globoconella pliozea* [encrusted] sin	*Globoconella pliozea?* [crust-free] dex	*Globoconella pliozea?* [crust-free] sin	*Globoconella pliozea?* [encrusted] dex	*Globoconella pliozea?* [encrusted] sin
139.93	139.96	16/1/43-46	upper Tk	30										13				1											
140.34	140.37	16/1/84-87	upper Tk	20										9															
140.73	140.76	16/1/123-126	upper Tk	25										8				2											
141.13	141.15	16/2/13-16	upper Tk	14										6															
141.54	141.57	16/2/54-57	upper Tk	37										18				2											
141.92	141.95	16/2/92-95	upper Tk	21										3															
142.32	142.35	16/2/132-135	upper Tk	22										12				2											
142.75	142.78	16/3/25-28	upper Tk	32										4				2											
143.15	143.18	16/3/65-68	upper Tk	24										2															
143.53	143.56	16/3/103-106	upper Tk	41		1								11				2											
143.84	143.87	16/3/134-137	lower Tk									5		4															
144.26	144.29	16/4/26-29	lower Tk											4				1											
144.67	144.70	16/4/67-70	lower Tk									3	1	10															
145.13	145.16	16/4/113-116	lower Tk									2		7				1											
145.50	145.53	16/5/0-3	lower Tk									4	1	11			1												
145.93	145.96	16/5/43-46	lower Tk			1						2	1	8															
146.36	146.38	16/5/86-88	lower Tk									1		4															
146.71	146.74	16/5/121-124	lower Tk									1		2															
147.06	147.09	16/6/6-9	lower Tk									1		6															
147.47	147.50	16/6/47-50	lower Tk									7		6															
147.93	147.96	16/6/93-96	lower Tk									1	1	2															
148.33	148.36	16/6/133-136	lower Tk											2															
148.67	148.69	16/7/17-19	lower Tk								1	1		5															
149.10	149.13	17/1/0-3	lower Tk									5	1	16															
149.52	149.55	17/1/42-45	lower Tk											11															
150.11	150.14	17/1/101-104	lower Tk									3		5															
150.51	150.54	17/1/141-144	lower Tk									3		5															
150.87	150.90	17/2/27-30	lower Tk									1	2	9															
151.07	151.10	17/2/47-50	lower Tk									4		2															
151.52	151.55	17/2/92-95	lower Tk									1	1	7															
151.96	151.98	17/2/136-138	lower Tk									6		6															
152.10	152.13	17/3/0-3	lower Tk											7															
152.25	152.28	17/3/15-18	lower Tk											5															
152.47	152.50	17/3/37-40	lower Tk			1						2		6															
152.75	152.77	17/3/65-67	lower Tk									1		10															
152.91	152.94	17/3/81-84	lower Tk											6															
153.12	153.15	17/3/102-105	lower Tk										1	7															
153.26	153.29	17/3/116-119	lower Tk											9															
153.45	153.48	17/3/135-138	lower Tk											7															
153.66	153.69	17/4/6-9	lower Tk											3															
153.97	153.99	17/4/37-39	lower Tk										3	1															
154.13	154.16	17/4/53-56	lower Tk									1	4	7															
154.32	154.35	17/4/72-75	lower Tk									1	1	7															
154.54	154.57	17/4/94-97	lower Tk									2		10															
154.77	154.79	17/4/117-119	lower Tk											4															
154.95	154.98	17/4/135-138	lower Tk											8															
155.10	155.13	17/5/0-3	lower Tk									2		5															
155.24	155.27	17/5/14-17	lower Tk										1	3															
155.48	155.50	17/5/38-40	lower Tk									3	2	9															
155.67	155.70	17/5/57-60	lower Tk									2	1	6															
155.94	155.97	17/5/84-87	lower Tk									3	2	7															
156.13	156.16	17/5/103-106	lower Tk								1	2	1	11															
156.27	156.30	17/5/117-120	lower Tk			1						2		3															
156.47	156.50	17/5/137-140	lower Tk									1		11															
156.71	156.74	17/6/11-14	lower Tk			1						2		15															
156.95	156.98	17/6/35-38	lower Tk											3															
157.12	157.15	17/6/52-55	lower Tk										1	8															
157.37	157.39	17/6/77-79	lower Tk										3	8															
157.52	157.55	17/6/92-95	lower Tk									1	2	6															
157.76	157.79	17/6/116-119	lower Tk			1						4	1	5															
157.93	157.96	17/6/133-136	lower Tk								2		7	2															
158.10	153.13	17/7/0-3	lower Tk										4	3															
158.27	158.30	17/7/17-20	lower Tk									2	1	14															
158.52	158.55	17CC/6-9	lower Tk											3															
158.70	158.73	18/1/0-3	lower Tk									3	1	7															
158.95	158.98	18/1/25-28	lower Tk									2		8															
159.13	159.16	18/1/43-46	lower Tk									2		6															
159.35	159.38	18/1/65-68	lower Tk									9		11															
159.49	159.52	18/1/79-82	lower Tk									8	1	12															
159.72	159.75	18/1/102-105	lower Tk								1	11		6															
159.86	159.89	18/1/116-119	lower Tk								1	9		4															
160.11	160.14	18/1/141-144	lower Tk									4	1	12															

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globoconella conomiozea* s.l. [crust-free] sin	*Globoconella explicationis* dex	*Globoconella explicationis* sin	*Globoconella miotumida* [crust-free] dex	*Globoconella miotumida* [crust-free] sin	*Globoconella miotumida* [encrusted] dex	*Globoconella miotumida* [encrusted] sin	*Globoconella miotumida* [weakly carinate] dex	*Globoconella miotumida* [weakly carinate] sin	*Globoconella miotumida* s.l. [crust-free] dex	*Globoconella miotumida* s.l. [crust-free] sin	*Globoconella mons* [crust-free] dex	*Globoconella mons* [crust-free] sin	*Globoconella mons* [encrusted] dex	*Globoconella mons* [encrusted] sin	*Globoconella mons?* [crust-free] dex	*Globoconella mons?* [crust-free] sin	*Globoconella mons?* [encrusted] dex	*Globoconella mons?* [encrusted] sin	*Globoconella pliozea* [crust-free] dex	*Globoconella pliozea* [encrusted] dex	*Globoconella pliozea* [encrusted] sin	*Globoconella pliozea?* [crust-free] dex	*Globoconella pliozea?* [crust-free] sin	*Globoconella pliozea?* [encrusted] dex	*Globoconella pliozea?* [encrusted] sin
160.33	160.36	18/2/13-16	lower Tk											7															
160.73	160.76	18/2/53-56	lower Tk									3	1	7															
161.16	161.19	18/2/96-99	lower Tk									4		30															
161.53	161.56	18/2/133-136	lower Tk										1	17															
161.84	161.87	18/3/14-17	lower Tk									5		13															
162.26	162.29	18/3/56-59	lower Tk									1		9															
162.87	162.90	18/3/117-120	lower Tk											25															
163.33	163.36	18/4/13-16	lower Tk									2		19															
163.56	163.59	18/4/36-39	lower Tk											18															
163.93	163.96	18/4/73-76	lower Tk											14															
164.31	164.33	18/4/111-113	lower Tk											11															
164.70	164.73	18/5/0-3	lower Tk									1		16															
165.13	165.16	18/5/43-46	lower Tk									2	1	20															
165.50	165.53	18/5/80-83	lower Tk											29															
165.95	165.97	18/5/125-127	lower Tk									3	2	22															
166.26	166.29	18/6/6-9	lower Tk									3		25															
166.66	166.69	18/6/46-49	lower Tk										1	17															
167.06	167.09	18/6/86-89	lower Tk											11															
167.44	167.47	18/6/124-127	upper Tt				2	22	1	113																			
168.30	168.33	19/1/0-3	upper Tt				2	25	1	67																			
168.71	168.74	19/1/41-44	upper Tt				2	33	2	85		4																	
169.13	169.15	19/1/83-85	upper Tt					20	2	61																			
169.51	169.54	19/1/121-124	upper Tt					23	1	55		1																	
169.85	169.88	19/2/5-8	upper Tt				1	30	4	57		2																	
170.32	170.35	19/2/52-55	upper Tt			1		46	4	85		7																	
170.73	170.76	19/2/93-96	upper Tt					31	2	89																			
171.15	171.18	19/2/135-138	upper Tt				1	40	6	99		1																	
171.57	171.59	19/3/27-29	upper Tt				1	29		74																			
171.92	171.94	19/3/62-64	upper Tt				1	34	3	54		1																	
172.32	172.35	19/3/102-105	upper Tt			1		33	5	75		2																	
172.66	172.68	19/3/136-138	upper Tt					32	1	61		1																	
173.07	173.09	19/4/27-29	upper Tt					35	2	60																			
173.52	173.54	19/4/72-74	upper Tt					35	1	64																			
173.93	173.95	19/4/113-115	upper Tt			1		52	3	71		3																	
174.30	174.33	19/5/0-3	upper Tt			1	1	42	5	78		3																	
174.72	174.75	19/5/42-45	upper Tt					34	2	95		1																	
175.26	175.28	19/5/96-99	upper Tt				1	36	1	55		7																	
175.71	175.74	19/5/141-144	upper Tt				1	20		57		1																	
176.06	176.09	19/6/26-29	upper Tt			1		32	1	54		2																	
176.47	176.49	19/6/67-69	upper Tt					15		41		1																	
176.92	176.94	19/6/112-114	upper Tt					22	2	43		3																	
177.30	177.33	19/7/0-3	upper Tt				1	18		61																			
177.52	177.55	19/7/22-25	upper Tt				2	49	5	97		3																	
177.90	177.93	20/1/0-3	upper Tt				3	31	1	62																			
178.27	178.30	20/1/37-40	upper Tt					36		62																			
178.68	178.70	20/1/78-80	upper Tt				1	60	2	100																			
179.08	179.10	20/1/118-120	upper Tt				2	42	2	84																			
179.45	179.47	20/2/5-7	upper Tt				3	62	5	99																			
179.86	179.88	20/2/46-48	upper Tt			1	1	41	2	70																			
180.33	180.35	20/2/93-95	upper Tt					35	3	88																			
180.73	180.75	20/2/133-135	upper Tt			1		31		81																			
181.14	181.16	20/3/24-26	upper Tt			1		25	1	81																			
181.57	181.59	20/3/67-69	upper Tt					17	1	56																			
181.86	181.88	20/3/96-98	upper Tt			1	1	47	1	73																			
182.23	182.25	20/3/133-135	upper Tt					37	2	76																			
182.68	182.70	20/4/28-30	upper Tt		1			28	1	53																			
183.08	183.10	20/4/68-70	upper Tt					34		72																			
183.45	183.47	20/4/105-107	upper Tt				1	51	2	108																			
183.91	183.93	20/5/1-3	upper Tt				1	31	2	69																			
184.32	184.34	20/5/42-44	upper Tt					27	1	42																			
184.72	184.74	20/5/82-84	upper Tt			1	1	36		68																			
185.07	185.09	20/5/117-119	upper Tt			1	4	42		83																			
185.47	185.49	20/6/7-9	upper Tt				1	23	1	78																			
185.92	185.94	20/6/52-54	upper Tt					23	1	54																			
186.32	186.34	20/6/92-94	upper Tt					36		48																			
186.72	186.74	20/6/132-134	upper Tt			2		31		60																			
187.07	187.09	20/7/17-19	upper Tt				1	31	1	39																			
187.51	187.53	21/1/1-3	upper Tt				1	22		54																			
187.93	187.95	21/1/43-45	upper Tt					17		23																			
188.32	188.34	21/182-84	upper Tt					21	2	32																			
188.67	188.69	21/1/117-119	upper Tt				1	20	2	48																			
189.08	189.10	21/2/8-10	upper Tt				1	17		36																			

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globoconella conomiozea* s.l. [crust-free] sin	*Globoconella explicationis* dex	*Globoconella explicationis* sin	*Globoconella miotumida* [crust-free] dex	*Globoconella miotumida* [crust-free] sin	*Globoconella miotumida* [encrusted] dex	*Globoconella miotumida* [encrusted] sin	*Globoconella miotumida* [weakly carinate] dex	*Globoconella miotumida* [weakly carinate] sin	*Globoconella miotumida* s.l. [crust-free] dex	*Globoconella miotumida* s.l. [crust-free] sin	*Globoconella mons* [crust-free] dex	*Globoconella mons* [crust-free] sin	*Globoconella mons* [encrusted] dex	*Globoconella mons* [encrusted] sin	*Globoconella mons?* [crust-free] dex	*Globoconella mons?* [crust-free] sin	*Globoconella mons?* [encrusted] dex	*Globoconella mons?* [encrusted] sin	*Globoconella pliozea* [crust-free] dex	*Globoconella pliozea* [encrusted] dex	*Globoconella pliozea* [encrusted] sin	*Globoconella pliozea?* [crust-free] dex	*Globoconella pliozea?* [crust-free] sin	*Globoconella pliozea?* [encrusted] dex	*Globoconella pliozea?* [encrusted] sin
189.46	189.48	21/2/46-48	upper Tt			1		18		70																			
189.93	189.96	21/2/93-96	upper Tt				1	22	1	43																			
190.42	190.44	21/2/142-144	upper Tt					12	1	46																			
190.66	190.68	21/3/16-18	upper Tt					28		41																			
191.12	191.14	21/3/62-64	upper Tt					9	2	42																			
191.52	191.54	21/3/102-104	upper Tt				2	33	2	63																			
191.86	191.89	21/3/136-139	upper Tt					18	1	60																			
192.36	192.38	21/4/36-38	upper Tt				2	13	1	40																			
192.73	193.75	21/4/73-75	upper Tt				3	20	2	47																			
193.12	193.14	21/4/112-114	upper Tt				1	25	2	37																			
193.50	193.52	21/5/0-2	upper Tt			1	3	43		103																			
193.92	193.94	21/5/42-44	upper Tt				1	28	1	58																			
194.34	194.26	21/5/84-86	upper Tt				1	13	2	50																			
194.72	194.74	21/5/122-124	upper Tt				1	26	2	64																			
195.07	195.09	21/6/7-9	upper Tt				1	12		27																			
195.49	195.51	21/6/49-51	upper Tt			1	2	33	1	45																			
195.87	195.89	21/6/87-89	upper Tt					32	1	32																			
196.34	196.36	21/6/134-136	upper Tt				2	32	1	51																			
196.72	196.74	21/7/22-24	upper Tt					15		25		2																	
197.11	197.13	22/1/1-3	upper Tt					28	1	78	1																		
197.48	197.50	22/1/38-40	upper Tt					20		23																			
197.94	197.96	22/1/84-86	upper Tt				1	17	2	38																			
198.32	198.34	22/1/122-124	upper Tt					26	1	67																			
198.73	198.75	22/2/13-15	upper Tt				1	19	1	63																			
199.14	199.16	22/2/54-56	upper Tt					15	6	69																			
199.53	199.55	22/2/93-95	upper Tt					20	2	68																			
199.93	199.95	22/2/133-135	upper Tt				1	5		7																			
200.25	200.27	22/3/15-17	upper Tt					14	1	41																			
200.66	200.68	22/3/56-58	upper Tt				1	22	1	55																			
201.05	201.07	22/3/95-97	upper Tt					15		41																			
201.42	201.44	22/3/132-134	upper Tt				3	40	5	114																			
201.93	201.95	22/4/33-35	upper Tt					23	3	46																			
202.52	202.55	22/4/92-95	upper Tt					21	2	43																			
202.93	202.95	22/4/133-135	upper Tt				1	28	3	65																			
203.17	203.20	22CC/7-10	upper Tt					25	1	31																			
206.71	206.73	23/1/1-3	upper Tt					25		48																			
207.13	207.15	23/1/43-45	upper Tt					23	1	41																			
207.48	207.50	23/1/78-80	upper Tt				1	26	2	47																			
207.88	207.90	23/1/118-120	upper Tt				2	18		38																			
208.26	208.28	23/2/6-8	upper Tt				1	19		32																			
208.52	208.54	23/2/32-34	upper Tt				2	28	3	51																			
209.06	209.08	23/2/86-88	upper Tt					22	1	39																			
209.54	209.56	23/2/134-136	upper Tt					19	1	27																			
209.85	209.87	23/3/15-17	upper Tt			3		25		42																			
210.33	210.35	23/3/63-65	upper Tt					18		37																			
210.53	210.55	23/3/83-85	upper Tt					24		47																			
210.87	210.89	23/3/117-119	upper Tt					29	3	49																			
211.27	211.29	23/4/7-9	upper Tt		1		1	28	1	56																			
211.72	211.74	23/4/52-54	upper Tt				1	25	3	33																			
212.13	212.15	23/4/93-95	upper Tt			1	1	22	1	44																			
212.32	212.34	23/4/112-114	upper Tt				1	37	3	88																			
212.71	212.73	23/5/1-3	upper Tt				2	22	1	53																			
213.12	213.14	23/5/42-44	upper Tt					22	1	29																			
213.72	213.74	23/5/102-104	upper Tt					23	2	31																			
214.12	214.14	23/5/142-144	upper Tt					4		29																			
214.51	214.53	23/6/31-33	upper Tt				1	28	5	100																			
215.05	215.07	23/6/85-87	upper Tt					31	2	73																			
215.53	215.55	23/6/133-135	upper Tt				2	37	5	67																			
215.93	215.95	23/7/23-25	upper Tt					32		42																			
216.31	216.33	24/1/1-3	upper Tt		1			28	1	36																			
216.57	216.59	24/1/27-29	upper Tt			1	1	53	3	123																			
216.94	216.96	24/1/64-66	upper Tt				1	34	2	74																			
217.34	217.36	24/1/104-106	upper Tt					26	1	63																			
217.72	217.74	24/1/142-144	upper Tt				1	38	1	66																			
218.08	218.10	24/2/28-30	upper Tt					37		70																			
218.52	218.54	24/2/72-74	upper Tt					56	2	155																			
218.87	218.89	24/2/107-109	upper Tt				2	49	1	76																			
219.31	219.33	24/3/1-3	upper Tt				1	20	2	49																			
219.72	219.74	24/3/42-44	upper Tt					26	4	36																			
220.12	220.14	24/3/82-84	upper Tt					55	1	33																			
220.46	220.48	24/3/116-118	upper Tt				1	28	1	26																			
220.87	220.89	24/4/7-9	upper Tt					20		18																			

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globoconella conomiozea* s.l. [crust-free] sin	*Globoconella explicationis* dex	*Globoconella explicationis* sin	*Globoconella miotumida* [crust-free] dex	*Globoconella miotumida* [crust-free] sin	*Globoconella miotumida* [encrusted] dex	*Globoconella miotumida* [encrusted] sin	*Globoconella miotumida* [weakly carinate] dex	*Globoconella miotumida* [weakly carinate] sin	*Globoconella miotumida* s.l. [crust-free] dex	*Globoconella miotumida* s.l. [crust-free] sin	*Globoconella mons* [crust-free] dex	*Globoconella mons* [crust-free] sin	*Globoconella mons* [encrusted] dex	*Globoconella mons* [encrusted] sin	*Globoconella mons?* [crust-free] dex	*Globoconella mons?* [crust-free] sin	*Globoconella mons?* [encrusted] dex	*Globoconella mons?* [encrusted] sin	*Globoconella pliozea* [crust-free] dex	*Globoconella pliozea* [encrusted] dex	*Globoconella pliozea* [encrusted] sin	*Globoconella pliozea?* [crust-free] dex	*Globoconella pliozea?* [crust-free] sin	*Globoconella pliozea?* [encrusted] dex	*Globoconella pliozea?* [encrusted] sin
221.27	221.29	24/4/47-49	upper Tt					18		17																			
221.66	221.68	24/4/86-88	upper Tt				2	26	1	38																			
222.13	222.15	24/4/133-135	upper Tt					21	3	30																			
222.45	222.47	24/5/15-17	upper Tt				1	11	3	26																			
222.93	222.95	24/5/63-65	upper Tt				1	20		34																			
223.33	223.35	24/5/103-105	upper Tt					23	1	39																			
223.72	223.74	24/5/142-144	upper Tt					19	2	36																			
224.07	224.09	24/6/27-29	upper Tt				1	22		33																			
224.47	224.49	24/6/67-69	upper Tt			1	1	27	2	54																			
224.87	224.89	24/6/107-109	upper Tt				1	24	1	19																			
225.36	225.38	24CC/9-11	upper Tt				1	22	2	33																			
226.13	226.15	25/1/23-25	upper Tt					30	1	22																			
226.53	226.55	25/1/63-65	upper Tt			4		59	3	100																			
226.93	226.95	25/1/103-105	upper Tt					21	2	30																			
227.34	227.36	25/1/144-146	upper Tt				1	15	1	22																			
227.72	227.74	25/2/-32-34	upper Tt				2	19		37																			
228.12	228.14	25/2/72-74	upper Tt				2	31	2	28																			
228.52	228.54	25/2/112-114	upper Tt					15	1	33																			
228.90	228.92	25/3/0-2	upper Tt				1	7		28																			
229.33	229.35	25/3/43-45	upper Tt					29	1	33																			
229.85	229.87	25/3/95-97	upper Tt				1	19		42																			
230.27	230.29	25/3/137-139	upper Tt					10		23																			
230.47	230.49	25/4/7-9	upper Tt					20	2	37																			
230.93	230.95	25/4/53-55	upper Tt				1	3		17																			
231.33	231.35	25/4/93-95	upper Tt				1	15		11																			
231.73	231.75	25/4/133-135	upper Tt					9		23																			
232.06	232.08	25/5/16-18	upper Tt					12		11																			
232.52	232.54	25/5/62-64	upper Tt				2	31	2	40																			
232.92	232.94	25/5/102-104	upper Tt					12	1	34																			
233.27	233.29	25/5137-139	upper Tt				1	8		15																			
233.67	233.69	25/6/27-29	upper Tt					23	1	18																			
234.15	234.17	25/6/75-77	upper Tt					22	3	31																			
234.52	234.54	25/6/112-114	upper Tt					25	2	34																			
234.91	234.93	25/7/1-3	upper Tt					22		24																			
235.26	235.28	25CC/10-22	upper Tt					11	2	17																			
235.73	235.75	26/1/23-25	upper Tt					11		22																			
236.08	236.10	26/1/58-60	upper Tt				1	22	1	44																			
236.52	236.54	26/1/102-104	upper Tt					22	1	71																			
236.92	236.94	26/1/142-144	upper Tt				1	27		57																			
237.32	237.34	26/2/32-34	upper Tt					27	4	67																			
237.93	237.95	26/2/93-95	upper Tt				2	16		60																			
238.33	238.35	26/2/133-135	upper Tt					11	4	24																			
238.51	238.53	26/3/1-3	upper Tt					10	1	29																			
238.93	238.95	26/3/43-45	upper Tt					8		13																			
239.32	239.34	26/3/82-84	upper Tt				2	15	3	31																			
239.67	239.69	26/3/117-119	upper Tt					11		19																			
240.07	240.09	26/4/7-9	upper Tt				1	17	2	29																			
240.52	240.54	26/4/52-54	upper Tt				1	10	1	43																			
240.92	240.94	26/4/92-94	upper Tt				1	21	1	28																			
241.32	241.34	26/4/132-134	upper Tt			1		24		33																			
241.65	241.67	26/5/15-17	upper Tt					14		40																			
242.13	242.15	26/5/63-65	upper Tt					23	2	33																			
242.52	242.54	26/5/102-104	upper Tt					19	2	82																			
242.92	242.94	26/5/142-144	upper Tt					37	1	58																			
243.26	243.28	26/6/26-28	upper Tt					21	1	33																			
243.63	243.65	26/6/63-65	upper Tt					17		21																			
243.86	243.88	26CC/13-15	upper Tt					19		26																			
245.11	245.13	27/1/1-3	upper Tt				1	28	1	31																			
245.53	245.55	27/1/43-45	upper Tt					17		14																			
245.91	245.93	27/1/81-83	upper Tt					8		22																			
246.27	246.29	27/1/117-119	upper Tt				3	17		23																			
246.52	246.54	27/1/142-144	upper Tt					27		39																			
246.87	246.89	27/2/27-29	upper Tt					19		34																			
247.33	247.35	27/2/73-76	upper Tt					14		26																			
247.67	247.69	27/2/107-109	upper Tt				1	23		20																			
248.11	248.13	27/3/1-3	upper Tt				1	12		18																			
248.47	248.49	27/3/37-39	upper Tt				3	24		29																			
248.93	248.95	27/3/83-85	upper Tt					10	1	11																			
249.27	249.27	27/3/117-119	upper Tt					15	1	10																			
249.67	249.69	27/4/7-9	upper Tt					14		20																			
250.12	250.14	27/4/52-54	upper Tt					29		33																			
250.46	250.48	27/4/86-88	upper Tt				1	11		33																			

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globoconella conomiozea* s.l. [crust-free] sin	*Globoconella explicationis* dex	*Globoconella explicationis* sin	*Globoconella miotumida* [crust-free] dex	*Globoconella miotumida* [crust-free] sin	*Globoconella miotumida* [encrusted] dex	*Globoconella miotumida* [encrusted] sin	*Globoconella miotumida* [weakly carinate] dex	*Globoconella miotumida* [weakly carinate] sin	*Globoconella miotumida* s.l. [crust-free] dex	*Globoconella miotumida* s.l. [crust-free] sin	*Globoconella mons* [crust-free] dex	*Globoconella mons* [crust-free] sin	*Globoconella mons* [encrusted] dex	*Globoconella mons* [encrusted] sin	*Globoconella mons?* [crust-free] dex	*Globoconella mons?* [crust-free] sin	*Globoconella mons?* [encrusted] dex	*Globoconella mons?* [encrusted] sin	*Globoconella pliozea* [crust-free] dex	*Globoconella pliozea* [encrusted] dex	*Globoconella pliozea* [encrusted] sin	*Globoconella pliozea?* [crust-free] dex	*Globoconella pliozea?* [crust-free] sin	*Globoconella pliozea?* [encrusted] dex	*Globoconella pliozea?* [encrusted] sin
250.92	250.94	27/4/132-134	upper Tt				1	28	1	36																			
251.33	251.36	27/5/23-26	upper Tt				2	12		27																			
251.67	251.69	27/5/57-59	upper Tt				1	13	1	20																			
252.13	252.15	27/5/103-105	upper Tt				2	20		28																			
252.53	252.55	27/5/143-145	upper Tt				1	23		34																			
252.92	252.94	27/6/32-34	upper Tt				1	24		38																			
253.33	253.35	27/6/73-75	upper Tt				1	22		23																			
253.67	253.69	27/6/107-109	upper Tt				1	41	1	46																			
254.10	254.12	27/7/0-2	upper Tt				2	30	1	33																			
254.49	254.51	27CC/10-12	lower Tt				1	30		29																			
254.93	254.95	28/4/23-25	lower Tt				1	26	2	25																			
255.28	255.30	28/1/58-60	lower Tt				1	41		24																			
255.73	255.75	28/1/103-105	lower Tt				1	40	1	53																			
256.11	256.13	28/1/141-143	lower Tt				1	22	2	29																			
256.53	256.55	28/2/33-35	lower Tt				3	26	1	21																			
257.03	257.05	28/2/83-85	lower Tt				1	31		29																			
257.33	257.35	28/2/113-115	lower Tt				1	25		23																			
257.71	257.73	28/3/1-3	lower Tt					24	1	19																			
258.12	258.14	28/3/42-44	lower Tt					29		23																			
258.54	258.56	28/3/84-86	lower Tt					22	4	24																			
259.07	259.09	28/3/137-139	lower Tt				1	17		25																			
259.53	259.55	28/4/33-35	lower Tt				1	43	2	40																			
259.86	259.88	28/4/66-68	lower Tt				3	37		34																			
260.28	260.30	28/4/108-110	lower Tt				3	31		29																			
260.54	260.56	28/4/134-136	lower Tt				1	29		21																			
260.86	260.88	28/5/16-18	lower Tt					27	2	21																			
261.31	261.33	28/5/61-63	lower Tt				1	25	1	23																			
261.72	261.74	28/5/102-104	lower Tt				2	33		31																			
262.11	262.13	28/5/141-143	lower Tt				1	13		16																			
262.45	262.47	28CC/8-10	lower Tt					29	1	34																			
264.30	264.32	29/1/0-2	lower Tt					13		17																			
264.64	264.66	29/1/34-36	lower Tt				2	39		39																			
264.88	264.90	29/1/58-60	lower Tt					34		37																			
265.26	265.28	29/1/96-98	lower Tt					31	2	39																			
265.72	265.74	29/1/142-144	lower Tt				2	38	3	41																			
266.12	266.14	29/2/32-34	lower Tt					38		41																			
266.44	266.46	29/2/64-66	lower Tt				1	19		34																			
266.87	266.89	29/2/107-109	lower Tt					21	1	43																			
267.31	267.33	29/3/1-3	lower Tt					32		54																			
267.53	267.55	29/3/23-25	lower Tt					24	1	46																			
267.72	267.74	29/3/42-44	lower Tt					29		34																			
267.87	267.89	29/3/57-59	lower Tt				2	24	1	28																			
268.14	268.16	29/3/84-86	lower Tt				2	32	1	14																			
268.34	268.36	29/3/104-106	lower Tt				2	48	3	45																			
268.47	268.49	29/3/117-119	lower Tt					53	1	70																			
268.68	268.70	29/3/138-140	lower Tt				1	28	1	35																			
268.86	268.88	29/4/6-8	lower Tt				1	14	4	30																			
269.28	269.30	29/4/48-50	lower Tt				8	10	10	17																			
269.52	269.54	29/4/72-74	lower Tt				15	2	18	7																			
269.75	269.77	29/4/95-97	lower Tt				19	21	30	29																			
269.87	269.89	29/4/107-109	lower Tt				17	25	26	20																			
270.15	270.17	29/4/135-137	lower Tt				18	15	33	19																			
270.31	270.33	29/5/1-3	lower Tt				28	17	26	19																			
270.45	270.47	29/5/15-17	lower Tt				20	8	20	11																			
270.72	270.74	29/5/42-44	lower Tt				24	17	18	15																			
270.91	270.93	29/5/61-63	lower Tt				2	44	4	31																			
271.15	271.17	29/5/85-87	lower Tt				2	37	7	52																			
271.34	271.36	29/5/104-106	lower Tt				3	24	2	61																			
271.48	271.50	29/5/118-120	lower Tt				2	37	1	61																			
271.72	271.74	29/5/142-144	lower Tt				1	18		22																			
271.94	271.96	29/6/14-16	lower Tt				7	24		33																			
272.19	272.21	29CC/17-19	lower Tt				6	32	4	34																			
273.91	273.93	30/1/1-A7303	lower Tt				6	27	7	34																			
274.04	274.06	30/1/14-16	lower Tt				4	30	1	38																			
274.32	274.34	30/1/42-44	lower Tt				2	42		61																			
274.48	274.50	30/1/58-60	lower Tt				1	36		39																			
274.72	274.74	30/1/82-84	lower Tt				2	44		42																			
274.93	274.95	30/1/103-105	lower Tt				1	38		39																			
275.12	275.14	30/1/122-124	lower Tt				2	33	3	36																			
275.31	275.33	30/1/141-143	lower Tt				2	28		42																			
275.45	275.47	30/2/5-7	lower Tt				26		2	25																			
275.93	275.95	30/2/53-55	lower Tt					24		35																			

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globoconella conomiozea* s.l. [crust-free] sin	*Globoconella explicationis* dex	*Globoconella explicationis* sin	*Globoconella miotumida* [crust-free] dex	*Globoconella miotumida* [crust-free] sin	*Globoconella miotumida* [encrusted] dex	*Globoconella miotumida* [encrusted] sin	*Globoconella miotumida* [weakly carinate] dex	*Globoconella miotumida* [weakly carinate] sin	*Globoconella miotumida* s.l. [crust-free] dex	*Globoconella miotumida* s.l. [crust-free] sin	*Globoconella mons* [crust-free] dex	*Globoconella mons* [crust-free] sin	*Globoconella mons* [encrusted] dex	*Globoconella mons* [encrusted] sin	*Globoconella mons?* [crust-free] dex	*Globoconella mons?* [crust-free] sin	*Globoconella mons?* [encrusted] dex	*Globoconella mons?* [encrusted] sin	*Globoconella pliozea* [crust-free] dex	*Globoconella pliozea* [encrusted] dex	*Globoconella pliozea* [encrusted] sin	*Globoconella pliozea?* [crust-free] dex	*Globoconella pliozea?* [crust-free] sin	*Globoconella pliozea?* [encrusted] dex	*Globoconella pliozea?* [encrusted] sin
276.52	276.54	30/2/112-114	lower Tt				2	25		34																			
276.91	276.93	30/3/1-3	lower Tt				1	20	1	27																			
277.33	277.35	30/3/43-45	lower Tt				1	30		27																			
277.74	277.76	30/3/84-86	lower Tt				2	24	3	28																			
278.07	278.09	30/3/117-119	lower Tt				1	32	3	29																			
278.49	278.51	30/4/9-11	lower Tt					30	1	35																			
278.88	278.90	30/4/48-50	lower Tt				3	25	2	31																			
279.33	279.35	30/4/93-95	lower Tt					14	3	20																			
279.75	279.77	30/4/135-137	lower Tt					16		19																			
280.05	280.07	30/5/15-17	lower Tt					27	1	29																			
280.25	280.27	30/5/35-37	lower Tt			1		14		30																			
280.92	280.94	30/5/102-104	lower Tt				1	20		21																			
283.51	283.53	31/1/1-3	lower Tt				1	34	1	35																			
283.94	283.96	31/1/44-46	lower Tt				2	26	1	33																			
284.33	284.35	31/1/83-85	lower Tt				2	22	1	31																			
284.55	284.57	31/1/105-107	lower Tt				4	36	3	40																			
284.88	284.90	31/1/138-140	lower Tt					15	2	20																			
285.29	285.31	31/2/29-31	lower Tt					14		21																			
285.73	285.75	31/2/73-75	lower Tt				4	27		37																			
286.10	286.12	31/2/110-112	lower Tt				1	27		40																			
286.51	286.53	31/3/1-3	lower Tt					41		38																			
286.88	286.90	31/3/38-40	lower Tt				1	14		25																			
287.32	287.34	31/3/82-84	lower Tt				1	30		22																			
287.67	287.69	31/3/117-119	lower Tt					26	2	31																			
288.08	288.10	31/4/8-10	lower Tt					26	3	52																			
288.55	288.57	31/4/55-57	lower Tt				2	22		39																			
288.89	288.91	31/4/89-91	lower Tt					21	3	74																			
289.34	289.36	31/4/134-136	lower Tt					17		23																			
289.73	289.75	31/5/23-25	lower Tt					25		32																			
290.12	290.14	31/5/62-64	lower Tt				2	24		22																			
290.51	290.53	31/5/101-103	lower Tt			1		21	2	38																			
290.74	290.76	31CC/0-2	lower Tt					30	1	47																			
293.11	293.13	32/1/1-3	lower Tt				1	29		32																			
293.33	293.35	32/1/23-25	lower Tt				3	30	1	29																			
293.71	293.73	32/1/61-63	lower Tt			1		14		12																			
294.12	294.14	32/1/102-104	lower Tt			1	2	27	2	23																			
294.51	294.53	32/1/141-143	lower Tt			3	1	20	2	19																			
294.90	294.92	32/2/30-32	lower Tt			1	1	39	3	33																			
295.33	295.35	32/2/73-75	lower Tt				1	32		35																			
295.73	295.75	32/2/113-115	lower Tt				2	14	4	31																			
295.93	295.95	32/2/133-135	lower Tt					30	1	35																			
296.50	296.52	32/3/40-42	lower Tt				2	34		42																			
296.93	296.95	32/3/83-85	lower Tt			2	1	47		54																			
297.33	297.35	32/3/123-125	lower Tt					9	3	34																			
297.70	297.72	32/4/10-12	lower Tt				5	21	1	26																			
298.08	298.10	32/4/48-50	lower Tt					21	1	41																			
298.52	298.54	32/4/92-94	lower Tt				1	16		20																			
298.93	298.95	32/4/133-135	lower Tt					47	1	61																			
299.38	299.40	32/5/28-30	lower Tt				6	27		30																			
299.67	299.69	32CC/2-4	lower Tt			1	1	31	1	41																			
302.71	302.73	33/1/1-3	lower Tt				1	35	1	27																			
302.97	302.99	33/1/27-29	lower Tt				3	43		27																			
303.29	303.31	33/1/59-61	lower Tt			1		70	2	31																			
303.77	303.79	33/1/107-109	lower Tt				3	54	3	38																			
304.13	304.15	33/1/143-145	lower Tt				3	37	3	33																			
304.29	304.31	33/2/9-11	lower Tt				3	56	1	33																			
304.47	304.49	33/2/27-29	lower Tt					83	1	36																			
304.66	304.68	33/2/46-48	lower Tt					30	2	30																			
305.02	305.04	33/2/82-84	lower Tt			1		46	2	42																			
305.15	305.17	33/2/95-97	lower Tt					19	1	39																			
305.34	305.36	33/2/114-116	lower Tt				1	31	1	42																			
305.55	305.57	33/2/135-137	lower Tt				1	37	2	63																			
305.71	305.73	33/3/1-3	lower Tt			1	1	38	2	57																			
305.93	305.95	33/3/23-25	lower Tt				1	30	1	59																			
306.11	306.13	33/3/41-43	lower Tt				14	15	5	13																			
306.27	306.29	33/3/57-59	lower Tt				29	4	20	4																			
306.54	306.56	33/3/84-86	lower Tt				8	16	8	13																			
306.75	306.77	33/3/105-107	lower Tt				7	63	4	71																			
306.86	306.88	33/3/116-118	lower Tt				1	42	2	54																			
307.08	307.10	33/3/138-140	lower Tt				1	25	2	66																			
307.30	307.32	33/4/10-12	lower Tt				2	46		74																			
307.49	307.51	33/4/29-31	lower Tt				2	25	4	67																			

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globoconella conomiozea* s.l. [crust-free] sin	*Globoconella explicationis* dex	*Globoconella explicationis* sin	*Globoconella miotumida* [crust-free] dex	*Globoconella miotumida* [crust-free] sin	*Globoconella miotumida* [encrusted] dex	*Globoconella miotumida* [encrusted] sin	*Globoconella miotumida* [weakly carinate] dex	*Globoconella miotumida* [weakly carinate] sin	*Globoconella miotumida* s.l. [crust-free] dex	*Globoconella miotumida* s.l. [crust-free] sin	*Globoconella mons* [crust-free] dex	*Globoconella mons* [crust-free] sin	*Globoconella mons* [encrusted] dex	*Globoconella mons* [encrusted] sin	*Globoconella mons?* [crust-free] dex	*Globoconella mons?* [crust-free] sin	*Globoconella mons?* [encrusted] dex	*Globoconella mons?* [encrusted] sin	*Globoconella pliozea* [crust-free] dex	*Globoconella pliozea* [encrusted] dex	*Globoconella pliozea* [encrusted] sin	*Globoconella pliozea?* [crust-free] dex	*Globoconella pliozea?* [crust-free] sin	*Globoconella pliozea?* [encrusted] dex	*Globoconella pliozea?* [encrusted] sin
307.70	307.72	33/4/50-52	lower Tt					29	1	85																			
307.93	307.95	33/4/73-75	lower Tt					31	3	53																			
308.14	308.16	33/4/94-96	lower Tt				1	27	5	28																			
308.30	308.32	33/4/110-112	lower Tt					10	1	26																			
308.53	308.55	33/4/133-135	lower Tt					45	9	47																			
308.71	308.73	33/5/1-3	lower Tt					45	2	47																			
308.99	309.01	33/5/29-31	lower Tt				4	21	3	44																			
309.11	309.13	33/5/41-43	lower Tt				4	20	3	32																			
309.28	309.30	33/5/58-60	lower Tt				29	17	65	18																			
309.54	309.56	33/5/84-86	lower Tt				36	11	61	5																			
309.74	309.76	33/5/104-106	lower Tt				33	8	61	8																			
312.31	312.33	34/1/1-3	lower Tt				21	4	41	10																			
312.54	312.56	34/1/24-26	lower Tt				17	9	33	15																			
312.67	312.69	34/1/37-39	lower Tt				13	4	23	5																			
312.87	312.89	34/1/57-59	lower Tt				17	2	21	8																			
313.07	313.09	34/1/77-79	lower Tt				18	10	58	16																			
313.31	313.33	34/1/101-103	lower Tt				10	8	33	4																			
313.53	313.55	34/1/123-125	lower Tt				7	23	14	30																			
313.71	313.73	34/1/141-143	lower Tt				3	27		27																			
313.90	313.92	34/2/10-12	lower Tt				4	21	2	49																			
314.09	314.11	34/2/29-31	lower Tt				7	16	10	42																			
314.29	314.31	34/2/49-51	lower Tt				5	7	9	48																			
314.45	314.47	34/2/65-67	lower Tt					24		39																			
314.69	314.71	34/2/89-91	lower Tt				3	9	7	35																			
314.90	314.92	34/2/110-112	lower Tt				3	6	9	14																			
315.13	315.15	34/2/133-135	lower Tt				4	8	18	37																			
315.30	315.32	34/3/0-2	upper Sw				3	22	3	32																			
315.52	315.54	34/3/22-24	upper Sw					16	2	44																			
315.71	315.73	34/3/41-43	upper Sw				1	10		28																			
316.06	316.08	34/3/76-78	upper Sw				1	20		42																			
316.27	316.29	34/3/97-99	upper Sw			1	1	30	2	51																			
316.48	316.50	34/3/118-120	upper Sw					26	1	47																			
316.67	316.69	34/3/137-139	upper Sw				2	15		40																			
317.10	317.12	34/4/30-32	upper Sw				2	18		33																			
317.50	317.52	34/4/70-72	upper Sw				1	22	2	81																			
317.90	317.92	34/4/110-112	upper Sw				1	9	4	56																			
318.35	318.37	34/5/5-7	upper Sw				2	19	1	47																			
318.60	318.62	34/5/30-32	upper Sw					16		37																			
321.91	321.93	35/1/1-3	upper Sw				2	16	1	46																			
322.33	322.35	35/1/43-45	upper Sw				1	24	3	38																			
322.72	322.74	35/1/82-84	upper Sw				3	20	2	33																			
323.09	323.11	35/1/119-121	upper Sw				1	23	3	33																			
323.48	323.50	35/2/8-10	upper Sw					7		36																			
323.91	323.93	35/2/51-53	upper Sw					28	1	71																			
324.50	324.52	35/2/110-112	upper Sw					8		30																			
324.91	324.93	35/3/1-3	upper Sw			1		13	1	27																			
325.33	325.35	35/3/43-45	upper Sw					18	1	55																			
325.71	325.73	35/3/81-83	upper Sw				1	18		30																			
325.94	325.96	35/3/104-106	upper Sw					13		38																			
326.28	326.30	35/3/138-140	upper Sw					9	6	45																			
326.70	326.72	35/4/30-32	upper Sw					27	1	40																			
327.09	327.11	35/4/69-71	upper Sw				1	15	2	27																			
327.50	327.52	35/4/110-112	upper Sw				5	9	2	22																			
327.91	327.93	35/5/1-3	upper Sw				1	14		26																			
328.27	328.29	35/5/37-39	upper Sw					7		24																			
328.72	328.74	35/5/82-84	upper Sw					7		18																			
331.69	331.71	36/1/19-21	upper Sw					4	3	28																			
332.11	332.13	36/1/61-63	upper Sw					26		37																			
332.68	332.70	36/1/118-120	upper Sw			1		16	1	42																			
332.98	333.00	36/1/148-150	upper Sw				1	26	1	34																			
333.40	333.42	36/2/40-42	upper Sw					13	1	17																			
334.00	334.02	36/2/100-102	upper Sw				1	17	1	27																			
334.36	334.38	36/2/136-138	upper Sw					2		13																			
334.87	334.89	36/3/37-39	upper Sw					7		12																			
335.47	335.49	36/3/97-99	upper Sw		1			7		7																			
335.88	335.90	36/3/138-140	upper Sw					7		3																			
336.20	336.22	36/4/20-22	upper Sw					14	1	12																			
336.60	336.62	36/4/60-62	upper Sw				2	15		6																			

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globoconella puncticulata* [crust-free] dex	*Globoconella puncticulata* [crust-free] sin	*Globoconella puncticulata* [encrusted] dex	*Globoconella puncticulata* [encrusted] sin	*Globoconella puncticulata* [5-chambers] sin	*Globoconella puncticulata* s.l. [crust-free] dex	*Globoconella puncticulata* s.l. [crust-free] sin	*Globoconella puncticulata* s.l. [encrusted] dex	*Globoconella puncticulata* s.l. [encrusted] sin	*Globoconella puncticulata* s.l. [5-chambers] sin	*Globoconella sphericomiozea* [encrusted] sin	*Globoconella sphericomiozea* [crust-free] dex	*Globoconella sphericomiozea* [crust-free] sin	*Globoconella sphericomiozea* [encrusted] dex	*Globoconella sphericomiozea* [encrusted] sin	*Globoconella* sp.	*Globoquadrina dehiscens*	*Globoquadrina* sp.?	*Globoquadrina venezuelana*?	*Globorotalia lenguaensis* dex	*Globorotalia lenguaensis* sin	*Globorotaloides hexagonus* dex	*Globorotaloides hexagonus* sin	*Hirsutella* cf. *ichinosekiensis* dex	*Hirsutella* cf. *ichinosekiensis* sin	*Hirsutella margaritae* dex
120.30	120.33	14/1/0-3	lower Wo		1	3	96																					
120.51	120.54	14/1/21-24	lower Wo		12	2	98							1														
120.69	120.72	14/1/39-42	lower Wo		11	1	52	1																				
120.90	120.93	14/1/60-63	lower Wo		3	1	30																					
121.11	121.14	14/1/81-84	lower Wo		2		37																					
121.26	121.29	14/1/96-99	lower Wo		3		35																					
121.49	121.52	14/1/119-122	lower Wo		6		42																					
121.69	121.72	14/1/139-142	lower Wo		6	1	88																					
121.90	121.93	14/2/10-13	lower Wo		15		104																					
122.09	122.12	14/2/29-32	lower Wo		10	2	124																					
122.26	122.29	14/2/46-49	lower Wo	1	3	6	136																					
122.51	122.55	14/2/71-75	lower Wo		13	2	70															1						
122.71	122.74	14/2/91-94	lower Wo	2	23	3	121																					
122.92	122.95	14/2/112-115	lower Wo		6	1	123	1																				
123.10	123.13	14/2/130-133	upper Tk						1	8	2	97						2										
123.30	123.33	14/3/0-3	upper Tk							9		78																
123.53	123.56	14/3/23-26	upper Tk							13		93																2
123.69	123.72	14/3/39-42	upper Tk							6	2	68																
123.88	123.91	14/3/58-61	upper Tk						1	3		67																
124.11	124.14	14/3/81-84	upper Tk							6	2	66																
124.30	124.33	14/3/100-103	upper Tk						2	10	1	133						5										
124.50	124.53	14/3/120-123	upper Tk							9	6	94																
124.68	124.71	14/3/138-141	upper Tk							7	1	90																
124.90	124.93	14/4/10-13	upper Tk						2	10	1	93																
125.10	125.13	14/4/30-33	upper Tk							8	1	108	1					3										
125.30	125.33	14/4/50-53	upper Tk								2	66	1			2												
125.48	125.51	14/4/68-71	upper Tk							7		56						2										
125.71	125.74	14/4/91-94	upper Tk							8		40			2	1												
125.91	125.94	14/4/111-114	upper Tk							7	2	106						2										
126.10	126.13	14/4/130-133	upper Tk							3	2	62						1										
126.30	126.33	14/5/0-3	upper Tk							7	2	54					2	3										
126.56	126.59	14/5/26-29	upper Tk						1	6	5	68				7		1										
126.70	126.73	14/5/40-43	upper Tk						1	10	1	52				1	1	5										
126.90	126.93	14/5/60-63	upper Tk							7	1	57				1		3										
127.12	127.15	14/5/82-85	upper Tk							10	1	86					1	5										
127.30	127.33	14/5/100-103	upper Tk							7	5	69				5	1	9										
127.51	127.54	14/5/121-124	upper Tk							4		58				2		6										
127.70	127.73	14/5/140-143	upper Tk							6	4	49				6		13										
127.90	127.93	14/6/10-13	upper Tk							1		36					1	6										
128.29	128.32	14/6/49-52	upper Tk							1	3	49					2	11										
128.72	128.75	14/6/92-95	upper Tk							5	2	71					1	16										
129.10	129.13	14/6/130-133	upper Tk							3	4	61						12										
129.50	129.53	14/7/20-23	upper Tk							6	5	101						22										
129.90	129.93	15/1/0-3	upper Tk							1		39				1		10										
130.29	130.32	15/1/39-42	upper Tk							1		28					1	29										
130.69	130.72	15/1/79-82	upper Tk							2	1	35					1	26										
131.10	131.13	15/1/120-123	upper Tk							1	1	22						21										
131.51	131.54	15/2/11-14	upper Tk									22				1	1	20										
131.91	131.93	15/2/51-53	upper Tk								3	60				2		25										
132.33	132.36	15/2/93-96	upper Tk									21						14										
132.74	132.76	15/2/134-136	upper Tk						1	1	1	24					1	21										
133.07	133.10	15/3/17-20	upper Tk						2	3		42					1	26										
133.46	133.49	15/3/56-59	upper Tk							7	3	72				6	1	33										
133.89	133.92	15/3/99-102	upper Tk							8		39						38										
134.30	134.33	15/3/140-143	upper Tk							8	1	57				8	1	39										
134.70	134.73	15/4/30-33	upper Tk							3		21						33										
135.10	135.13	15/4/70-73	upper Tk							2	3	55						52										
135.30	135.33	15/4/90-93	upper Tk						1		1	72				2	2	81										
135.50	135.53	15/4/110-113	upper Tk							4	3	60					3	83										
135.70	135.73	15/4/130-133	upper Tk							7	5	68					1	56										
135.90	135.93	15/5/0-3	upper Tk							1	2	41						67										
136.06	136.09	15/5/16-19	upper Tk							3		38					2	42										
136.32	136.35	15/5/42-45	upper Tk						1			22					1	64										
136.51	136.53	15/5/61-63	upper Tk							1	2	31					2	65										
136.92	136.95	15/5/102-105	upper Tk							2		35					3	93										
137.13	137.16	15/5/123-126	upper Tk							6		29					1	66										
137.52	137.55	15/6/12-15	upper Tk							2	3	25					3	103										
137.91	137.94	15/6/51-54	upper Tk							2	2	23					2	57										
138.27	138.30	15/6/87-90	upper Tk							1		21					3	61										
138.66	138.69	15/6/126-129	upper Tk									20					1	74										
139.07	139.10	15/7/17-20	upper Tk							3		3					2	71										
139.50	139.53	16/1/0-3	upper Tk									7						57										

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globoconella puncticulata* [crust-free] dex	*Globoconella puncticulata* [crust-free] sin	*Globoconella puncticulata* [encrusted] dex	*Globoconella puncticulata* [encrusted] sin	*Globoconella puncticulata* [5-chambers] sin	*Globoconella puncticulata* s.l. [crust-free] dex	*Globoconella puncticulata* s.l. [crust-free] sin	*Globoconella puncticulata* s.l. [encrusted] dex	*Globoconella puncticulata* s.l. [encrusted] sin	*Globoconella puncticulata* s.l. [5-chambers] sin	*Globoconella sphericomiozea* [encrusted] sin	*Globoconella sphericomiozea* [crust-free] dex	*Globoconella sphericomiozea* [crust-free] sin	*Globoconella sphericomiozea* [encrusted] dex	*Globoconella sphericomiozea* [encrusted] sin	*Globoconella* sp.	*Globoquadrina dehiscens*	*Globoquadrina* sp.?	*Globoquadrina venezuelana*?	*Globorotalia lenguaensis* dex	*Globorotalia lenguaensis* sin	*Globorotaloides hexagonus* dex	*Globorotaloides hexagonus* sin	*Hirsutella* cf. *ichinosekiensis* dex	*Hirsutella* cf. *ichinosekiensis* sin	*Hirsutella margaritae* dex
139.93	139.96	16/1/43-46	upper Tk								1	7					4	100										
140.34	140.37	16/1/84-87	upper Tk							1		12					3	104										
140.73	140.76	16/1/123-126	upper Tk							2	1	11					3	61										
141.13	141.15	16/2/13-16	upper Tk									12					4	58										
141.54	141.57	16/2/54-57	upper Tk									5					2	130										
141.92	141.95	16/2/92-95	upper Tk							1	1	12					1	82										
142.32	142.35	16/2/132-135	upper Tk							1	1	8						109										
142.75	142.78	16/3/25-28	upper Tk									8					3	72										
143.15	143.18	16/3/65-68	upper Tk							1		11						65										
143.53	143.56	16/3/103-106	upper Tk									5						103										
143.84	143.87	16/3/134-137	lower Tk									1																
144.26	144.29	16/4/26-29	lower Tk																									
144.67	144.70	16/4/67-70	lower Tk																									
145.13	145.16	16/4/113-116	lower Tk									1																
145.50	145.53	16/5/0-3	lower Tk																									
145.93	145.96	16/5/43-46	lower Tk																									
146.36	146.38	16/5/86-88	lower Tk																									
146.71	146.74	16/5/121-124	lower Tk																									
147.06	147.09	16/6/6-9	lower Tk																									
147.47	147.50	16/6/47-50	lower Tk																									
147.93	147.96	16/6/93-96	lower Tk																									
148.33	148.36	16/6/133-136	lower Tk																									
148.67	148.69	16/7/17-19	lower Tk																									
149.10	149.13	17/1/0-3	lower Tk																									
149.52	149.55	17/1/42-45	lower Tk																									
150.11	150.14	17/1/101-104	lower Tk																									
150.51	150.54	17/1/141-144	lower Tk																									
150.87	150.90	17/2/27-30	lower Tk																									
151.07	151.10	17/2/47-50	lower Tk									1																
151.52	151.55	17/2/92-95	lower Tk																									
151.96	151.98	17/2/136-138	lower Tk									1																
152.10	152.13	17/3/0-3	lower Tk									1																
152.25	152.28	17/3/15-18	lower Tk									2																
152.47	152.50	17/3/37-40	lower Tk									1																
152.75	152.77	17/3/65-67	lower Tk																									
152.91	152.94	17/3/81-84	lower Tk									1																
153.12	153.15	17/3/102-105	lower Tk									2																
153.26	153.29	17/3/116-119	lower Tk									2																
153.45	153.48	17/3/135-138	lower Tk									2																
153.66	153.69	17/4/6-9	lower Tk																									
153.97	153.99	17/4/37-39	lower Tk									1																
154.13	154.16	17/4/53-56	lower Tk																									
154.32	154.35	17/4/72-75	lower Tk																									
154.54	154.57	17/4/94-97	lower Tk									2																
154.77	154.79	17/4/117-119	lower Tk									1																
154.95	154.98	17/4/135-138	lower Tk									2																
155.10	155.13	17/5/0-3	lower Tk																									
155.24	155.27	17/5/14-17	lower Tk																									
155.48	155.50	17/5/38-40	lower Tk																									
155.67	155.70	17/5/57-60	lower Tk																									
155.94	155.97	17/5/84-87	lower Tk									1																
156.13	156.16	17/5/103-106	lower Tk																									
156.27	156.30	17/5/117-120	lower Tk																									
156.47	156.50	17/5/137-140	lower Tk																									
156.71	156.74	17/6/11-14	lower Tk																									
156.95	156.98	17/6/35-38	lower Tk																									
157.12	157.15	17/6/52-55	lower Tk																									
157.37	157.39	17/6/77-79	lower Tk								2	1																
157.52	157.55	17/6/92-95	lower Tk																									
157.76	157.79	17/6/116-119	lower Tk																									
157.93	157.96	17/6/133-136	lower Tk																									
158.10	153.13	17/7/0-3	lower Tk																									
158.27	158.30	17/7/17-20	lower Tk																									
158.52	158.55	17CC/6-9	lower Tk																									
158.70	158.73	18/1/0-3	lower Tk																									
158.95	158.98	18/1/25-28	lower Tk																									
159.13	159.16	18/1/43-46	lower Tk																									
159.35	159.38	18/1/65-68	lower Tk																									
159.49	159.52	18/1/79-82	lower Tk																									
159.72	159.75	18/1/102-105	lower Tk																									
159.86	159.89	18/1/116-119	lower Tk																									
160.11	160.14	18/1/141-144	lower Tk																									

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globoconella puncticulata* [crust-free] dex	*Globoconella puncticulata* [crust-free] sin	*Globoconella puncticulata* [encrusted] dex	*Globoconella puncticulata* [encrusted] sin	*Globoconella puncticulata* [5-chambers] sin	*Globoconella puncticulata* s.l. [crust-free] dex	*Globoconella puncticulata* s.l. [crust-free] sin	*Globoconella puncticulata* s.l. [encrusted] dex	*Globoconella puncticulata* s.l. [encrusted] sin	*Globoconella puncticulata* s.l. [5-chambers] sin	*Globoconella sphericomiozea* [encrusted] sin	*Globoconella sphericomiozea* [crust-free] dex	*Globoconella sphericomiozea* [crust-free] sin	*Globoconella sphericomiozea* [encrusted] dex	*Globoconella sphericomiozea* [encrusted] sin	*Globoconella* sp.	*Globoquadrina dehiscens*	*Globoquadrina* sp.?	*Globoquadrina venezuelana*?	*Globorotalia lenguaensis* dex	*Globorotalia lenguaensis* sin	*Globorotaloides hexagonus* dex	*Globorotaloides hexagonus* sin	*Hirsutella* cf. *ichinosekiensis* dex	*Hirsutella* cf. *ichinosekiensis* sin	*Hirsutella margaritae* dex
160.33	160.36	18/2/13-16	lower Tk																									
160.73	160.76	18/2/53-56	lower Tk																									
161.16	161.19	18/2/96-99	lower Tk																									
161.53	161.56	18/2/133-136	lower Tk																									
161.84	161.87	18/3/14-17	lower Tk																									
162.26	162.29	18/3/56-59	lower Tk																									
162.87	162.90	18/3/117-120	lower Tk																									
163.33	163.36	18/4/13-16	lower Tk																									
163.56	163.59	18/4/36-39	lower Tk																									
163.93	163.96	18/4/73-76	lower Tk																1									1
164.31	164.33	18/4/111-113	lower Tk																									
164.70	164.73	18/5/0-3	lower Tk																									
165.13	165.16	18/5/43-46	lower Tk																									
165.50	165.53	18/5/80-83	lower Tk																									
165.95	165.97	18/5/125-127	lower Tk																									
166.26	166.29	18/6/6-9	lower Tk																									
166.66	166.69	18/6/46-49	lower Tk																									
167.06	167.09	18/6/86-89	lower Tk																									
167.44	167.47	18/6/124-127	upper Tt																									
168.30	168.33	19/1/0-3	upper Tt																									
168.71	168.74	19/1/41-44	upper Tt																									
169.13	169.15	19/1/83-85	upper Tt																									
169.51	169.54	19/1/121-124	upper Tt																									
169.85	169.88	19/2/5-8	upper Tt																									
170.32	170.35	19/2/52-55	upper Tt																									
170.73	170.76	19/2/93-96	upper Tt																									
171.15	171.18	19/2/135-138	upper Tt																									
171.57	171.59	19/3/27-29	upper Tt																									
171.92	171.94	19/3/62-64	upper Tt																									
172.32	172.35	19/3/102-105	upper Tt																									
172.66	172.68	19/3/136-138	upper Tt																									
173.07	173.09	19/4/27-29	upper Tt																									
173.52	173.54	19/4/72-74	upper Tt																									
173.93	173.95	19/4/113-115	upper Tt																									
174.30	174.33	19/5/0-3	upper Tt																									
174.72	174.75	19/5/42-45	upper Tt																									
175.26	175.28	19/5/96-99	upper Tt																									
175.71	175.74	19/5/141-144	upper Tt																									
176.06	176.09	19/6/26-29	upper Tt																									
176.47	176.49	19/6/67-69	upper Tt																									
176.92	176.94	19/6/112-114	upper Tt																									
177.30	177.33	19/7/0-3	upper Tt																									
177.52	177.55	19/7/22-25	upper Tt																									
177.90	177.93	20/1/0-3	upper Tt																									
178.27	178.30	20/1/37-40	upper Tt																									
178.68	178.70	20/1/78-80	upper Tt																									
179.08	179.10	20/1/118-120	upper Tt																									
179.45	179.47	20/2/5-7	upper Tt																									
179.86	179.88	20/2/46-48	upper Tt																									
180.33	180.35	20/2/93-95	upper Tt																									
180.73	180.75	20/2/133-135	upper Tt																									
181.14	181.16	20/3/24-26	upper Tt																									
181.57	181.59	20/3/67-69	upper Tt																									
181.86	181.88	20/3/96-98	upper Tt																									
182.23	182.25	20/3/133-135	upper Tt																									
182.68	182.70	20/4/28-30	upper Tt																									
183.08	183.10	20/4/68-70	upper Tt																									
183.45	183.47	20/4/105-107	upper Tt																									
183.91	183.93	20/5/1-3	upper Tt																									
184.32	184.34	20/5/42-44	upper Tt																									
184.72	184.74	20/5/82-84	upper Tt																									
185.07	185.09	20/5/117-119	upper Tt																									
185.47	185.49	20/6/7-9	upper Tt																									
185.92	185.94	20/6/52-54	upper Tt																									
186.32	186.34	20/6/92-94	upper Tt																									
186.72	186.74	20/6/132-134	upper Tt																									
187.07	187.09	20/7/17-19	upper Tt																									
187.51	187.53	21/1/1-3	upper Tt																									
187.93	187.95	21/1/43-45	upper Tt																									
188.32	188.34	21/182-84	upper Tt																									
188.67	188.69	21/1/117-119	upper Tt																									
189.08	189.10	21/2/8-10	upper Tt																									

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globoconella puncticulata* [crust-free] dex	*Globoconella puncticulata* [crust-free] sin	*Globoconella puncticulata* [encrusted] dex	*Globoconella puncticulata* [encrusted] sin	*Globoconella puncticulata* [5-chambers] sin	*Globoconella puncticulata* s.l. [crust-free] dex	*Globoconella puncticulata* s.l. [crust-free] sin	*Globoconella puncticulata* s.l. [encrusted] dex	*Globoconella puncticulata* s.l. [encrusted] sin	*Globoconella puncticulata* s.l. [5-chambers] sin	*Globoconella sphericomiozea* [encrusted] sin	*Globoconella sphericomiozea* [crust-free] dex	*Globoconella sphericomiozea* [crust-free] sin	*Globoconella sphericomiozea* [encrusted] dex	*Globoconella sphericomiozea* [encrusted] sin	*Globoconella* sp.	*Globoquadrina dehiscens*	*Globoquadrina* sp.?	*Globoquadrina venezuelana*?	*Globorotalia lenguaensis* dex	*Globorotalia lenguaensis* sin	*Globorotaloides hexagonus* dex	*Globorotaloides hexagonus* sin	*Hirsutella* cf. *ichinosekiensis* dex	*Hirsutella* cf. *ichinosekiensis* sin	*Hirsutella margaritae* dex
189.46	189.48	21/2/46-48	upper Tt																									
189.93	189.96	21/2/93-96	upper Tt																									
190.42	190.44	21/2/142-144	upper Tt																									
190.66	190.68	21/3/16-18	upper Tt																									
191.12	191.14	21/3/62-64	upper Tt																									
191.52	191.54	21/3/102-104	upper Tt																									
191.86	191.89	21/3/136-139	upper Tt																									
192.36	192.38	21/4/36-38	upper Tt																									
192.73	193.75	21/4/73-75	upper Tt																									
193.12	193.14	21/4/112-114	upper Tt																									
193.50	193.52	21/5/0-2	upper Tt																									
193.92	193.94	21/5/42-44	upper Tt																									
194.34	194.26	21/5/84-86	upper Tt																									
194.72	194.74	21/5/122-124	upper Tt																									
195.07	195.09	21/6/7-9	upper Tt																									
195.49	195.51	21/6/49-51	upper Tt																									
195.87	195.89	21/6/87-89	upper Tt																									
196.34	196.36	21/6/134-136	upper Tt																									
196.72	196.74	21/7/22-24	upper Tt																									
197.11	197.13	22/1/1-3	upper Tt																									
197.48	197.50	22/1/38-40	upper Tt																									
197.94	197.96	22/1/84-86	upper Tt																									
198.32	198.34	22/1/122-124	upper Tt																			1						
198.73	198.75	22/2/13-15	upper Tt																									
199.14	199.16	22/2/54-56	upper Tt																									
199.53	199.55	22/2/93-95	upper Tt																									
199.93	199.95	22/2/133-135	upper Tt																									
200.25	200.27	22/3/15-17	upper Tt																									
200.66	200.68	22/3/56-58	upper Tt																									
201.05	201.07	22/3/95-97	upper Tt																									
201.42	201.44	22/3/132-134	upper Tt																									
201.93	201.95	22/4/33-35	upper Tt																									
202.52	202.55	22/4/92-95	upper Tt																									
202.93	202.95	22/4/133-135	upper Tt																									
203.17	203.20	22CC/7-10	upper Tt																									
206.71	206.73	23/1/1-3	upper Tt																									
207.13	207.15	23/1/43-45	upper Tt																									
207.48	207.50	23/1/78-80	upper Tt																									
207.88	207.90	23/1/118-120	upper Tt																									
208.26	208.28	23/2/6-8	upper Tt																									
208.52	208.54	23/2/32-34	upper Tt																									
209.06	209.08	23/2/86-88	upper Tt																									
209.54	209.56	23/2/134-136	upper Tt																									
209.85	209.87	23/3/15-17	upper Tt																									
210.33	210.35	23/3/63-65	upper Tt																									
210.53	210.55	23/3/83-85	upper Tt																									
210.87	210.89	23/3/117-119	upper Tt																									
211.27	211.29	23/4/7-9	upper Tt																									
211.72	211.74	23/4/52-54	upper Tt																									
212.13	212.15	23/4/93-95	upper Tt																									
212.32	212.34	23/4/112-114	upper Tt																									
212.71	212.73	23/5/1-3	upper Tt																									
213.12	213.14	23/5/42-44	upper Tt																									
213.72	213.74	23/5/102-104	upper Tt																									
214.12	214.14	23/5/142-144	upper Tt																									
214.51	214.53	23/6/31-33	upper Tt																									
215.05	215.07	23/6/85-87	upper Tt																									
215.53	215.55	23/6/133-135	upper Tt																									
215.93	215.95	23/7/23-25	upper Tt																									
216.31	216.33	24/1/1-3	upper Tt																		1							
216.57	216.59	24/1/27-29	upper Tt																									
216.94	216.96	24/1/64-66	upper Tt																									
217.34	217.36	24/1/104-106	upper Tt																									
217.72	217.74	24/1/142-144	upper Tt																									
218.08	218.10	24/2/28-30	upper Tt																									
218.52	218.54	24/2/72-74	upper Tt																									
218.87	218.89	24/2/107-109	upper Tt																									
219.31	219.33	24/3/1-3	upper Tt																									
219.72	219.74	24/3/42-44	upper Tt																									
220.12	220.14	24/3/82-84	upper Tt																									
220.46	220.48	24/3/116-118	upper Tt																									
220.87	220.89	24/4/7-9	upper Tt																									

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globoconella puncticulata* [crust-free] dex	*Globoconella puncticulata* [crust-free] sin	*Globoconella puncticulata* [encrusted] dex	*Globoconella puncticulata* [encrusted] sin	*Globoconella puncticulata* [5-chambers] sin	*Globoconella puncticulata* s.l. [crust-free] dex	*Globoconella puncticulata* s.l. [crust-free] sin	*Globoconella puncticulata* s.l. [encrusted] dex	*Globoconella puncticulata* s.l. [encrusted] sin	*Globoconella puncticulata* s.l. [5-chambers] sin	*Globoconella sphericomiozea* [encrusted] sin	*Globoconella sphericomiozea* [crust-free] dex	*Globoconella sphericomiozea* [crust-free] sin	*Globoconella sphericomiozea* [encrusted] dex	*Globoconella sphericomiozea* [encrusted] sin	*Globoconella* sp.	*Globoquadrina dehiscens*	*Globoquadrina* sp.?	*Globoquadrina venezuelana*?	*Globorotalia lenguaensis* dex	*Globorotalia lenguaensis* sin	*Globorotaloides hexagonus* dex	*Globorotaloides hexagonus* sin	*Hirsutella* cf. *ichinosekiensis* dex	*Hirsutella* cf. *ichinosekiensis* sin	*Hirsutella margaritae* dex
221.27	221.29	24/4/47-49	upper Tt																										
221.66	221.68	24/4/86-88	upper Tt																										
222.13	222.15	24/4/133-135	upper Tt																										
222.45	222.47	24/5/15-17	upper Tt																										
222.93	222.95	24/5/63-65	upper Tt																										
223.33	223.35	24/5/103-105	upper Tt																										
223.72	223.74	24/5/142-144	upper Tt																										
224.07	224.09	24/6/27-29	upper Tt																										
224.47	224.49	24/6/67-69	upper Tt																										
224.87	224.89	24/6/107-109	upper Tt																										
225.36	225.38	24CC/9-11	upper Tt																										
226.13	226.15	25/1/23-25	upper Tt																										
226.53	226.55	25/1/63-65	upper Tt																										
226.93	226.95	25/1/103-105	upper Tt																										
227.34	227.36	25/1/144-146	upper Tt																										
227.72	227.74	25/2/-32-34	upper Tt																										
228.12	228.14	25/2/72-74	upper Tt																										
228.52	228.54	25/2/112-114	upper Tt																										
228.90	228.92	25/3/0-2	upper Tt																										
229.33	229.35	25/3/43-45	upper Tt																										
229.85	229.87	25/3/95-97	upper Tt																										
230.27	230.29	25/3/137-139	upper Tt																										
230.47	230.49	25/4/7-9	upper Tt																										
230.93	230.95	25/4/53-55	upper Tt																										
231.33	231.35	25/4/93-95	upper Tt																										
231.73	231.75	25/4/133-135	upper Tt																										
232.06	232.08	25/5/16-18	upper Tt																										
232.52	232.54	25/5/62-64	upper Tt																										
232.92	232.94	25/5/102-104	upper Tt																										
233.27	233.29	25/5137-139	upper Tt																										
233.67	233.69	25/6/27-29	upper Tt																										
234.15	234.17	25/6/75-77	upper Tt																										
234.52	234.54	25/6/112-114	upper Tt																										
234.91	234.93	25/7/1-3	upper Tt																										
235.26	235.28	25CC/10-22	upper Tt																										
235.73	235.75	26/1/23-25	upper Tt																										
236.08	236.10	26/1/58-60	upper Tt																										
236.52	236.54	26/1/102-104	upper Tt																										
236.92	236.94	26/1/142-144	upper Tt																										
237.32	237.34	26/2/32-34	upper Tt																										
237.93	237.95	26/2/93-95	upper Tt																										
238.33	238.35	26/2/133-135	upper Tt																										
238.51	238.53	26/3/1-3	upper Tt																										
238.93	238.95	26/3/43-45	upper Tt																										
239.32	239.34	26/3/82-84	upper Tt																										1
239.67	239.69	26/3/117-119	upper Tt																									2	2
240.07	240.09	26/4/7-9	upper Tt																										6
240.52	240.54	26/4/52-54	upper Tt																										
240.92	240.94	26/4/92-94	upper Tt																										
241.32	241.34	26/4/132-134	upper Tt																										
241.65	241.67	26/5/15-17	upper Tt																										
242.13	242.15	26/5/63-65	upper Tt																										
242.52	242.54	26/5/102-104	upper Tt																										
242.92	242.94	26/5/142-144	upper Tt																			1						2	2
243.26	243.28	26/6/26-28	upper Tt																										
243.63	243.65	26/6/63-65	upper Tt																									3	1
243.86	243.88	26CC/13-15	upper Tt																									1	1
245.11	245.13	27/1/1-3	upper Tt																										
245.53	245.55	27/1/43-45	upper Tt																										
245.91	245.93	27/1/81-83	upper Tt																										
246.27	246.29	27/1/117-119	upper Tt																										
246.52	246.54	27/1/142-144	upper Tt																										
246.87	246.89	27/2/27-29	upper Tt																			1							
247.33	247.35	27/2/73-76	upper Tt																										
247.67	247.69	27/2/107-109	upper Tt																										
248.11	248.13	27/3/1-3	upper Tt																			1							
248.47	248.49	27/3/37-39	upper Tt																										
248.93	248.95	27/3/83-85	upper Tt																										
249.27	249.27	27/3/117-119	upper Tt																										
249.67	249.69	27/4/7-9	upper Tt																										
250.12	250.14	27/4/52-54	upper Tt																									1	
250.46	250.48	27/4/86-88	upper Tt																										

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globoconella puncticulata* [crust-free] dex	*Globoconella puncticulata* [crust-free] sin	*Globoconella puncticulata* [encrusted] dex	*Globoconella puncticulata* [encrusted] sin	*Globoconella puncticulata* [5-chambers] sin	*Globoconella puncticulata* s.l. [crust-free] dex	*Globoconella puncticulata* s.l. [crust-free] sin	*Globoconella puncticulata* s.l. [encrusted] dex	*Globoconella puncticulata* s.l. [encrusted] sin	*Globoconella puncticulata* s.l. [5-chambers] sin	*Globoconella sphericomiozea* [encrusted] sin	*Globoconella sphericomiozea* [crust-free] dex	*Globoconella sphericomiozea* [crust-free] sin	*Globoconella sphericomiozea* [encrusted] dex	*Globoconella sphericomiozea* [encrusted] sin	*Globoconella* sp.	*Globoquadrina dehiscens*	*Globoquadrina* sp.?	*Globoquadrina venezuelana?*	*Globorotalia lenguaensis* dex	*Globorotalia lenguaensis* sin	*Globorotaloides hexagonus* dex	*Globorotaloides hexagonus* sin	*Hirsutella* cf. *ichinosekiensis* dex	*Hirsutella* cf. *ichinosekiensis* sin	*Hirsutella margaritae* dex
250.92	250.94	27/4/132-134	upper Tt																									
251.33	251.36	27/5/23-26	upper Tt																									
251.67	251.69	27/5/57-59	upper Tt																	1								
252.13	252.15	27/5/103-105	upper Tt																									
252.53	252.55	27/5/143-145	upper Tt																									
252.92	252.94	27/6/32-34	upper Tt																								1	
253.33	253.35	27/6/73-75	upper Tt																									
253.67	253.69	27/6/107-109	upper Tt																									
254.10	254.12	27/7/0-2	upper Tt																									
254.49	254.51	27CC/10-12	lower Tt																3						1			
254.93	254.95	28/4/23-25	lower Tt																10									
255.28	255.30	28/1/58-60	lower Tt																3						6			
255.73	255.75	28/1/103-105	lower Tt																									
256.11	256.13	28/1/141-143	lower Tt																1									
256.53	256.55	28/2/33-35	lower Tt																1						2			
257.03	257.05	28/2/83-85	lower Tt																									
257.33	257.35	28/2/113-115	lower Tt																5									
257.71	257.73	28/3/1-3	lower Tt																6					1	2			
258.12	258.14	28/3/42-44	lower Tt																5						3		1	
258.54	258.56	28/3/84-86	lower Tt																10									
259.07	259.09	28/3/137-139	lower Tt																6									
259.53	259.55	28/4/33-35	lower Tt																4					1				
259.86	259.88	28/4/66-68	lower Tt																14									
260.28	260.30	28/4/108-110	lower Tt																5					1				
260.54	260.56	28/4/134-136	lower Tt																8						1			
260.86	260.88	28/5/16-18	lower Tt																6									
261.31	261.33	28/5/61-63	lower Tt																2						1			
261.72	261.74	28/5/102-104	lower Tt																10									
262.11	262.13	28/5/141-143	lower Tt																9									
262.45	262.47	28CC/8-10	lower Tt																16									
264.30	264.32	29/1/0-2	lower Tt																7									
264.64	264.66	29/1/34-36	lower Tt																13									
264.88	264.90	29/1/58-60	lower Tt																14									
265.26	265.28	29/1/96-98	lower Tt																4						1			
265.72	265.74	29/1/142-144	lower Tt																8						1			
266.12	266.14	29/2/32-34	lower Tt																8						1			
266.44	266.46	29/2/64-66	lower Tt																12						1			
266.87	266.89	29/2/107-109	lower Tt																4						1			
267.31	267.33	29/3/1-3	lower Tt																4						4			
267.53	267.55	29/3/23-25	lower Tt																5						3			
267.72	267.74	29/3/42-44	lower Tt																4						2			
267.87	267.89	29/3/57-59	lower Tt																2					2	3			
268.14	268.16	29/3/84-86	lower Tt																7						3			
268.34	268.36	29/3/104-106	lower Tt																6									
268.47	268.49	29/3/117-119	lower Tt																2									
268.68	268.70	29/3/138-140	lower Tt																3									
268.86	268.88	29/4/6-8	lower Tt																4									
269.28	269.30	29/4/48-50	lower Tt																	1								
269.52	269.54	29/4/72-74	lower Tt																4									
269.75	269.77	29/4/95-97	lower Tt																7									
269.87	269.89	29/4/107-109	lower Tt																7						1			
270.15	270.17	29/4/135-137	lower Tt																2									
270.31	270.33	29/5/1-3	lower Tt																2						4			
270.45	270.47	29/5/15-17	lower Tt																1						2			
270.72	270.74	29/5/42-44	lower Tt																2						5			
270.91	270.93	29/5/61-63	lower Tt																1						1			
271.15	271.17	29/5/85-87	lower Tt																									
271.34	271.36	29/5/104-106	lower Tt																1					1				
271.48	271.50	29/5/118-120	lower Tt																						1			
271.72	271.74	29/5/142-144	lower Tt																1					1				
271.94	271.96	29/6/14-16	lower Tt																1									
272.19	272.21	29CC/17-19	lower Tt																1	1				1	2			
273.91	273.93	30/1/1-A7303	lower Tt																						2			
274.04	274.06	30/1/14-16	lower Tt																									
274.32	274.34	30/1/42-44	lower Tt																1									
274.48	274.50	30/1/58-60	lower Tt																									
274.72	274.74	30/1/82-84	lower Tt																						1			
274.93	274.95	30/1/103-105	lower Tt																									
275.12	275.14	30/1/122-124	lower Tt																					1				
275.31	275.33	30/1/141-143	lower Tt																									
275.45	275.47	30/2/5-7	lower Tt																									
275.93	275.95	30/2/53-55	lower Tt																									

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globoconella puncticulata* [crust-free] dex	*Globoconella puncticulata* [crust-free] sin	*Globoconella puncticulata* [encrusted] dex	*Globoconella puncticulata* [encrusted] sin	*Globoconella puncticulata* [5-chambers] sin	*Globoconella puncticulata* s.l. [crust-free] dex	*Globoconella puncticulata* s.l. [crust-free] sin	*Globoconella puncticulata* s.l. [encrusted] dex	*Globoconella puncticulata* s.l. [encrusted] sin	*Globoconella puncticulata* s.l. [5-chambers] sin	*Globoconella sphericomiozea* [encrusted] sin	*Globoconella sphericomiozea* [crust-free] dex	*Globoconella sphericomiozea* [crust-free] sin	*Globoconella sphericomiozea* [encrusted] dex	*Globoconella sphericomiozea* [encrusted] sin	*Globoconella* sp.	*Globoquadrina dehiscens*	*Globoquadrina* sp.?	*Globoquadrina venezuelana*?	*Globorotalia lenguaensis* dex	*Globorotalia lenguaensis* sin	*Globorotaloides hexagonus* dex	*Globorotaloides hexagonus* sin	*Hirsutella* cf. *ichinosekiensis* dex	*Hirsutella* cf. *ichinosekiensis* sin	*Hirsutella margaritae* dex
276.52	276.54	30/2/112-114	lower Tt																									
276.91	276.93	30/3/1-3	lower Tt																									
277.33	277.35	30/3/43-45	lower Tt																									
277.74	277.76	30/3/84-86	lower Tt																									
278.07	278.09	30/3/117-119	lower Tt																1									
278.49	278.51	30/4/9-11	lower Tt																13									
278.88	278.90	30/4/48-50	lower Tt																15				1					
279.33	279.35	30/4/93-95	lower Tt																13							1		
279.75	279.77	30/4/135-137	lower Tt																7				2			1		
280.05	280.07	30/5/15-17	lower Tt																4				2					
280.25	280.27	30/5/35-37	lower Tt																5				2			1		
280.92	280.94	30/5/102-104	lower Tt																2									
283.51	283.53	31/1/1-3	lower Tt																3				1					
283.94	283.96	31/1/44-46	lower Tt																8				3					
284.33	284.35	31/1/83-85	lower Tt																5									
284.55	284.57	31/1/105-107	lower Tt																4									
284.88	284.90	31/1/138-140	lower Tt																6				5					
285.29	285.31	31/2/29-31	lower Tt																11									
285.73	285.75	31/2/73-75	lower Tt																11				1					
286.10	286.12	31/2/110-112	lower Tt																8									
286.51	286.53	31/3/1-3	lower Tt																7									
286.88	286.90	31/3/38-40	lower Tt																7									
287.32	287.34	31/3/82-84	lower Tt																4				1					
287.67	287.69	31/3/117-119	lower Tt																7			4	25					
288.08	288.10	31/4/8-10	lower Tt																4				1					
288.55	288.57	31/4/55-57	lower Tt																14				1					
288.89	288.91	31/4/89-91	lower Tt																15						1			
289.34	289.36	31/4/134-136	lower Tt																18							1		
289.73	289.75	31/5/23-25	lower Tt																11									
290.12	290.14	31/5/62-64	lower Tt																18									
290.51	290.53	31/5/101-103	lower Tt																6									
290.74	290.76	31CC/0-2	lower Tt																5									
293.11	293.13	32/1/1-3	lower Tt																2									
293.33	293.35	32/1/23-25	lower Tt																2									
293.71	293.73	32/1/61-63	lower Tt																7									
294.12	294.14	32/1/102-104	lower Tt																19									
294.51	294.53	32/1/141-143	lower Tt																16									
294.90	294.92	32/2/30-32	lower Tt																4									
295.33	295.35	32/2/73-75	lower Tt																7									
295.73	295.75	32/2/113-115	lower Tt																	1								
295.93	295.95	32/2/133-135	lower Tt																6							1		
296.50	296.52	32/3/40-42	lower Tt																4									
296.93	296.95	32/3/83-85	lower Tt																6									
297.33	297.35	32/3/123-125	lower Tt																7									
297.70	297.72	32/4/10-12	lower Tt																7									
298.08	298.10	32/4/48-50	lower Tt																10									
298.52	298.54	32/4/92-94	lower Tt																11									
298.93	298.95	32/4/133-135	lower Tt																9									
299.38	299.40	32/5/28-30	lower Tt																2							1		
299.67	299.69	32CC/2-4	lower Tt																11									
302.71	302.73	33/1/1-3	lower Tt																4						0	3		
302.97	302.99	33/1/27-29	lower Tt																6							5		
303.29	303.31	33/1/59-61	lower Tt																16							4		
303.77	303.79	33/1/107-109	lower Tt																9							2		
304.13	304.15	33/1/143-145	lower Tt																6							1	2	
304.29	304.31	33/2/9-11	lower Tt																							3		
304.47	304.49	33/2/27-29	lower Tt																4							4		
304.66	304.68	33/2/46-48	lower Tt																2							2	1	
305.02	305.04	33/2/82-84	lower Tt																2								2	
305.15	305.17	33/2/95-97	lower Tt																2							3		
305.34	305.36	33/2/114-116	lower Tt																4					0	0			
305.55	305.57	33/2/135-137	lower Tt																4									
305.71	305.73	33/3/1-3	lower Tt																3									
305.93	305.95	33/3/23-25	lower Tt																2									
306.11	306.13	33/3/41-43	lower Tt																11					0	0			
306.27	306.29	33/3/57-59	lower Tt																27						0			
306.54	306.56	33/3/84-86	lower Tt																21					0				
306.75	306.77	33/3/105-107	lower Tt																32					1	2			
306.86	306.88	33/3/116-118	lower Tt																6					0	2			
307.08	307.10	33/3/138-140	lower Tt																						0			
307.30	307.32	33/4/10-12	lower Tt																						0			
307.49	307.51	33/4/29-31	lower Tt																2						0			

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Globoconella puncticulata* [crust-free] dex	*Globoconella puncticulata* [crust-free] sin	*Globoconella puncticulata* [encrusted] dex	*Globoconella puncticulata* [encrusted] sin	*Globoconella puncticulata* [5-chambers] sin	*Globoconella puncticulata* s.l. [crust-free] dex	*Globoconella puncticulata* s.l. [crust-free] sin	*Globoconella puncticulata* s.l. [encrusted] dex	*Globoconella puncticulata* s.l. [encrusted] sin	*Globoconella puncticulata* s.l. [5-chambers] sin	*Globoconella sphericomiozea* [encrusted] sin	*Globoconella sphericomiozea* [crust-free] dex	*Globoconella sphericomiozea* [crust-free] sin	*Globoconella sphericomiozea* [encrusted] dex	*Globoconella sphericomiozea* [encrusted] sin	*Globoconella* sp.	*Globoquadrina dehiscens*	*Globoquadrina* sp.?	*Globoquadrina venezuelana?*	*Globorotalia lenguaensis* dex	*Globorotalia lenguaensis* sin	*Globorotaloides hexagonus* dex	*Globorotaloides hexagonus* sin	*Hirsutella* cf. *ichinosekiensis* dex	*Hirsutella* cf. *ichinosekiensis* sin	*Hirsutella margaritae* dex
307.70	307.72	33/4/50-52	lower Tt																	2					0	0			
307.93	307.95	33/4/73-75	lower Tt																	4					0	0			
308.14	308.16	33/4/94-96	lower Tt																						0				
308.30	308.32	33/4/110-112	lower Tt																	1									
308.53	308.55	33/4/133-135	lower Tt																	1									
308.71	308.73	33/5/1-3	lower Tt																	5						0			
308.99	309.01	33/5/29-31	lower Tt																						1	1			
309.11	309.13	33/5/41-43	lower Tt																	4									
309.28	309.30	33/5/58-60	lower Tt																	2									
309.54	309.56	33/5/84-86	lower Tt																	10						1			
309.74	309.76	33/5/104-106	lower Tt																	6									
312.31	312.33	34/1/1-3	lower Tt																	9									
312.54	312.56	34/1/24-26	lower Tt																	13									
312.67	312.69	34/1/37-39	lower Tt																	6									
312.87	312.89	34/1/57-59	lower Tt																	5									
313.07	313.09	34/1/77-79	lower Tt																	3									
313.31	313.33	34/1/101-103	lower Tt																	6									
313.53	313.55	34/1/123-125	lower Tt																	9									
313.71	313.73	34/1/141-143	lower Tt																	10									
313.90	313.92	34/2/10-12	lower Tt																	8									
314.09	314.11	34/2/29-31	lower Tt																	4									
314.29	314.31	34/2/49-51	lower Tt																	5									
314.45	314.47	34/2/65-67	lower Tt																	2									
314.69	314.71	34/2/89-91	lower Tt																	19									
314.90	314.92	34/2/110-112	lower Tt																	7									
315.13	315.15	34/2/133-135	lower Tt																	1									
315.30	315.32	34/3/0-2	upper Sw																	3									
315.52	315.54	34/3/22-24	upper Sw																	5									
315.71	315.73	34/3/41-43	upper Sw																										
316.06	316.08	34/3/76-78	upper Sw																	4									
316.27	316.29	34/3/97-99	upper Sw																	3									
316.48	316.50	34/3/118-120	upper Sw																	4									
316.67	316.69	34/3/137-139	upper Sw																										
317.10	317.12	34/4/30-32	upper Sw																	2							1		
317.50	317.52	34/4/70-72	upper Sw																	6									
317.90	317.92	34/4/110-112	upper Sw																	3									
318.35	318.37	34/5/5-7	upper Sw																	5									
318.60	318.62	34/5/30-32	upper Sw																	5									
321.91	321.93	35/1/1-3	upper Sw																	2									
322.33	322.35	35/1/43-45	upper Sw																		2								
322.72	322.74	35/1/82-84	upper Sw																	1									
323.09	323.11	35/1/119-121	upper Sw																	1									
323.48	323.50	35/2/8-10	upper Sw																	10							1		
323.91	323.93	35/2/51-53	upper Sw																	1									
324.50	324.52	35/2/110-112	upper Sw																	2									
324.91	324.93	35/3/1-3	upper Sw																	11									
325.33	325.35	35/3/43-45	upper Sw																	5									
325.71	325.73	35/3/81-83	upper Sw																										
325.94	325.96	35/3/104-106	upper Sw																	1									
326.28	326.30	35/3/138-140	upper Sw																	2									
326.70	326.72	35/4/30-32	upper Sw																	25									
327.09	327.11	35/4/69-71	upper Sw																	6									
327.50	327.52	35/4/110-112	upper Sw																	6									
327.91	327.93	35/5/1-3	upper Sw																	5									
328.27	328.29	35/5/37-39	upper Sw																										
328.72	328.74	35/5/82-84	upper Sw																	1									
331.69	331.71	36/1/19-21	upper Sw																	10									
332.11	332.13	36/1/61-63	upper Sw																	6									
332.68	332.70	36/1/118-120	upper Sw																	5									
332.98	333.00	36/1/148-150	upper Sw																	12									
333.40	333.42	36/2/40-42	upper Sw																	3								1	
334.00	334.02	36/2/100-102	upper Sw																	18									
334.36	334.38	36/2/136-138	upper Sw																	3									
334.87	334.89	36/3/37-39	upper Sw																	12									
335.47	335.49	36/3/97-99	upper Sw																	2									
335.88	335.90	36/3/138-140	upper Sw																	7								1	
336.20	336.22	36/4/20-22	upper Sw																	3									
336.60	336.62	36/4/60-62	upper Sw																	1								1	

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Hirsutella margaritae* sin	*Hirsutella panda* dex	*Hirsutella panda* sin	*Hirsutella scitula* dex	*Hirsutella scitula* sin	*Hirsutella sp.* dex	*Hirsutella sp.* sin	*Menardella* cf. *limbata* dex	*Menardella* cf. *limbata* sin	*Menardella* cf. *limbata?* dex	*Menardella* cf. *limbata?* sin	*Neogloboquadrina dutertrei* dex	*Neogloboquadrina dutertrei* sin	*Neogloboquadrina mayeri continuosa* dex	*Neogloboquadrina mayeri continuosa* sin	*Neogloboquadrina mayeri mayeri* dex	*Neogloboquadrina mayeri mayeri* sin	*Neogloboquadrina mayeri nympha* dex	*Neogloboquadrina mayeri nympha* sin	*Neogloboquadrina pachyderma* dex	*Neogloboquadrina pachyderma* sin	*Orbulina bilobata*	*Orbulina bilobata?*	*Orbulina universa*	*Orbulina universa* "juvenile"	*Sphaeroidinellopsis disjuncta?*
120.30	120.33	14/1/0-3	lower Wo				4									1							2	42				8	
120.51	120.54	14/1/21-24	lower Wo				2									1							2	51			1	1	
120.69	120.72	14/1/39-42	lower Wo				2	1								2							4	49			2	4	
120.90	120.93	14/1/60-63	lower Wo				6																4	69			1	3	
121.11	121.14	14/1/81-84	lower Wo				1									1							3	59			1	7	
121.26	121.29	14/1/96-99	lower Wo	1			4									2							2	40			1	8	
121.49	121.52	14/1/119-122	lower Wo				1																3	19			2	7	
121.69	121.72	14/1/139-142	lower Wo				2									1							2	50			4	10	
121.90	121.93	14/2/10-13	lower Wo				2																1	38			5	8	
122.09	122.12	14/2/29-32	lower Wo				2	1		1													7	29			7	7	
122.26	122.29	14/2/46-49	lower Wo	1			2									1							2	23	1		1	2	
122.51	122.55	14/2/71-75	lower Wo				4									1							3	38			5	7	
122.71	122.74	14/2/91-94	lower Wo				6	1															10	78				9	
122.92	122.95	14/2/112-115	lower Wo					1								2							15	56			3	5	
123.10	123.13	14/2/130-133	upper Tk				2																10	67				8	
123.30	123.33	14/3/0-3	upper Tk				4									3							16	35			1	7	
123.53	123.56	14/3/23-26	upper Tk				1									1							27	40				16	
123.69	123.72	14/3/39-42	upper Tk				5	1															12	28			1	10	
123.88	123.91	14/3/58-61	upper Tk				3																10	50			2	4	
124.11	124.14	14/3/81-84	upper Tk				8	1															16	48			2	10	
124.30	124.33	14/3/100-103	upper Tk				3																14	32			1	9	
124.50	124.53	14/3/120-123	upper Tk				2									1							17	23			2	3	
124.68	124.71	14/3/138-141	upper Tk				3																8	45			2	13	
124.90	124.93	14/4/10-13	upper Tk				8									2							13	71			2	6	
125.10	125.13	14/4/30-33	upper Tk				1									1							22	26				10	
125.30	125.33	14/4/50-53	upper Tk				1																17	31				5	
125.48	125.51	14/4/68-71	upper Tk				4									1							7	60			2	10	
125.71	125.74	14/4/91-94	upper Tk				3																5	50				3	
125.91	125.94	14/4/111-114	upper Tk				8	1															18	68			2	7	
126.10	126.13	14/4/130-133	upper Tk				4																9	33			1	7	
126.30	126.33	14/5/0-3	upper Tk				3																6	31			2	10	
126.56	126.59	14/5/26-29	upper Tk				2																21	21				4	
126.70	126.73	14/5/40-43	upper Tk				7	1															13	6			1	3	
126.90	126.93	14/5/60-63	upper Tk				3																16	9				4	
127.12	127.15	14/5/82-85	upper Tk				3	2							1								32	5				14	
127.30	127.33	14/5/100-103	upper Tk				2																20	5			3	6	
127.51	127.54	14/5/121-124	upper Tk				1																27	9			2	2	
127.70	127.73	14/5/140-143	upper Tk				1	1															28	15				9	
127.90	127.93	14/6/10-13	upper Tk				3									1							34	29			1	4	
128.29	128.32	14/6/49-52	upper Tk				3	1															31	5			1	6	
128.72	128.75	14/6/92-95	upper Tk												1								26	4			1	2	
129.10	129.13	14/6/130-133	upper Tk				7	1															9	3			1	1	
129.50	129.53	14/7/20-23	upper Tk				5																22	7			1	1	
129.90	129.93	15/1/0-3	upper Tk				3	1															3	4			2		
130.29	130.32	15/1/39-42	upper Tk				1																4	6				1	
130.69	130.72	15/1/79-82	upper Tk				2	1															3	23				12	
131.10	131.13	15/1/120-123	upper Tk				1	3															16	10				2	
131.51	131.54	15/2/11-14	upper Tk				3																8	16					
131.91	131.93	15/2/51-53	upper Tk					1								1							1	10			2	2	
132.33	132.36	15/2/93-96	upper Tk				4									1								14				2	
132.74	132.76	15/2/134-136	upper Tk				2																1	16					
133.07	133.10	15/3/17-20	upper Tk				2																2	10			1		
133.46	133.49	15/3/56-59	upper Tk				1																1	6			1	1	
133.89	133.92	15/3/99-102	upper Tk				1	2																19			1	1	
134.30	134.33	15/3/140-143	upper Tk				3																	10			6	1	
134.70	134.73	15/4/30-33	upper Tk													1							3	23				5	
135.10	135.13	15/4/70-73	upper Tk																				1	16				1	
135.30	135.33	15/4/90-93	upper Tk				2																3	16					
135.50	135.53	15/4/110-113	upper Tk				1									1								6				2	
135.70	135.73	15/4/130-133	upper Tk	1			2																4	27			2	2	
135.90	135.93	15/5/0-3	upper Tk				2																	38				2	
136.06	136.09	15/5/16-19	upper Tk				1																1	33			3	3	
136.32	136.35	15/5/42-45	upper Tk												1	1							1	29			2	2	
136.51	136.53	15/5/61-63	upper Tk				3																4	75			1	4	
136.92	136.95	15/5/102-105	upper Tk				1	1								2							1	34				3	
137.13	137.16	15/5/123-126	upper Tk				4	5															1	16			2	2	
137.52	137.55	15/6/12-15	upper Tk				5																1	5					
137.91	137.94	15/6/51-54	upper Tk				1	1																5				1	
138.27	138.30	15/6/87-90	upper Tk				1									1							2	3			1	1	
138.66	138.69	15/6/126-129	upper Tk				3																	8				1	
139.07	139.10	15/7/17-20	upper Tk				5	1																1			2	1	
139.50	139.53	16/1/0-3	upper Tk				5	1																5					

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Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Hirsutella margaritae* sin	*Hirsutella panda* dex	*Hirsutella panda* sin	*Hirsutella scitula* dex	*Hirsutella scitula* sin	*Hirsutella sp.* dex	*Hirsutella sp.* sin	*Menardella* cf. *limbata* dex	*Menardella* cf. *limbata* sin	*Menardella* cf. *limbata?* dex	*Menardella* cf. *limbata?* sin	*Neogloboquadrina dutertrei* dex	*Neogloboquadrina dutertrei* sin	*Neogloboquadrina mayeri continuosa* dex	*Neogloboquadrina mayeri continuosa* sin	*Neogloboquadrina mayeri mayeri* dex	*Neogloboquadrina mayeri mayeri* sin	*Neogloboquadrina mayeri nympha* dex	*Neogloboquadrina mayeri nympha* sin	*Neogloboquadrina pachyderma* dex	*Neogloboquadrina pachyderma* sin	*Orbulina bilobata*	*Orbulina bilobata?*	*Orbulina universa*	*Orbulina universa* "juvenile"	*Sphaeroidinellopsis disjuncta?*
139.93	139.96	16/1/43-46	upper Tk				3																	3					
140.34	140.37	16/1/84-87	upper Tk				1																1	3			1		
140.73	140.76	16/1/123-126	upper Tk				4																	2					
141.13	141.15	16/2/13-16	upper Tk				3																	7				3	
141.54	141.57	16/2/54-57	upper Tk				3	3																5			1	2	
141.92	141.95	16/2/92-95	upper Tk				7																	2				2	
142.32	142.35	16/2/132-135	upper Tk				7	2																8			2	1	
142.75	142.78	16/3/25-28	upper Tk				2	1																11			1	1	
143.15	143.18	16/3/65-68	upper Tk				5																	4			4	1	
143.53	143.56	16/3/103-106	upper Tk	2			6	2																14				5	
143.84	143.87	16/3/134-137	lower Tk				2																	7			3	1	
144.26	144.29	16/4/26-29	lower Tk				2																	5				3	
144.67	144.70	16/4/67-70	lower Tk				10	2	1															6				1	
145.13	145.16	16/4/113-116	lower Tk				8																1	9				4	
145.50	145.53	16/5/0-3	lower Tk				19																1	10			1	1	
145.93	145.96	16/5/43-46	lower Tk				10	1																4				2	
146.36	146.38	16/5/86-88	lower Tk				13																2	12			2	6	
146.71	146.74	16/5/121-124	lower Tk				10	1																8			3	3	
147.06	147.09	16/6/6-9	lower Tk				15	4																10			1	1	
147.47	147.50	16/6/47-50	lower Tk				16	1															1	14			1	2	
147.93	147.96	16/6/93-96	lower Tk				17																	9			3	4	
148.33	148.36	16/6/133-136	lower Tk				15	2															1	16			4		
148.67	148.69	16/7/17-19	lower Tk				11	2																8			1		
149.10	149.13	17/1/0-3	lower Tk				11																	12					
149.52	149.55	17/1/42-45	lower Tk				11	1															3	10				1	
150.11	150.14	17/1/101-104	lower Tk				4	1																13			2	1	
150.51	150.54	17/1/141-144	lower Tk				8																	15			1	1	
150.87	150.90	17/2/27-30	lower Tk				14																	14				3	
151.07	151.10	17/2/47-50	lower Tk				6	2																9			3	1	
151.52	151.55	17/2/92-95	lower Tk				16																1	15					
151.96	151.98	17/2/136-138	lower Tk				5	1								1								11					
152.10	152.13	17/3/0-3	lower Tk				8	1															1	13				2	
152.25	152.28	17/3/15-18	lower Tk				9	1															1	15					
152.47	152.50	17/3/37-40	lower Tk				7																	10				3	
152.75	152.77	17/3/65-67	lower Tk				9	2																24				2	
152.91	152.94	17/3/81-84	lower Tk				11	2															1	11			5	2	
153.12	153.15	17/3/102-105	lower Tk				8																1	9				1	
153.26	153.29	17/3/116-119	lower Tk				9	1																20				3	
153.45	153.48	17/3/135-138	lower Tk				14																1	10				2	
153.66	153.69	17/4/6-9	lower Tk				4																	11				2	
153.97	153.99	17/4/37-39	lower Tk				7																	8				2	
154.13	154.16	17/4/53-56	lower Tk				4	2															1	8				5	
154.32	154.35	17/4/72-75	lower Tk				12	2																11				23	
154.54	154.57	17/4/94-97	lower Tk	1			16																1	20				16	
154.77	154.79	17/4/117-119	lower Tk				10																2	10	3		3	13	
154.95	154.98	17/4/135-138	lower Tk				14	2								3							7	37			2	20	
155.10	155.13	17/5/0-3	lower Tk				13	4															3	12	1		5	40	
155.24	155.27	17/5/14-17	lower Tk				4																3	10			5	24	
155.48	155.50	17/5/38-40	lower Tk				9																	7	1			7	
155.67	155.70	17/5/57-60	lower Tk				10																	10				4	
155.94	155.97	17/5/84-87	lower Tk				24																3	18			2	4	
156.13	156.16	17/5/103-106	lower Tk				15	2															1	9			1	10	
156.27	156.30	17/5/117-120	lower Tk				9	1															2	5			1	3	
156.47	156.50	17/5/137-140	lower Tk				12	1																17			2	6	
156.71	156.74	17/6/11-14	lower Tk				9																5	7				3	
156.95	156.98	17/6/35-38	lower Tk				21	1																9				6	
157.12	157.15	17/6/52-55	lower Tk				14	1															4	19			2	5	
157.37	157.39	17/6/77-79	lower Tk				10									1							2	13				2	
157.52	157.55	17/6/92-95	lower Tk				3									1							2	9				2	
157.76	157.79	17/6/116-119	lower Tk				7	1								1							12	29			1	4	
157.93	157.96	17/6/133-136	lower Tk				10	5															4	24			2	1	
158.10	153.13	17/7/0-3	lower Tk				18	1								1							3	29				4	
158.27	158.30	17/7/17-20	lower Tk				12																3	37				4	
158.52	158.55	17CC/6-9	lower Tk				3	4															2	15				15	
158.70	158.73	18/1/0-3	lower Tk				10	4								1							6	31			1	11	
158.95	158.98	18/1/25-28	lower Tk				10	2															1	18				6	
159.13	159.16	18/1/43-46	lower Tk				11	2															2	12			1	1	
159.35	159.38	18/1/65-68	lower Tk				11	2																30				16	
159.49	159.52	18/1/79-82	lower Tk				20																3	22			4	11	
159.72	159.75	18/1/102-105	lower Tk				18																1	27				4	
159.86	159.89	18/1/116-119	lower Tk				39	2															3	20				4	
160.11	160.14	18/1/141-144	lower Tk				56	1															1	15				2	

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Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Hirsutella margaritae* sin	*Hirsutella panda* dex	*Hirsutella panda* sin	*Hirsutella scitula* dex	*Hirsutella scitula* sin	*Hirsutella sp.* dex	*Hirsutella sp.* sin	*Menardella* cf. *limbata* dex	*Menardella* cf. *limbata* sin	*Menardella* cf. *limbata?* dex	*Menardella* cf. *limbata?* sin	*Neogloboquadrina dutertrei* dex	*Neogloboquadrina dutertrei* sin	*Neogloboquadrina mayeri continuosa* dex	*Neogloboquadrina mayeri continuosa* sin	*Neogloboquadrina mayeri mayeri* dex	*Neogloboquadrina mayeri mayeri* sin	*Neogloboquadrina mayeri nympha* dex	*Neogloboquadrina mayeri nympha* sin	*Neogloboquadrina pachyderma* dex	*Neogloboquadrina pachyderma* sin	*Orbulina bilobata*	*Orbulina bilobata?*	*Orbulina universa*	*Orbulina universa* "juvenile"	*Sphaeroidinellopsis disjuncta?*
160.33	160.36	18/2/13-16	lower Tk				26	2							1								2	27			1	15	
160.73	160.76	18/2/53-56	lower Tk				30	1								1							4	14	2		5	7	
161.16	161.19	18/2/96-99	lower Tk				37	3															3	33					
161.53	161.56	18/2/133-136	lower Tk				21	2															3	30			1	9	
161.84	161.87	18/3/14-17	lower Tk				39	3															1	17			3	10	
162.26	162.29	18/3/56-59	lower Tk				28																4	8				4	
162.87	162.90	18/3/117-120	lower Tk				16	7																11			2	3	
163.33	163.36	18/4/13-16	lower Tk				17	2								1							1	18			2	7	
163.56	163.59	18/4/36-39	lower Tk				53	1															3	44			5	13	
163.93	163.96	18/4/73-76	lower Tk				37																	16			3	12	
164.31	164.33	18/4/111-113	lower Tk				31	1																6			2	10	
164.70	164.73	18/5/0-3	lower Tk				19	3															1	9			3	4	
165.13	165.16	18/5/43-46	lower Tk				65																1	35			2	6	
165.50	165.53	18/5/80-83	lower Tk				43	2															1	31				4	1
165.95	165.97	18/5/125-127	lower Tk				69	4																14				1	
166.26	166.29	18/6/6-9	lower Tk				22																2	21			1	8	
166.66	166.69	18/6/46-49	lower Tk				44	2																29			1		
167.06	167.09	18/6/86-89	lower Tk				57	1																32			1	9	
167.44	167.47	18/6/124-127	upper Tt				68	4															1	38			5	7	
168.30	168.33	19/1/0-3	upper Tt				42	5															1	9			1	10	
168.71	168.74	19/1/41-44	upper Tt				33	4								1							4	21				6	
169.13	169.15	19/1/83-85	upper Tt				32	1															1	25			2		
169.51	169.54	19/1/121-124	upper Tt				45	5															1	11			2		
169.85	169.88	19/2/5-8	upper Tt				40	4															2	14			2	3	
170.32	170.35	19/2/52-55	upper Tt				42	2																8				8	
170.73	170.76	19/2/93-96	upper Tt				51	1															3	10				5	
171.15	171.18	19/2/135-138	upper Tt				41	3																14			1	11	
171.57	171.59	19/3/27-29	upper Tt				65	3																17			2	7	
171.92	171.94	19/3/62-64	upper Tt				23																1	13				3	
172.32	172.35	19/3/102-105	upper Tt				30																1	20				5	
172.66	172.68	19/3/136-138	upper Tt				22	2																21				6	
173.07	173.09	19/4/27-29	upper Tt				20																	15				4	
173.52	173.54	19/4/72-74	upper Tt				13																1	7					
173.93	173.95	19/4/113-115	upper Tt				32	4															1	18			1	4	
174.30	174.33	19/5/0-3	upper Tt				27	1																10			3	7	
174.72	174.75	19/5/42-45	upper Tt				5	13																24				1	
175.26	175.28	19/5/96-99	upper Tt				6	31																6			1	7	
175.71	175.74	19/5/141-144	upper Tt				1	31															1	10				2	
176.06	176.09	19/6/26-29	upper Tt				1	10																13				2	
176.47	176.49	19/6/67-69	upper Tt				3	10																18				8	
176.92	176.94	19/6/112-114	upper Tt				2	6																27				2	
177.30	177.33	19/7/0-3	upper Tt				12																	15	1		1	4	
177.52	177.55	19/7/22-25	upper Tt				48	4								1							3	32			1	12	
177.90	177.93	20/1/0-3	upper Tt				2																5	37				2	
178.27	178.30	20/1/37-40	upper Tt				14																1	34			1	10	
178.68	178.70	20/1/78-80	upper Tt				3	2																48				10	
179.08	179.10	20/1/118-120	upper Tt				4																1	25				14	
179.45	179.47	20/2/5-7	upper Tt				9																2	21				17	
179.86	179.88	20/2/46-48	upper Tt				16																2	46				10	
180.33	180.35	20/2/93-95	upper Tt				16																	37				8	
180.73	180.75	20/2/133-135	upper Tt				10	2															1	19			2	9	
181.14	181.16	20/3/24-26	upper Tt				2																	17				1	
181.57	181.59	20/3/67-69	upper Tt				11	2								1							2	20				20	
181.86	181.88	20/3/96-98	upper Tt				14	1															1	39	1		1	7	
182.23	182.25	20/3/133-135	upper Tt				7																	27				10	
182.68	182.70	20/4/28-30	upper Tt				9	4															3	25			1	5	
183.08	183.10	20/4/68-70	upper Tt				9	1																12				5	
183.45	183.47	20/4/105-107	upper Tt				10	2								2							2	42			2	21	
183.91	183.93	20/5/1-3	upper Tt				10	8															1	38			1	12	
184.32	184.34	20/5/42-44	upper Tt				5	28							1									25				13	
184.72	184.74	20/5/82-84	upper Tt				3	22																32				17	
185.07	185.09	20/5/117-119	upper Tt				2	43															1	24				13	
185.47	185.49	20/6/7-9	upper Tt				2	13																9				9	
185.92	185.94	20/6/52-54	upper Tt				6	56															4	17	1			20	
186.32	186.34	20/6/92-94	upper Tt				2	44															2	20			2	23	
186.72	186.74	20/6/132-134	upper Tt				3	51															1	25			1	9	
187.07	187.09	20/7/17-19	upper Tt				3	37															3	59			1	19	
187.51	187.53	21/1/1-3	upper Tt				4	8															8	65				35	
187.93	187.95	21/1/43-45	upper Tt				6	59								1							3	40				29	
188.32	188.34	21/182-84	upper Tt				2	28															1	23				12	
188.67	188.69	21/1/117-119	upper Tt				2	36																22			2	14	
189.08	189.10	21/2/8-10	upper Tt				2	37																17				3	

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Hirsutella margaritae* sin	*Hirsutella panda* dex	*Hirsutella panda* sin	*Hirsutella scitula* dex	*Hirsutella scitula* sin	*Hirsutella sp.* dex	*Hirsutella sp.* sin	*Menardella* cf. *limbata* dex	*Menardella* cf. *limbata* sin	*Menardella* cf. *limbata?* dex	*Menardella* cf. *limbata?* sin	*Neogloboquadrina dutertrei* dex	*Neogloboquadrina dutertrei* sin	*Neogloboquadrina mayeri continuosa* dex	*Neogloboquadrina mayeri continuosa* sin	*Neogloboquadrina mayeri mayeri* dex	*Neogloboquadrina mayeri mayeri* sin	*Neogloboquadrina mayeri nympha* dex	*Neogloboquadrina mayeri nympha* sin	*Neogloboquadrina pachyderma* dex	*Neogloboquadrina pachyderma* sin	*Orbulina bilobata*	*Orbulina bilobata?*	*Orbulina universa*	*Orbulina universa* "juvenile"	*Sphaeroidinellopsis disjuncta?*
189.46	189.48	21/2/46-48	upper Tt				6	9															2	20			1	10	
189.93	189.96	21/2/93-96	upper Tt				3	12																20				11	
190.42	190.44	21/2/142-144	upper Tt				6	34																24			6	13	
190.66	190.68	21/3/16-18	upper Tt				2	41															1	14			1	6	
191.12	191.14	21/3/62-64	upper Tt				2	20															1	22				13	
191.52	191.54	21/3/102-104	upper Tt				1	13																42			2	15	
191.86	191.89	21/3/136-139	upper Tt				2	27															2	25				3	
192.36	192.38	21/4/36-38	upper Tt				6	54															1	36				19	
192.73	193.75	21/4/73-75	upper Tt				12	97																19			6	9	
193.12	193.14	21/4/112-114	upper Tt				4	15								1							2	19			7	3	
193.50	193.52	21/5/0-2	upper Tt				4	22															1	49			5	7	
193.92	193.94	21/5/42-44	upper Tt				8	13																20			2	12	
194.34	194.26	21/5/84-86	upper Tt				1	9																15			2	7	
194.72	194.74	21/5/122-124	upper Tt				13	25															2	49				10	
195.07	195.09	21/6/7-9	upper Tt				13	22																27			2	9	
195.49	195.51	21/6/49-51	upper Tt				10	19							1	2							1	34				6	
195.87	195.89	21/6/87-89	upper Tt				16	4								2							1	69			2		
196.34	196.36	21/6/134-136	upper Tt				20	1								1								28				2	
196.72	196.74	21/7/22-24	upper Tt				7									1							1	51			1	13	
197.11	197.13	22/1/1-3	upper Tt				32	3															1	29				12	
197.48	197.50	22/1/38-40	upper Tt				24	1								2							3	52			1	7	
197.94	197.96	22/1/84-86	upper Tt				23	1															4	42			1	11	
198.32	198.34	22/1/122-124	upper Tt				54	4								3							2	36			8	11	
198.73	198.75	22/2/13-15	upper Tt				17	2															2	32			2	2	
199.14	199.16	22/2/54-56	upper Tt				20	1								1							14	72			1	20	
199.53	199.55	22/2/93-95	upper Tt				76	2								3							3	30				9	
199.93	199.95	22/2/133-135	upper Tt				15																13	81			3	3	
200.25	200.27	22/3/15-17	upper Tt				32	2															11	102			1	9	
200.66	200.68	22/3/56-58	upper Tt				9	3															3	34				1	
201.05	201.07	22/3/95-97	upper Tt				15	23								2							9	93			1	11	
201.42	201.44	22/3/132-134	upper Tt				9	29								1							10	10			6	15	
201.93	201.95	22/4/33-35	upper Tt				8	17															3	23			1	11	
202.52	202.55	22/4/92-95	upper Tt				25	44															3	26			5	23	
202.93	202.95	22/4/133-135	upper Tt				5	43															4	35			2	14	
203.17	203.20	22CC/7-10	upper Tt				8	22																18	1		1	21	
206.71	206.73	23/1/1-3	upper Tt				49	3																21	1		1	19	
207.13	207.15	23/1/43-45	upper Tt				26	1																11				14	
207.48	207.50	23/1/78-80	upper Tt				16																	6			1	26	
207.88	207.90	23/1/118-120	upper Tt				51	5																4				9	
208.26	208.28	23/2/6-8	upper Tt				28	1																9			1	5	
208.52	208.54	23/2/32-34	upper Tt				41	5															1	18				13	
209.06	209.08	23/2/86-88	upper Tt				43	5																5			3	10	
209.54	209.56	23/2/134-136	upper Tt				25	4																13				6	
209.85	209.87	23/3/15-17	upper Tt				30																	9		1	1	14	
210.33	210.35	23/3/63-65	upper Tt				61	1																9				12	
210.53	210.55	23/3/83-85	upper Tt				71	2															1	17			2	12	
210.87	210.89	23/3/117-119	upper Tt				30	5															2	13				13	
211.27	211.29	23/4/7-9	upper Tt				35	2																3			2	16	
211.72	211.74	23/4/52-54	upper Tt				21	7																16			1	25	
212.13	212.15	23/4/93-95	upper Tt				2	13								1								5			1	19	
212.32	212.34	23/4/112-114	upper Tt				3	22				2				1							2	27	1			15	
212.71	212.73	23/5/1-3	upper Tt				3	4															1	23	1			5	
213.12	213.14	23/5/42-44	upper Tt				5	23															4	31	1			12	
213.72	213.74	23/5/102-104	upper Tt				1	8															1	23			1	11	
214.12	214.14	23/5/142-144	upper Tt				3	10															1	20			3	8	
214.51	214.53	23/6/31-33	upper Tt				5	21															5	40			1	12	
215.05	215.07	23/6/85-87	upper Tt				2	8															2	6			1	13	
215.53	215.55	23/6/133-135	upper Tt				1	12				1											2	9			1	29	
215.93	215.95	23/7/23-25	upper Tt				7	17																10			1	32	
216.31	216.33	24/1/1-3	upper Tt				3	24															1	20			3	6	
216.57	216.59	24/1/27-29	upper Tt				6	44															12	92			2	45	
216.94	216.96	24/1/64-66	upper Tt				4	37															2	18				6	
217.34	217.36	24/1/104-106	upper Tt				1	21															1	21				5	
217.72	217.74	24/1/142-144	upper Tt				4	28																15			1	4	
218.08	218.10	24/2/28-30	upper Tt				3	25																11			2	10	
218.52	218.54	24/2/72-74	upper Tt				6	46															4	53				28	
218.87	218.89	24/2/107-109	upper Tt				1	26															2	31			1	18	
219.31	219.33	24/3/1-3	upper Tt				9	20								4							6	93			2	12	
219.72	219.74	24/3/42-44	upper Tt				2	23								6							3	107			2	13	
220.12	220.14	24/3/82-84	upper Tt				4	23								3							5	70			2	24	
220.46	220.48	24/3/116-118	upper Tt				1	33								4							10	100			1	15	
220.87	220.89	24/4/7-9	upper Tt				9	40								3							8	45			1	10	

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Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Hirsutella margaritae* sin	*Hirsutella panda* dex	*Hirsutella panda* sin	*Hirsutella scitula* dex	*Hirsutella scitula* sin	*Hirsutella sp.* dex	*Hirsutella sp.* sin	*Menardella* cf. *limbata* dex	*Menardella* cf. *limbata* sin	*Menardella* cf. *limbata?* dex	*Menardella* cf. *limbata?* sin	*Neogloboquadrina dutertrei* dex	*Neogloboquadrina dutertrei* sin	*Neogloboquadrina mayeri continuosa* dex	*Neogloboquadrina mayeri continuosa* sin	*Neogloboquadrina mayeri mayeri* dex	*Neogloboquadrina mayeri mayeri* sin	*Neogloboquadrina mayeri nympha* dex	*Neogloboquadrina mayeri nympha* sin	*Neogloboquadrina pachyderma* dex	*Neogloboquadrina pachyderma* sin	*Orbulina bilobata*	*Orbulina bilobata?*	*Orbulina universa*	*Orbulina universa* "juvenile"	*Sphaeroidinellopsis disjuncta?*
221.27	221.29	24/4/47-49	upper Tt				3	63								1							1	65			5	22	
221.66	221.68	24/4/86-88	upper Tt				2	31								1								49			2	30	
222.13	222.15	24/4/133-135	upper Tt				6	38								1							2	44			2	7	
222.45	222.47	24/5/15-17	upper Tt				4	24								2							6	68				7	
222.93	222.95	24/5/63-65	upper Tt				4	30								1							4	33			1	5	
223.33	223.35	24/5/103-105	upper Tt				4	5								1							3	51			1	5	
223.72	223.74	24/5/142-144	upper Tt				2	16								1							3	82			3	9	
224.07	224.09	24/6/27-29	upper Tt				2	28								2							1	66			2	13	
224.47	224.49	24/6/67-69	upper Tt				4	49															9	112				13	
224.87	224.89	24/6/107-109	upper Tt				1	12								1							2	30			2	7	
225.36	225.38	24CC/9-11	upper Tt				1	36								1							2	42			2	11	
226.13	226.15	25/1/23-25	upper Tt				16	5								2							3	34				9	
226.53	226.55	25/1/63-65	upper Tt				37	2															7	69			3	17	
226.93	226.95	25/1/103-105	upper Tt				12	1															5	37			1	12	
227.34	227.36	25/1/144-146	upper Tt				6	10							1	1								25				14	
227.72	227.74	25/2/-32-34	upper Tt				6	8															1	21			1	17	
228.12	228.14	25/2/72-74	upper Tt				5	11								5							1	29			1	22	
228.52	228.54	25/2/112-114	upper Tt				13	5							1	7							2	29			4	32	
228.90	228.92	25/3/0-2	upper Tt				6								1	3							1	30				24	
229.33	229.35	25/3/43-45	upper Tt				10	14								1								17			5	31	
229.85	229.87	25/3/95-97	upper Tt				7	8								2							1	13			5	34	
230.27	230.29	25/3/137-139	upper Tt				5	28								1								15			2	27	
230.47	230.49	25/4/7-9	upper Tt				11	96		1						11							1	33			6	71	
230.93	230.95	25/4/53-55	upper Tt				2	61								2							3	18			1	15	
231.33	231.35	25/4/93-95	upper Tt				7	92								2							4	21			5	37	
231.73	231.75	25/4/133-135	upper Tt				2	56							1	8							3	82			2	22	
232.06	232.08	25/5/16-18	upper Tt				6	42																3			2	14	
232.52	232.54	25/5/62-64	upper Tt				17	64		1						1							1	7			4	43	
232.92	232.94	25/5/102-104	upper Tt				9	6							1	2							4	26			1	15	
233.27	233.29	25/5137-139	upper Tt				9	27					1			6								31				12	
233.67	233.69	25/6/27-29	upper Tt				8	32		2														4			2	15	
234.15	234.17	25/6/75-77	upper Tt				3	69								1								3			3	18	
234.52	234.54	25/6/112-114	upper Tt				11	88															1	9			5	24	
234.91	234.93	25/7/1-3	upper Tt				8	32	1							1							1	10			4	12	
235.26	235.28	25CC/10-22	upper Tt				5	46							1									20			5	21	
235.73	235.75	26/1/23-25	upper Tt				1	6															2	32			2	8	
236.08	236.10	26/1/58-60	upper Tt					7								2							2	54			2	18	
236.52	236.54	26/1/102-104	upper Tt				1	11								2							3	19				23	
236.92	236.94	26/1/142-144	upper Tt					5							1	2								7				9	
237.32	237.34	26/2/32-34	upper Tt				1	14								1							5	48			6	20	
237.93	237.95	26/2/93-95	upper Tt				1	14															1	19			4	9	
238.33	238.35	26/2/133-135	upper Tt				1	2								1							3	40			5	7	
238.51	238.53	26/3/1-3	upper Tt				1	25								8							2	66			2	16	
238.93	238.95	26/3/43-45	upper Tt				1	61		1														17			1	8	
239.32	239.34	26/3/82-84	upper Tt				4	53								2							1	53			1	12	
239.67	239.69	26/3/117-119	upper Tt				3	43															1	15			4	10	
240.07	240.09	26/4/7-9	upper Tt				4	63					1	16									2	21			4	13	
240.52	240.54	26/4/52-54	upper Tt				1	15							1	4							1	48				7	
240.92	240.94	26/4/92-94	upper Tt				2	20						1									1	17			4	10	
241.32	241.34	26/4/132-134	upper Tt				2	32															2	9			2	14	
241.65	241.67	26/5/15-17	upper Tt				4	37																33			2	10	
242.13	242.15	26/5/63-65	upper Tt				6	13						4									2	9			3	7	
242.52	242.54	26/5/102-104	upper Tt				8	10								2							3	13			2	5	
242.92	242.94	26/5/142-144	upper Tt				10	20								3								54				13	
243.26	243.28	26/6/26-28	upper Tt				6	9															1	31			2	3	
243.63	243.65	26/6/63-65	upper Tt				18	4								6							2	71			1	2	
243.86	243.88	26CC/13-15	upper Tt				22	4								9							2	47			4	8	
245.11	245.13	27/1/1-3	upper Tt				11	4								2							4	89			1	5	
245.53	245.55	27/1/43-45	upper Tt				2	12								1							2	47			4	6	
245.91	245.93	27/1/81-83	upper Tt					6																22				2	
246.27	246.29	27/1/117-119	upper Tt				3	2								1							2	10			3	16	
246.52	246.54	27/1/142-144	upper Tt				2	6								2							3	31				22	
246.87	246.89	27/2/27-29	upper Tt					10		1													1	46			2	12	
247.33	247.35	27/2/73-76	upper Tt					3															1	44				13	
247.67	247.69	27/2/107-109	upper Tt					2								3							5	57			2	12	
248.11	248.13	27/3/1-3	upper Tt				3	5															1	33			1	5	
248.47	248.49	27/3/37-39	upper Tt				4	10								7							6	67				7	
248.93	248.95	27/3/83-85	upper Tt				1	5								1							1	37				3	
249.27	249.27	27/3/117-119	upper Tt				2	11								2							2	60				2	
249.67	249.69	27/4/7-9	upper Tt				2	27															1	57			3	11	
250.12	250.14	27/4/52-54	upper Tt				5	11																26			1	5	
250.46	250.48	27/4/86-88	upper Tt				1									2							3	26			1	7	

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Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Hirsutella margaritae* sin	*Hirsutella panda* dex	*Hirsutella panda* sin	*Hirsutella scitula* dex	*Hirsutella scitula* sin	*Hirsutella sp.* dex	*Hirsutella sp.* sin	*Menardella* cf. *limbata* dex	*Menardella* cf. *limbata* sin	*Menardella* cf. *limbata?* dex	*Menardella* cf. *limbata?* sin	*Neogloboquadrina dutertrei* dex	*Neogloboquadrina dutertrei* sin	*Neogloboquadrina mayeri continuosa* dex	*Neogloboquadrina mayeri continuosa* sin	*Neogloboquadrina mayeri mayeri* dex	*Neogloboquadrina mayeri mayeri* sin	*Neogloboquadrina mayeri nympha* dex	*Neogloboquadrina mayeri nympha* sin	*Neogloboquadrina pachyderma* dex	*Neogloboquadrina pachyderma* sin	*Orbulina bilobata*	*Orbulina bilobata?*	*Orbulina universa*	*Orbulina universa* "juvenile"	*Sphaeroidinellopsis disjuncta?*
250.92	250.94	27/4/132-134	upper Tt				6																2	63			5	10	
251.33	251.36	27/5/23-26	upper Tt				7	2								4							2	88				9	
251.67	251.69	27/5/57-59	upper Tt				4	3		1						4							4	115			1	6	
252.13	252.15	27/5/103-105	upper Tt				1	2															1	114			5	9	
252.53	252.55	27/5/143-145	upper Tt				5	10								1								36				5	
252.92	252.94	27/6/32-34	upper Tt				3	11															7	55			2	6	
253.33	253.35	27/6/73-75	upper Tt				1	9															4	25			1	4	
253.67	253.69	27/6/107-109	upper Tt				1	16															1	23			2	12	
254.10	254.12	27/7/0-2	upper Tt				2	7																26				8	
254.49	254.51	27CC/10-12	lower Tt				7	18							1	5							8	79			2	8	
254.93	254.95	28/4/23-25	lower Tt				19	4															1	26				16	
255.28	255.30	28/1/58-60	lower Tt				11	5															3	44			1	4	
255.73	255.75	28/1/103-105	lower Tt				4	3															2	32				5	
256.11	256.13	28/1/141-143	lower Tt					2																14	1		1	5	
256.53	256.55	28/2/33-35	lower Tt				6	2								2								11			1	17	
257.03	257.05	28/2/83-85	lower Tt				2	1																3			1	1	
257.33	257.35	28/2/113-115	lower Tt				1	1																1			1	4	
257.71	257.73	28/3/1-3	lower Tt				5	9																3				10	
258.12	258.14	28/3/42-44	lower Tt				1	6		1			1											3			3	9	
258.54	258.56	28/3/84-86	lower Tt					2															1	4				5	
259.07	259.09	28/3/137-139	lower Tt				3	1															2	32				9	
259.53	259.55	28/4/33-35	lower Tt				2									2								47			2	21	
259.86	259.88	28/4/66-68	lower Tt				3	1															1	45				10	
260.28	260.30	28/4/108-110	lower Tt				1	3								1								42			2	11	
260.54	260.56	28/4/134-136	lower Tt				2	7								1							1	2			1	11	
260.86	260.88	28/5/16-18	lower Tt				1	3																9			4	8	
261.31	261.33	28/5/61-63	lower Tt				3	5															1	35			3	18	
261.72	261.74	28/5/102-104	lower Tt				10	11																20			2	16	
262.11	262.13	28/5/141-143	lower Tt				5	8															2	23			1	7	
262.45	262.47	28CC/8-10	lower Tt				6	3								1							2	16			2	18	
264.30	264.32	29/1/0-2	lower Tt				1	2																8			1	6	
264.64	264.66	29/1/34-36	lower Tt					4															1	34			5	12	
264.88	264.90	29/1/58-60	lower Tt				1	4					1										3	35			2	7	
265.26	265.28	29/1/96-98	lower Tt				1																9	65				4	
265.72	265.74	29/1/142-144	lower Tt				2	1															2	45			1	8	
266.12	266.14	29/2/32-34	lower Tt				6																	40	1		1	5	
266.44	266.46	29/2/64-66	lower Tt				3									4							5	31			1	9	
266.87	266.89	29/2/107-109	lower Tt				1																1	39			1	4	
267.31	267.33	29/3/1-3	lower Tt				1																	34			2	6	
267.53	267.55	29/3/23-25	lower Tt				2	1															1	41			1	7	
267.72	267.74	29/3/42-44	lower Tt				3																1	45			1	13	
267.87	267.89	29/3/57-59	lower Tt				5																1	43				14	
268.14	268.16	29/3/84-86	lower Tt				9																1	36				2	
268.34	268.36	29/3/104-106	lower Tt				1																	25				6	
268.47	268.49	29/3/117-119	lower Tt				7									2							1	28			1	14	
268.68	268.70	29/3/138-140	lower Tt				1	1							1									14				8	
268.86	268.88	29/4/6-8	lower Tt				1	1																11				5	
269.28	269.30	29/4/48-50	lower Tt				2									1						3		3				5	
269.52	269.54	29/4/72-74	lower Tt				5									3						2	5	15				22	
269.75	269.77	29/4/95-97	lower Tt				3															1	2	14	1		1	26	
269.87	269.89	29/4/107-109	lower Tt				2	1														2		7				12	
270.15	270.17	29/4/135-137	lower Tt				9	1															1	16				20	
270.31	270.33	29/5/1-3	lower Tt				10																2	14			1	9	
270.45	270.47	29/5/15-17	lower Tt				7																1	11				11	
270.72	270.74	29/5/42-44	lower Tt				24															1	3	8				9	
270.91	270.93	29/5/61-63	lower Tt				8	3																13	2		2	16	
271.15	271.17	29/5/85-87	lower Tt																			8	2	28				17	
271.34	271.36	29/5/104-106	lower Tt																			4	1	9			2	18	
271.48	271.50	29/5/118-120	lower Tt				4																	1				15	
271.72	271.74	29/5/142-144	lower Tt																									5	
271.94	271.96	29/6/14-16	lower Tt				3																					11	
272.19	272.21	29CC/17-19	lower Tt				2																	1			4	16	
273.91	273.93	30/1/1-A7303	lower Tt																				1	1			1	8	
274.04	274.06	30/1/14-16	lower Tt																								1	9	
274.32	274.34	30/1/42-44	lower Tt				7	3																				10	
274.48	274.50	30/1/58-60	lower Tt				9																				2	12	
274.72	274.74	30/1/82-84	lower Tt				10																2	17			1	18	
274.93	274.95	30/1/103-105	lower Tt				1	1						1									1	24			1	6	
275.12	275.14	30/1/122-124	lower Tt				1																1	3				18	
275.31	275.33	30/1/141-143	lower Tt																				1	16				4	
275.45	275.47	30/2/5-7	lower Tt																				1	31			2	13	
275.93	275.95	30/2/53-55	lower Tt																				2	28			2	5	

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Hirsutella margaritae* sin	*Hirsutella panda* dex	*Hirsutella panda* sin	*Hirsutella scitula* dex	*Hirsutella scitula* sin	*Hirsutella sp.* dex	*Hirsutella sp.* sin	*Menardella* cf. *limbata* dex	*Menardella* cf. *limbata* sin	*Menardella* cf. *limbata?* dex	*Menardella* cf. *limbata?* sin	*Neogloboquadrina dutertrei* dex	*Neogloboquadrina dutertrei* sin	*Neogloboquadrina mayeri continuosa* dex	*Neogloboquadrina mayeri continuosa* sin	*Neogloboquadrina mayeri mayeri* dex	*Neogloboquadrina mayeri mayeri* sin	*Neogloboquadrina mayeri nympha* dex	*Neogloboquadrina mayeri nympha* sin	*Neogloboquadrina pachyderma* dex	*Neogloboquadrina pachyderma* sin	*Orbulina bilobata*	*Orbulina bilobata?*	*Orbulina universa*	*Orbulina universa* "juvenile"	*Sphaeroidinellopsis disjuncta?*
276.52	276.54	30/2/112-114	lower Tt				2									4							2	30				12	
276.91	276.93	30/3/1-3	lower Tt				4																1	34			1	8	
277.33	277.35	30/3/43-45	lower Tt				1							1										26				6	
277.74	277.76	30/3/84-86	lower Tt			1								1									1	26				9	
278.07	278.09	30/3/117-119	lower Tt			1	1							5									2	22			3	8	
278.49	278.51	30/4/9-11	lower Tt								1	3											1	32				8	
278.88	278.90	30/4/48-50	lower Tt										1	3										31			2	10	
279.33	279.35	30/4/93-95	lower Tt				1																	17				7	
279.75	279.77	30/4/135-137	lower Tt		1																			22			1	9	
280.05	280.07	30/5/15-17	lower Tt																					19				4	
280.25	280.27	30/5/35-37	lower Tt				4			1						5							2	34				10	
280.92	280.94	30/5/102-104	lower Tt				1	1															3	59			1	16	
283.51	283.53	31/1/1-3	lower Tt		1											3							6	51				12	
283.94	283.96	31/1/44-46	lower Tt																				1	67				10	
284.33	284.35	31/1/83-85	lower Tt				2							1									3	59			1	7	
284.55	284.57	31/1/105-107	lower Tt				1			2						5								77			2	13	
284.88	284.90	31/1/138-140	lower Tt																				4	88				18	
285.29	285.31	31/2/29-31	lower Tt				3																1	43			2	4	
285.73	285.75	31/2/73-75	lower Tt																					9				3	
286.10	286.12	31/2/110-112	lower Tt				2	1																23			1	10	
286.51	286.53	31/3/1-3	lower Tt													1							1	23				6	
286.88	286.90	31/3/38-40	lower Tt				1																	23				3	
287.32	287.34	31/3/82-84	lower Tt																				1	41				7	
287.67	287.69	31/3/117-119	lower Tt																				7	86				2	
288.08	288.10	31/4/8-10	lower Tt			2																	2	36				10	
288.55	288.57	31/4/55-57	lower Tt				1																1	55				13	
288.89	288.91	31/4/89-91	lower Tt												1								2	12				6	
289.34	289.36	31/4/134-136	lower Tt													3							10	134				4	
289.73	289.75	31/5/23-25	lower Tt				1																4	112				12	
290.12	290.14	31/5/62-64	lower Tt				3																1	40				9	
290.51	290.53	31/5/101-103	lower Tt				2									7							3	48				7	
290.74	290.76	31CC/0-2	lower Tt				5									1							5	101			1	7	
293.11	293.13	32/1/1-3	lower Tt				4								2	3							3	52				12	
293.33	293.35	32/1/23-25	lower Tt				3									1								99				3	
293.71	293.73	32/1/61-63	lower Tt				2									2							9	119	1			6	
294.12	294.14	32/1/102-104	lower Tt				8	1								1							8	68				6	
294.51	294.53	32/1/141-143	lower Tt				4									1							118	55				7	
294.90	294.92	32/2/30-32	lower Tt				6																45	3				12	
295.33	295.35	32/2/73-75	lower Tt				4																14	1	1			5	
295.73	295.75	32/2/113-115	lower Tt																									11	
295.93	295.95	32/2/133-135	lower Tt				1																				1	6	
296.50	296.52	32/3/40-42	lower Tt				2				2													1				2	
296.93	296.95	32/3/83-85	lower Tt				5																	1				5	
297.33	297.35	32/3/123-125	lower Tt				1	1																				3	
297.70	297.72	32/4/10-12	lower Tt																					2				2	
298.08	298.10	32/4/48-50	lower Tt		5		3																					13	
298.52	298.54	32/4/92-94	lower Tt		11		2																					5	
298.93	298.95	32/4/133-135	lower Tt		1		3																	1				6	
299.38	299.40	32/5/28-30	lower Tt		2		7																					16	
299.67	299.69	32CC/2-4	lower Tt		5		4									1							3	27				17	
302.71	302.73	33/1/1-3	lower Tt				2	1								1	0											13	
302.97	302.99	33/1/27-29	lower Tt		1		2										1	2										14	
303.29	303.31	33/1/59-61	lower Tt		3		2	3									1											9	
303.77	303.79	33/1/107-109	lower Tt				1	2											2	5					1			10	
304.13	304.15	33/1/143-145	lower Tt																1	1								17	
304.29	304.31	33/2/9-11	lower Tt		4		2											1		1								9	
304.47	304.49	33/2/27-29	lower Tt		1		3								1				2									18	
304.66	304.68	33/2/46-48	lower Tt		4		1												1	2								12	
305.02	305.04	33/2/82-84	lower Tt				1										1	1	1									12	
305.15	305.17	33/2/95-97	lower Tt		1												2	1										5	
305.34	305.36	33/2/114-116	lower Tt		1														1	3								14	
305.55	305.57	33/2/135-137	lower Tt		2														1	2								13	
305.71	305.73	33/3/1-3	lower Tt		15																							8	
305.93	305.95	33/3/23-25	lower Tt		32	3	3																					12	
306.11	306.13	33/3/41-43	lower Tt		38														2	1								10	
306.27	306.29	33/3/57-59	lower Tt		35	2	1																					23	
306.54	306.56	33/3/84-86	lower Tt		6																							21	
306.75	306.77	33/3/105-107	lower Tt		6	1	1																					17	
306.86	306.88	33/3/116-118	lower Tt		4																				1			12	
307.08	307.10	33/3/138-140	lower Tt		17																							21	
307.30	307.32	33/4/10-12	lower Tt		1													1		1								40	
307.49	307.51	33/4/29-31	lower Tt		7		1																					16	

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Hirsutella margaritae* sin	*Hirsutella panda* dex	*Hirsutella panda* sin	*Hirsutella scitula* dex	*Hirsutella scitula* sin	*Hirsutella sp.* dex	*Hirsutella sp.* sin	*Menardella* cf. *limbata* dex	*Menardella* cf. *limbata* sin	*Menardella* cf. *limbata?* dex	*Menardella* cf. *limbata?* sin	*Neogloboquadrina dutertrei* dex	*Neogloboquadrina dutertrei* sin	*Neogloboquadrina mayeri continuosa* dex	*Neogloboquadrina mayeri continuosa* sin	*Neogloboquadrina mayeri mayeri* dex	*Neogloboquadrina mayeri mayeri* sin	*Neogloboquadrina mayeri nympha* dex	*Neogloboquadrina mayeri nympha* sin	*Neogloboquadrina pachyderma* dex	*Neogloboquadrina pachyderma* sin	*Orbulina bilobata*	*Orbulina bilobata?*	*Orbulina universa*	*Orbulina universa* "juvenile"	*Sphaeroidinellopsis disjuncta?*
307.70	307.72	33/4/50-52	lower Tt		8	2													1									19	
307.93	307.95	33/4/73-75	lower Tt		47	2													1	2								13	
308.14	308.16	33/4/94-96	lower Tt		76	3	1													1								6	
308.30	308.32	33/4/110-112	lower Tt		86	2		2										1										18	
308.53	308.55	33/4/133-135	lower Tt		81	3																						19	
308.71	308.73	33/5/1-3	lower Tt		35	2	3	1																			6	20	
308.99	309.01	33/5/29-31	lower Tt		44	2											1	1		1								18	
309.11	309.13	33/5/41-43	lower Tt		55	2		1											1									12	
309.28	309.30	33/5/58-60	lower Tt		4	2											1	3		2								10	
309.54	309.56	33/5/84-86	lower Tt				1											8		6	1	4			1			13	
309.74	309.76	33/5/104-106	lower Tt														2	14		6	1							22	
312.31	312.33	34/1/1-3	lower Tt		2		2	1									1	16	1	3					1			20	
312.54	312.56	34/1/24-26	lower Tt					1										4	1	8	1							23	
312.67	312.69	34/1/37-39	lower Tt															7	2	5		3						25	
312.87	312.89	34/1/57-59	lower Tt														1	5	2	5		4						17	
313.07	313.09	34/1/77-79	lower Tt		1		1	1										4	1	4		1						20	
313.31	313.33	34/1/101-103	lower Tt														1	10	2	6		4						14	
313.53	313.55	34/1/123-125	lower Tt				1										2	17	2	7		2						30	
313.71	313.73	34/1/141-143	lower Tt		2		1										2	22	1	12		4						29	
313.90	313.92	34/2/10-12	lower Tt		1		2										3	19	2	20	1	10						17	
314.09	314.11	34/2/29-31	lower Tt				1										1	28	1	16	2	5						22	
314.29	314.31	34/2/49-51	lower Tt		6		1										2	23	1	9	3	7						19	
314.45	314.47	34/2/65-67	lower Tt			1	3										13	101	5	62	3	32						13	
314.69	314.71	34/2/89-91	lower Tt		3												5	86	3	40	2	17						9	
314.90	314.92	34/2/110-112	lower Tt		1												7	44	1	13	1	6						12	
315.13	315.15	34/2/133-135	lower Tt		18												6	61	3	24	2	19						10	
315.30	315.32	34/3/0-2	upper Sw		1	2	1										1	20		6		2						6	
315.52	315.54	34/3/22-24	upper Sw		2	1		1										12	1	10		12			1			16	
315.71	315.73	34/3/41-43	upper Sw		1		1	1									1	16	2	8		2						14	
316.06	316.08	34/3/76-78	upper Sw		2												4	29	3	9	2	4			1			13	
316.27	316.29	34/3/97-99	upper Sw														12	76	1	26		17						26	
316.48	316.50	34/3/118-120	upper Sw														5	48	2	13	1	2						11	
316.67	316.69	34/3/137-139	upper Sw														3	41	4	18	1	6						12	
317.10	317.12	34/4/30-32	upper Sw														1	48	2	25	3	3					1	12	
317.50	317.52	34/4/70-72	upper Sw														9	35	1	13	2	11						8	
317.90	317.92	34/4/110-112	upper Sw		1												4	36	2	20	1	8						4	
318.35	318.37	34/5/5-7	upper Sw		3												5	43	1	29	3	12						18	
318.60	318.62	34/5/30-32	upper Sw		1												9	63	4	25	1	6						28	
321.91	321.93	35/1/1-3	upper Sw		1												3	50	1	33	1	4			1			19	
322.33	322.35	35/1/43-45	upper Sw														8	49	2	33	1	11						30	
322.72	322.74	35/1/82-84	upper Sw														9	37	2	9	1	8			2			12	
323.09	323.11	35/1/119-121	upper Sw														4	38	3	15	3	6						21	
323.48	323.50	35/2/8-10	upper Sw					1									4	60	3	16		8						29	
323.91	323.93	35/2/51-53	upper Sw														30	239	8	66	2	83						20	
324.50	324.52	35/2/110-112	upper Sw														14	100	3	20	3	15						13	
324.91	324.93	35/3/1-3	upper Sw														6	69		17	6	9						4	
325.33	325.35	35/3/43-45	upper Sw														23	117	7	40	5	27						11	
325.71	325.73	35/3/81-83	upper Sw														22	113	9	50	3	25						9	
325.94	325.96	35/3/104-106	upper Sw		1												24	169	15	85	4	17						19	
326.28	326.30	35/3/138-140	upper Sw		1												9	52	5	26	1	13						3	
326.70	326.72	35/4/30-32	upper Sw		2												13	55	5	21	1	5						2	
327.09	327.11	35/4/69-71	upper Sw		7	1		1									5	15	1	9	2	5						7	
327.50	327.52	35/4/110-112	upper Sw		20	2											10	40	24	120	1	23						10	
327.91	327.93	35/5/1-3	upper Sw		4	1											5	61		36	1	9						9	
328.27	328.29	35/5/37-39	upper Sw														24	215	8	34	2	25						27	
328.72	328.74	35/5/82-84	upper Sw														34	299	15	129	4	36						14	
331.69	331.71	36/1/19-21	upper Sw			1											30	166	3	44	6	18						11	
332.11	332.13	36/1/61-63	upper Sw														8	47	1	19		9					1	19	
332.68	332.70	36/1/118-120	upper Sw			1				3							5	34	5	23		1			1		2	8	
332.98	333.00	36/1/148-150	upper Sw							1								41	5	42	4	18						8	
333.40	333.42	36/2/40-42	upper Sw			1											37	148	14	57	9	30						2	
334.00	334.02	36/2/100-102	upper Sw				1										15	83	8	48	4	18						7	
334.36	334.38	36/2/136-138	upper Sw		1												14	121	8	40	3	16					1	9	
334.87	334.89	36/3/37-39	upper Sw				2										4	15		18								8	
335.47	335.49	36/3/97-99	upper Sw														4	16	2	4							1	16	
335.88	335.90	36/3/138-140	upper Sw		1												1	22	5	13								22	
336.20	336.22	36/4/20-22	upper Sw					4									4	18	2	11		1						13	
336.60	336.62	36/4/60-62	upper Sw														3	16	2	15		4						27	

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Sphaeroidinellopsis paenedehiscens*	*Sphaeroidinellopsis seminulina*	*Sphaeroidinellopsis sp.?*	*Truncorotalia* aff. *crassaconica* dex	*Truncorotalia* aff. *crassaconica* sin	*Truncorotalia* cf. *crassaformis* sin	*Truncorotalia crassaformis* sin	*Truncorotalia juanai* dex	*Truncorotalia juanai* sin	*Truncorotalia juanai?* dex	*Truncorotalia juanai?* sin	*Truncorotalia neojuanai* dex	*Truncorotalia neojuanai* sin	*Truncorotalila neojuanai?* dex	*Truncorotalia neojuanai?* sin	*Zeaglobigerina nepenthes*	*Zeaglobigerina nepenthes?*	*Zeaglobigerina* sp.	*Zeaglobigerina woodi apertura*	*Zeaglobigerina woodi apertura?*	*Zeaglobigerina woodi decoraperta*	*Zeaglobigerina woodi decoraperta?*	*Zeaglobigerina woodi woodi*	*Zeaglobigerina woodi woodi?*	Misc: unidentified planktics
120.30	120.33	14/1/0-3	lower Wo							1									1		75					10		
120.51	120.54	14/1/21-24	lower Wo																		109					9		
120.69	120.72	14/1/39-42	lower Wo											1						1	96					6		
120.90	120.93	14/1/60-63	lower Wo																		90	1				9		
121.11	121.14	14/1/81-84	lower Wo					1													76					9		
121.26	121.29	14/1/96-99	lower Wo					1													97				1	23		
121.49	121.52	14/1/119-122	lower Wo					1													67					15		
121.69	121.72	14/1/139-142	lower Wo							2											111					28		
121.90	121.93	14/2/10-13	lower Wo				1			3			1	2							90					10		
122.09	122.12	14/2/29-32	lower Wo							3	1			4							74					8		
122.26	122.29	14/2/46-49	lower Wo					5													77				1	9		
122.51	122.55	14/2/71-75	lower Wo					1				6									93					7		
122.71	122.74	14/2/91-94	lower Wo					1			2	26									142					15		
122.92	122.95	14/2/112-115	lower Wo					1				24									117			2		8		
123.10	123.13	14/2/130-133	upper Tk					2				6								2	118	1				21		
123.30	123.33	14/3/0-3	upper Tk									8									79	1				12		
123.53	123.56	14/3/23-26	upper Tk					2				50									128	1				14		
123.69	123.72	14/3/39-42	upper Tk									20									106					21		
123.88	123.91	14/3/58-61	upper Tk						1		1	3									71	2				16		
124.11	124.14	14/3/81-84	upper Tk									1									101	2				13		
124.30	124.33	14/3/100-103	upper Tk						1										1		125					33		
124.50	124.53	14/3/120-123	upper Tk						2			1									86			1		15		
124.68	124.71	14/3/138-141	upper Tk								1	5									96	1			2	7		
124.90	124.93	14/4/10-13	upper Tk					2	1			12				3					121					10		
125.10	125.13	14/4/30-33	upper Tk				1				1	32				7					118					4		
125.30	125.33	14/4/50-53	upper Tk					1	1		4	56				4					150		1		2	13		
125.48	125.51	14/4/68-71	upper Tk								1	58			1						171					8		
125.71	125.74	14/4/91-94	upper Tk								2	30				1			1		103					4		
125.91	125.94	14/4/111-114	upper Tk								1	70				11					211					8		
126.10	126.13	14/4/130-133	upper Tk					2	2	1	2	44				4					93				1			
126.30	126.33	14/5/0-3	upper Tk									34				3			1		84							
126.56	126.59	14/5/26-29	upper Tk				1				1	52				3					114					1		
126.70	126.73	14/5/40-43	upper Tk					2				41				3					74					6		
126.90	126.93	14/5/60-63	upper Tk					4				40			1	9			1		121	1			3	10		
127.12	127.15	14/5/82-85	upper Tk							1		49				8					140	1				10		
127.30	127.33	14/5/100-103	upper Tk								2	48				5					131					3		
127.51	127.54	14/5/121-124	upper Tk								1	38				6					114				1	5		
127.70	127.73	14/5/140-143	upper Tk								3	24				4			2		127					17		
127.90	127.93	14/6/10-13	upper Tk									34				11			1	2	145				1	10		
128.29	128.32	14/6/49-52	upper Tk									36			3	6					133				2	8		
128.72	128.75	14/6/92-95	upper Tk								2	31						3			103					2		
129.10	129.13	14/6/130-133	upper Tk							1	1	29				8					104					1		
129.50	129.53	14/7/20-23	upper Tk								3	31									162					14		
129.90	129.93	15/1/0-3	upper Tk								1	29				6					107					2		
130.29	130.32	15/1/39-42	upper Tk								1	45				21					154					6		
130.69	130.72	15/1/79-82	upper Tk								1	43				14					181					11		
131.10	131.13	15/1/120-123	upper Tk								1	37				10					158					12		
131.51	131.54	15/2/11-14	upper Tk								2	42			1	4				1	172					9		
131.91	131.93	15/2/51-53	upper Tk									20				6			1		171					10		
132.33	132.36	15/2/93-96	upper Tk									68			1	9					175					1		
132.74	132.76	15/2/134-136	upper Tk									14				4				1	142					2		
133.07	133.10	15/3/17-20	upper Tk									29			1	6			2		140					13		
133.46	133.49	15/3/56-59	upper Tk								1	42				9			4		195					33		
133.89	133.92	15/3/99-102	upper Tk						2		2	29				7				1	124					10		
134.30	134.33	15/3/140-143	upper Tk								2	40			1	25			1		130					11		
134.70	134.73	15/4/30-33	upper Tk								3	20				13					151					10		
135.10	135.13	15/4/70-73	upper Tk					1				4				2					102					7		
135.30	135.33	15/4/90-93	upper Tk					5			1	29				4				1	104					11		
135.50	135.53	15/4/110-113	upper Tk									8				5				1	90		1			6		
135.70	135.73	15/4/130-133	upper Tk									11				1					151					12		
135.90	135.93	15/5/0-3	upper Tk								1	11				8					132		1			13		
136.06	136.09	15/5/16-19	upper Tk									15			1	2					104					16		
136.32	136.35	15/5/42-45	upper Tk								1	19			1	3			1		122					11		
136.51	136.53	15/5/61-63	upper Tk									10				2				1	164			2		14		
136.92	136.95	15/5/102-105	upper Tk								1	24			1	6			1		112					1		
137.13	137.16	15/5/123-126	upper Tk								3	33				8					108							
137.52	137.55	15/6/12-15	upper Tk								1	40				20					129					3		
137.91	137.94	15/6/51-54	upper Tk									32			1	15					136				1	3		
138.27	138.30	15/6/87-90	upper Tk								2	26				10					129					3		
138.66	138.69	15/6/126-129	upper Tk									30			1	3					152	1				3		
139.07	139.10	15/7/17-20	upper Tk								1	30				7					164		1			14		
139.50	139.53	16/1/0-3	upper Tk								2	8				3					115					3		

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Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Sphaeroidinellopsis paenedehiscens*	*Sphaeroidinellopsis seminulina*	*Sphaeroidinellopsis sp.?*	*Truncorotalia* aff. *crassaconica* dex	*Truncorotalia* aff. *crassaconica* sin	*Truncorotalia* cf. *crassaformis* sin	*Truncorotalia crassaformis* sin	*Truncorotalia juanai* dex	*Truncorotalia juanai* sin	*Truncorotalia juanai?* dex	*Truncorotalia juanai?* sin	*Truncorotalia neojuanai* dex	*Truncorotalia neojuanai* sin	*Truncorotalila neojuanai?* dex	*Truncorotalia neojuanai?* sin	*Zeaglobigerina nepenthes*	*Zeaglobigerina nepenthes?*	*Zeaglobigerina* sp.	*Zeaglobigerina woodi apertura*	*Zeaglobigerina woodi apertura?*	*Zeaglobigerina woodi decoraperta*	*Zeaglobigerina woodi decoraperta?*	*Zeaglobigerina woodi woodi*	*Zeaglobigerina woodi woodi?*	Misc: unidentified planktics
139.93	139.96	16/1/43-46	upper Tk								5	36				8					166							
140.34	140.37	16/1/84-87	upper Tk								2	35				2					98					1		
140.73	140.76	16/1/123-126	upper Tk								2	45			1	23					158					1		
141.13	141.15	16/2/13-16	upper Tk								2	7				10					74							
141.54	141.57	16/2/54-57	upper Tk									20				2					91					3		
141.92	141.95	16/2/92-95	upper Tk								2	19									56							
142.32	142.35	16/2/132-135	upper Tk								1	23				1					116					1		
142.75	142.78	16/3/25-28	upper Tk									10				2					154							
143.15	143.18	16/3/65-68	upper Tk								1	19				5					165							
143.53	143.56	16/3/103-106	upper Tk								1	22				8					191					4		
143.84	143.87	16/3/134-137	lower Tk								1	37				1				1	156					4		
144.26	144.29	16/4/26-29	lower Tk								3	29									123					7		
144.67	144.70	16/4/67-70	lower Tk									7				1					55							
145.13	145.16	16/4/113-116	lower Tk								2	28								2	151					20		
145.50	145.53	16/5/0-3	lower Tk									1				1				1	181					3		
145.93	145.96	16/5/43-46	lower Tk								2	5									117					1		
146.36	146.38	16/5/86-88	lower Tk									1							1		145				1			
146.71	146.74	16/5/121-124	lower Tk																		172	1				2		
147.06	147.09	16/6/6-9	lower Tk																		118							
147.47	147.50	16/6/47-50	lower Tk									6									149				1	30		
147.93	147.96	16/6/93-96	lower Tk									24							1		124				1	18		
148.33	148.36	16/6/133-136	lower Tk									2									235					20		
148.67	148.69	16/7/17-19	lower Tk																		172					22		
149.10	149.13	17/1/0-3	lower Tk																		167				1	3		
149.52	149.55	17/1/42-45	lower Tk																		176					3		
150.11	150.14	17/1/101-104	lower Tk																		145					1		
150.51	150.54	17/1/141-144	lower Tk																		134				1			
150.87	150.90	17/2/27-30	lower Tk																1		148				1	1		
151.07	151.10	17/2/47-50	lower Tk																		154					6		
151.52	151.55	17/2/92-95	lower Tk																	2	263				1	8		
151.96	151.98	17/2/136-138	lower Tk																		143							
152.10	152.13	17/3/0-3	lower Tk																		186					3		
152.25	152.28	17/3/15-18	lower Tk																		180				2	9		
152.47	152.50	17/3/37-40	lower Tk																3		120			3		30		
152.75	152.77	17/3/65-67	lower Tk																		155					14		
152.91	152.94	17/3/81-84	lower Tk																		145				1	3		
153.12	153.15	17/3/102-105	lower Tk																		132					7		
153.26	153.29	17/3/116-119	lower Tk																		185					9		
153.45	153.48	17/3/135-138	lower Tk																		187				1	26		
153.66	153.69	17/4/6-9	lower Tk																		129					11		
153.97	153.99	17/4/37-39	lower Tk																		206					20		
154.13	154.16	17/4/53-56	lower Tk																		203					13		
154.32	154.35	17/4/72-75	lower Tk																		224	2				28		
154.54	154.57	17/4/94-97	lower Tk																		292	2				26		
154.77	154.79	17/4/117-119	lower Tk																		166					45		
154.95	154.98	17/4/135-138	lower Tk																		201				3	37		
155.10	155.13	17/5/0-3	lower Tk		1															1	197	2			1	47		
155.24	155.27	17/5/14-17	lower Tk																		166		1			34		
155.48	155.50	17/5/38-40	lower Tk																		182				2	82		
155.67	155.70	17/5/57-60	lower Tk																		103		1		1	11		
155.94	155.97	17/5/84-87	lower Tk																		211	1				49		
156.13	156.16	17/5/103-106	lower Tk																1		123					33		
156.27	156.30	17/5/117-120	lower Tk																		201					18		
156.47	156.50	17/5/137-140	lower Tk											1							176					22		
156.71	156.74	17/6/11-14	lower Tk																		150					22		
156.95	156.98	17/6/35-38	lower Tk																	1	154					22		
157.12	157.15	17/6/52-55	lower Tk											1							163	2				47		
157.37	157.39	17/6/77-79	lower Tk																		137					10		
157.52	157.55	17/6/92-95	lower Tk																		127				2	16		
157.76	157.79	17/6/116-119	lower Tk											1						1	199					14		
157.93	157.96	17/6/133-136	lower Tk																		290	1			4	50		
158.10	153.13	17/7/0-3	lower Tk											2							260					35		
158.27	158.30	17/7/17-20	lower Tk																		229					15		
158.52	158.55	17CC/6-9	lower Tk																		148	1				28		
158.70	158.73	18/1/0-3	lower Tk																	1	183				1	32		
158.95	158.98	18/1/25-28	lower Tk																		159				1	14		
159.13	159.16	18/1/43-46	lower Tk																		139					9		
159.35	159.38	18/1/65-68	lower Tk																	1	202					22		
159.49	159.52	18/1/79-82	lower Tk																		237	1				73		
159.72	159.75	18/1/102-105	lower Tk																		179					40		
159.86	159.89	18/1/116-119	lower Tk																1		135	2				12		
160.11	160.14	18/1/141-144	lower Tk																		136					9		

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Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Sphaeroidinellopsis paenedehiscens*	*Sphaeroidinellopsis seminulina*	*Sphaeroidinellopsis sp.?*	*Truncorotalia* aff. *crassaconica* dex	*Truncorotalia* aff. *crassaconica* sin	*Truncorotalia* cf. *crassaformis* sin	*Truncorotalia crassaformis* sin	*Truncorotalia juanai* dex	*Truncorotalia juanai* sin	*Truncorotalia juanai?* dex	*Truncorotalia juanai?* sin	*Truncorotalia neojuanai* dex	*Truncorotalia neojuanai* sin	*Truncorotalia neojuanai?* dex	*Truncorotalia neojuanai?* sin	*Zeaglobigerina nepenthes*	*Zeaglobigerina nepenthes?*	*Zeaglobigerina* sp.	*Zeaglobigerina woodi apertura*	*Zeaglobigerina woodi apertura?*	*Zeaglobigerina woodi decoraperta*	*Zeaglobigerina woodi decoraperta?*	*Zeaglobigerina woodi woodi*	*Zeaglobigerina woodi woodi?*	Misc: unidentified planktics
160.33	160.36	18/2/13-16	lower Tk																		222	3			2	48		
160.73	160.76	18/2/53-56	lower Tk																		106	5				40		
161.16	161.19	18/2/96-99	lower Tk																		190				2	13		
161.53	161.56	18/2/133-136	lower Tk																		216	1		1	2	44		
161.84	161.87	18/3/14-17	lower Tk																		125	2				29		
162.26	162.29	18/3/56-59	lower Tk																		159	2				27		
162.87	162.90	18/3/117-120	lower Tk																		126					14		
163.33	163.36	18/4/13-16	lower Tk																		95					18		
163.56	163.59	18/4/36-39	lower Tk																		219				2	50		
163.93	163.96	18/4/73-76	lower Tk																		93			1	1	9		
164.31	164.33	18/4/111-113	lower Tk																	1	80					29		
164.70	164.73	18/5/0-3	lower Tk																		115	3		2		45		
165.13	165.16	18/5/43-46	lower Tk																		188	2		1	2	32		
165.50	165.53	18/5/80-83	lower Tk			1													3		138	3			5	106		
165.95	165.97	18/5/125-127	lower Tk																		133	2				35		
166.26	166.29	18/6/6-9	lower Tk																	1	115	5			5	43		
166.66	166.69	18/6/46-49	lower Tk																		141		1			36		
167.06	167.09	18/6/86-89	lower Tk																		144	2				75		
167.44	167.47	18/6/124-127	upper Tt																	4	195	3				77		
168.30	168.33	19/1/0-3	upper Tt																		100	1			1	55		
168.71	168.74	19/1/41-44	upper Tt																		155	3		2		80		
169.13	169.15	19/1/83-85	upper Tt																2		125	1			2	57		
169.51	169.54	19/1/121-124	upper Tt																		126	6		1	1	103		
169.85	169.88	19/2/5-8	upper Tt																	1	108	4			1	64		
170.32	170.35	19/2/52-55	upper Tt																		117	1				41		
170.73	170.76	19/2/93-96	upper Tt																1		109				3	69		
171.15	171.18	19/2/135-138	upper Tt																		89					58		
171.57	171.59	19/3/27-29	upper Tt																	6	100	2			5	76		
171.92	171.94	19/3/62-64	upper Tt																		89	1				32		
172.32	172.35	19/3/102-105	upper Tt																	1	128	2				71		
172.66	172.68	19/3/136-138	upper Tt															1			60		1			19		
173.07	173.09	19/4/27-29	upper Tt									1								1	99					27		
173.52	173.54	19/4/72-74	upper Tt																	1	47	2			1	26		
173.93	173.95	19/4/113-115	upper Tt									2				1					97	1				13		
174.30	174.33	19/5/0-3	upper Tt																	2	64	2		3		21		
174.72	174.75	19/5/42-45	upper Tt																		62	1				51		
175.26	175.28	19/5/96-99	upper Tt									3							1		96					45		
175.71	175.74	19/5/141-144	upper Tt									5									67				1	30		
176.06	176.09	19/6/26-29	upper Tt																		93	2		2		34		
176.47	176.49	19/6/67-69	upper Tt																	1	159					22		
176.92	176.94	19/6/112-114	upper Tt																	1	97	2		1		14		
177.30	177.33	19/7/0-3	upper Tt																	1	98			1	2	19		
177.52	177.55	19/7/22-25	upper Tt																23		272				7	142		
177.90	177.93	20/1/0-3	upper Tt																		106					6		
178.27	178.30	20/1/37-40	upper Tt																		121				1	11		
178.68	178.70	20/1/78-80	upper Tt																		85					7		
179.08	179.10	20/1/118-120	upper Tt																		106	1				22		
179.45	179.47	20/2/5-7	upper Tt																	2	125				4	68		
179.86	179.88	20/2/46-48	upper Tt																	1	101	4				56		
180.33	180.35	20/2/93-95	upper Tt																		96	1				24		
180.73	180.75	20/2/133-135	upper Tt																		59	3			1	67		
181.14	181.16	20/3/24-26	upper Tt																		40	3				54		
181.57	181.59	20/3/67-69	upper Tt								1	3									66	1				66		
181.86	181.88	20/3/96-98	upper Tt									1									78	2				71		
182.23	182.25	20/3/133-135	upper Tt	1																	51	2				47		
182.68	182.70	20/4/28-30	upper Tt																		58	1				43		
183.08	183.10	20/4/68-70	upper Tt																		63					55		
183.45	183.47	20/4/105-107	upper Tt																		116					117		
183.91	183.93	20/5/1-3	upper Tt															1			98					59		
184.32	184.34	20/5/42-44	upper Tt									1						4		1	119	1		1		43		
184.72	184.74	20/5/82-84	upper Tt									1						2			80					34		
185.07	185.09	20/5/117-119	upper Tt								1	3						1		1	112	2			2	41		
185.47	185.49	20/6/7-9	upper Tt									11									121				3	53		
185.92	185.94	20/6/52-54	upper Tt								4	31						4			61	3				44		
186.32	186.34	20/6/92-94	upper Tt									37						1	1		80				3	50		
186.72	186.74	20/6/132-134	upper Tt								1	12						3			112		1		1	46		
187.07	187.09	20/7/17-19	upper Tt								2	6						1		1	168				1	55		
187.51	187.53	21/1/1-3	upper Tt									58									138				3	85		
187.93	187.95	21/1/43-45	upper Tt								5	48									180					78		
188.32	188.34	21/182-84	upper Tt									19									114	1		2		36		
188.67	188.69	21/1/117-119	upper Tt								2	18									136	1				54		
189.08	189.10	21/2/8-10	upper Tt								2	17									84				1	42		

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Sphaeroidinellopsis paenedehiscens*	*Sphaeroidinellopsis seminulina*	*Sphaeroidinellopsis sp.?*	*Truncorotalia* aff. *crassaconica* dex	*Truncorotalia* aff. *crassaconica* sin	*Truncorotalia* cf. *crassaformis* sin	*Truncorotalia crassaformis* sin	*Truncorotalia juanai* dex	*Truncorotalia juanai* sin	*Truncorotalia juanai?* dex	*Truncorotalia juanai?* sin	*Truncorotalia neojuanai* dex	*Truncorotalia neojuanai* sin	*Truncorotalia neojuanai?* dex	*Truncorotalia neojuanai?* sin	*Zeaglobigerina nepenthes*	*Zeaglobigerina nepenthes?*	*Zeaglobigerina* sp.	*Zeaglobigerina woodi apertura*	*Zeaglobigerina woodi apertura?*	*Zeaglobigerina woodi decoraperta*	*Zeaglobigerina woodi decoraperta?*	*Zeaglobigerina woodi woodi*	*Zeaglobigerina woodi woodi?*	Misc: unidentified planktics
189.46	189.48	21/2/46-48	upper Tt								2	9									115	2				81		
189.93	189.96	21/2/93-96	upper Tt									17									147	1				80		
190.42	190.44	21/2/142-144	upper Tt								2	25									114	1			1	69		
190.66	190.68	21/3/16-18	upper Tt								1	9								1	123	1				60		
191.12	191.14	21/3/62-64	upper Tt								1	14									106		1	1		60		
191.52	191.54	21/3/102-104	upper Tt								1	89									138			1		76		
191.86	191.89	21/3/136-139	upper Tt								2	8									90				1	34		
192.36	192.38	21/4/36-38	upper Tt								1	8									181					58		
192.73	193.75	21/4/73-75	upper Tt								1	22									126	1			1	91		
193.12	193.14	21/4/112-114	upper Tt	1							1	11						1			107	2			1	66		
193.50	193.52	21/5/0-2	upper Tt									8									167					147		
193.92	193.94	21/5/42-44	upper Tt															1		1	114	4				94		
194.34	194.26	21/5/84-86	upper Tt									1									84				2	66		
194.72	194.74	21/5/122-124	upper Tt															8	1		212	1			1	61		
195.07	195.09	21/6/7-9	upper Tt															1			163	2				83		
195.49	195.51	21/6/49-51	upper Tt									2								3	159					102		
195.87	195.89	21/6/87-89	upper Tt																	2	237				1	82		
196.34	196.36	21/6/134-136	upper Tt																		99				1	44		
196.72	196.74	21/7/22-24	upper Tt																		134					36		
197.11	197.13	22/1/1-3	upper Tt																		126					82		
197.48	197.50	22/1/38-40	upper Tt																3		236	4				119		
197.94	197.96	22/1/84-86	upper Tt														1				180				3	61		
198.32	198.34	22/1/122-124	upper Tt														1				158					82		
198.73	198.75	22/2/13-15	upper Tt																		115	1				50		
199.14	199.16	22/2/54-56	upper Tt																		191	3				83		
199.53	199.55	22/2/93-95	upper Tt																		156					148		
199.93	199.95	22/2/133-135	upper Tt																		104	1				57		
200.25	200.27	22/3/15-17	upper Tt																		164	2				86		
200.66	200.68	22/3/56-58	upper Tt									1									99	3			1	53		
201.05	201.07	22/3/95-97	upper Tt																		136					46		
201.42	201.44	22/3/132-134	upper Tt															1			199	3				121		
201.93	201.95	22/4/33-35	upper Tt			1														3	157	1				47		
202.52	202.55	22/4/92-95	upper Tt																		218	3				65		
202.93	202.95	22/4/133-135	upper Tt																	1	175	3				61		
203.17	203.20	22CC/7-10	upper Tt	1																2	236	1				95		
206.71	206.73	23/1/1-3	upper Tt																		326	3				129		
207.13	207.15	23/1/43-45	upper Tt																1		229					46		
207.48	207.50	23/1/78-80	upper Tt																		170	2				27		
207.88	207.90	23/1/118-120	upper Tt																		238				1	38		
208.26	208.28	23/2/6-8	upper Tt																	2	277					33		
208.52	208.54	23/2/32-34	upper Tt																3		365	11				171		
209.06	209.08	23/2/86-88	upper Tt																1		232	2				61		
209.54	209.56	23/2/134-136	upper Tt																		218	1			1	48		
209.85	209.87	23/3/15-17	upper Tt																		207					50		
210.33	210.35	23/3/63-65	upper Tt																		205	1			1	36		
210.53	210.55	23/3/83-85	upper Tt																		304	3		2		60		
210.87	210.89	23/3/117-119	upper Tt																		291					13		
211.27	211.29	23/4/7-9	upper Tt																		187					19		
211.72	211.74	23/4/52-54	upper Tt																1		247	3			1	52		
212.13	212.15	23/4/93-95	upper Tt																1		177	3				52		
212.32	212.34	23/4/112-114	upper Tt																		240	6				115		
212.71	212.73	23/5/1-3	upper Tt																		236					29		
213.12	213.14	23/5/42-44	upper Tt																		282	2			1	87		
213.72	213.74	23/5/102-104	upper Tt																	2	147	2			3	46		
214.12	214.14	23/5/142-144	upper Tt																		207	1				49		
214.51	214.53	23/6/31-33	upper Tt																	2	248	3			1	166		
215.05	215.07	23/6/85-87	upper Tt																		140	1				14		
215.53	215.55	23/6/133-135	upper Tt																		181	2				33		
215.93	215.95	23/7/23-25	upper Tt																		167				2	28		
216.31	216.33	24/1/1-3	upper Tt																1		125	2			2	53		
216.57	216.59	24/1/27-29	upper Tt																1		250	16				213		
216.94	216.96	24/1/64-66	upper Tt																	2	150	2				44		
217.34	217.36	24/1/104-106	upper Tt																		134	4			1	41		
217.72	217.74	24/1/142-144	upper Tt																		140				1	52		
218.08	218.10	24/2/28-30	upper Tt																	1	170				2	33		
218.52	218.54	24/2/72-74	upper Tt																3		273	7		5		156		
218.87	218.89	24/2/107-109	upper Tt																3		237	4				32		
219.31	219.33	24/3/1-3	upper Tt																		194	20		3		82		
219.72	219.74	24/3/42-44	upper Tt																		151	2		2		41		
220.12	220.14	24/3/82-84	upper Tt																		178	5				65		
220.46	220.48	24/3/116-118	upper Tt																		223	12				76		
220.87	220.89	24/4/7-9	upper Tt																		122	6		5		54		

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Sphaeroidinellopsis paenedehiscens*	*Sphaeroidinellopsis seminulina*	*Sphaeroidinellopsis sp.?*	*Truncorotalia* aff. *crassaconica* dex	*Truncorotalia* aff. *crassaconica* sin	*Truncorotalia* cf. *crassaformis* sin	*Truncorotalia crassaformis* sin	*Truncorotalia juanai* dex	*Truncorotalia juanai* sin	*Truncorotalia juanai?* dex	*Truncorotalia juanai?* sin	*Truncorotalia neojuanai* dex	*Truncorotalia neojuanai* sin	*Truncorotalila neojuanai?* dex	*Truncorotalia neojuanai?* sin	*Zeaglobigerina nepenthes*	*Zeaglobigerina nepenthes?*	*Zeaglobigerina* sp.	*Zeaglobigerina woodi apertura*	*Zeaglobigerina woodi apertura?*	*Zeaglobigerina woodi decoraperta*	*Zeaglobigerina woodi decoraperta?*	*Zeaglobigerina woodi woodi*	*Zeaglobigerina woodi woodi?*	Misc: unidentified planktics
221.27	221.29	24/4/47-49	upper Tt																		194	14		1		81		
221.66	221.68	24/4/86-88	upper Tt																		196	10		1		64		
222.13	222.15	24/4/133-135	upper Tt																1		195	10		2		70		
222.45	222.47	24/5/15-17	upper Tt																		232	18		2		103		
222.93	222.95	24/5/63-65	upper Tt																		164	12		5		96		
223.33	223.35	24/5/103-105	upper Tt		1														4		136	11		2		64		
223.72	223.74	24/5/142-144	upper Tt																2		146	7		2		68		
224.07	224.09	24/6/27-29	upper Tt																4		99	16		2		55		
224.47	224.49	24/6/67-69	upper Tt																		198	27		3		98		
224.87	224.89	24/6/107-109	upper Tt									1									100	9				58		
225.36	225.38	24CC/9-11	upper Tt																1		100	9				84		
226.13	226.15	25/1/23-25	upper Tt																8		124	2		1		85		
226.53	226.55	25/1/63-65	upper Tt			2															234	28		12		136		
226.93	226.95	25/1/103-105	upper Tt																4		102	6		3		66		
227.34	227.36	25/1/144-146	upper Tt																6		108	16		4		95		1
227.72	227.74	25/2/-32-34	upper Tt																		87	10		6		76		
228.12	228.14	25/2/72-74	upper Tt																2		158	9		5		88		1
228.52	228.54	25/2/112-114	upper Tt																3		164	34		12		135		
228.90	228.92	25/3/0-2	upper Tt																1		99	13		6		55		
229.33	229.35	25/3/43-45	upper Tt																		129	19		7		128		
229.85	229.87	25/3/95-97	upper Tt																7		120	16		2		93		
230.27	230.29	25/3/137-139	upper Tt																6		58	16		1		98		
230.47	230.49	25/4/7-9	upper Tt																		198	15			3	138		
230.93	230.95	25/4/53-55	upper Tt																1		85	7				75		1
231.33	231.35	25/4/93-95	upper Tt																		136	18		4		84		
231.73	231.75	25/4/133-135	upper Tt																1		94	13		2		76		2
232.06	232.08	25/5/16-18	upper Tt																5		92	17		1		89		3
232.52	232.54	25/5/62-64	upper Tt														1	7		4	121	28			1	131		
232.92	232.94	25/5/102-104	upper Tt																1		84	9				54		
233.27	233.29	25/5137-139	upper Tt																15		118	4		2		35		
233.67	233.69	25/6/27-29	upper Tt											1						5	155	9		8		95		2
234.15	234.17	25/6/75-77	upper Tt																5		165	12				72		
234.52	234.54	25/6/112-114	upper Tt															6	3		186	15				59		
234.91	234.93	25/7/1-3	upper Tt																7		151	6		6		67		
235.26	235.28	25CC/10-22	upper Tt																3		109	5				71		
235.73	235.75	26/1/23-25	upper Tt																4		66	4		3		52		
236.08	236.10	26/1/58-60	upper Tt																12		107	8		1		63		
236.52	236.54	26/1/102-104	upper Tt															4	7		117	11		1		77		
236.92	236.94	26/1/142-144	upper Tt																5		75	3				40		
237.32	237.34	26/2/32-34	upper Tt																		144	5				65		
237.93	237.95	26/2/93-95	upper Tt																1		88	3		1		42		
238.33	238.35	26/2/133-135	upper Tt																		119	3		1		31		
238.51	238.53	26/3/1-3	upper Tt																2		188	9				81		
238.93	238.95	26/3/43-45	upper Tt																5		169	5				57		
239.32	239.34	26/3/82-84	upper Tt																3		138	8				71		
239.67	239.69	26/3/117-119	upper Tt																7		128	8				51		
240.07	240.09	26/4/7-9	upper Tt																2		123	3				56		1
240.52	240.54	26/4/52-54	upper Tt															10	4		166	22				180		
240.92	240.94	26/4/92-94	upper Tt																1		227	9				89		
241.32	241.34	26/4/132-134	upper Tt																		129	6				67		
241.65	241.67	26/5/15-17	upper Tt																4		137	4				61		
242.13	242.15	26/5/63-65	upper Tt																1		82	5				56		
242.52	242.54	26/5/102-104	upper Tt															1			79	14				58		
242.92	242.94	26/5/142-144	upper Tt																	7	107	5				45		
243.26	243.28	26/6/26-28	upper Tt																1		103	5				23		
243.63	243.65	26/6/63-65	upper Tt																		56	5				38		
243.86	243.88	26CC/13-15	upper Tt																		55	27				75		
245.11	245.13	27/1/1-3	upper Tt																1		88	15		2		76		
245.53	245.55	27/1/43-45	upper Tt																21		121	14				96		
245.91	245.93	27/1/81-83	upper Tt																13		86	3			1	46		
246.27	246.29	27/1/117-119	upper Tt																7		148	2		1		91		
246.52	246.54	27/1/142-144	upper Tt																		155	27			2	142		1
246.87	246.89	27/2/27-29	upper Tt																7		154	3		2		116		
247.33	247.35	27/2/73-76	upper Tt																8		122	3				39		
247.67	247.69	27/2/107-109	upper Tt																9		202	8		1		78		
248.11	248.13	27/3/1-3	upper Tt																3		120	4				57		
248.47	248.49	27/3/37-39	upper Tt																		154	20		1		160		
248.93	248.95	27/3/83-85	upper Tt																		103	1				35		
249.27	249.27	27/3/117-119	upper Tt																2		153	8				99		
249.67	249.69	27/4/7-9	upper Tt																4		178	10				94		2
250.12	250.14	27/4/52-54	upper Tt																2		162	3			1	78		
250.46	250.48	27/4/86-88	upper Tt																		71	15				93		

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Sphaeroidinellopsis paenedehiscens*	*Sphaeroidinellopsis seminulina*	*Sphaeroidinellopsis sp.?*	*Truncorotalia* aff. *crassaconica* dex	*Truncorotalia* aff. *crassaconica* sin	*Truncorotalia* cf. *crassaformis* sin	*Truncorotalia crassaformis* sin	*Truncorotalia juanai* dex	*Truncorotalia juanai* sin	*Truncorotalia juanai?* dex	*Truncorotalia juanai?* sin	*Truncorotalia neojuanai* dex	*Truncorotalia neojuanai* sin	*Truncorotalia neojuanai?* dex	*Truncorotalia neojuanai?* sin	*Zeaglobigerina nepenthes*	*Zeaglobigerina nepenthes?*	*Zeaglobigerina* sp.	*Zeaglobigerina woodi apertura*	*Zeaglobigerina woodi apertura?*	*Zeaglobigerina woodi decoraperta*	*Zeaglobigerina woodi decoraperta?*	*Zeaglobigerina woodi woodi*	*Zeaglobigerina woodi woodi?*	Misc: unidentified planktics
250.92	250.94	27/4/132-134	upper Tt																1		129	14				68		
251.33	251.36	27/5/23-26	upper Tt																1		137	6				42		
251.67	251.69	27/5/57-59	upper Tt																		84	1		1		57		
252.13	252.15	27/5/103-105	upper Tt																4		125	6				72		
252.53	252.55	27/5/143-145	upper Tt															2			95	30				85		
252.92	252.94	27/6/32-34	upper Tt																		108	8				67		
253.33	253.35	27/6/73-75	upper Tt																		51	3			1	35		
253.67	253.69	27/6/107-109	upper Tt																		127	20				80		
254.10	254.12	27/7/0-2	upper Tt																		121	7		2		72		
254.49	254.51	27CC/10-12	lower Tt															1			109	16		1		120		
254.93	254.95	28/4/23-25	lower Tt																3		113	3				76		
255.28	255.30	28/1/58-60	lower Tt																2		109	8			1	76		
255.73	255.75	28/1/103-105	lower Tt																3		83	4				47		
256.11	256.13	28/1/141-143	lower Tt																2		69	6				57		
256.53	256.55	28/2/33-35	lower Tt																		84	9		1		106		
257.03	257.05	28/2/83-85	lower Tt																6		108	3				48		
257.33	257.35	28/2/113-115	lower Tt																6		74	9				62		
257.71	257.73	28/3/1-3	lower Tt																8		96	8		2		53		
258.12	258.14	28/3/42-44	lower Tt																1		103	7		1		97		
258.54	258.56	28/3/84-86	lower Tt	1															4		74	6		1		39		
259.07	259.09	28/3/137-139	lower Tt																3		68	3		2		41		
259.53	259.55	28/4/33-35	lower Tt																1		99	4		2		72		
259.86	259.88	28/4/66-68	lower Tt																1		129	12		1		103		
260.28	260.30	28/4/108-110	lower Tt																2		115	8				65		
260.54	260.56	28/4/134-136	lower Tt																		74	21				144		
260.86	260.88	28/5/16-18	lower Tt																1		81	5				64		
261.31	261.33	28/5/61-63	lower Tt																		155	6		4		44		
261.72	261.74	28/5/102-104	lower Tt																		129	15		1		108		
262.11	262.13	28/5/141-143	lower Tt																1		100	9		2		73		
262.45	262.47	28CC/8-10	lower Tt																5		161	33		1		150		
264.30	264.32	29/1/0-2	lower Tt																6		82	3		3		44		
264.64	264.66	29/1/34-36	lower Tt																		88	21		3		97		
264.88	264.90	29/1/58-60	lower Tt																1		128	3		3		70		
265.26	265.28	29/1/96-98	lower Tt																		110	2		2		58		
265.72	265.74	29/1/142-144	lower Tt																		92	2		1		30		
266.12	266.14	29/2/32-34	lower Tt																		85			2		13		
266.44	266.46	29/2/64-66	lower Tt																		78	4				45		
266.87	266.89	29/2/107-109	lower Tt																		81			2		32		
267.31	267.33	29/3/1-3	lower Tt																		74					16		
267.53	267.55	29/3/23-25	lower Tt																		132	3				46		
267.72	267.74	29/3/42-44	lower Tt																		146	5				75		
267.87	267.89	29/3/57-59	lower Tt																		123	4		1		43		
268.14	268.16	29/3/84-86	lower Tt																1		109	2				57		
268.34	268.36	29/3/104-106	lower Tt																		95	6				48		
268.47	268.49	29/3/117-119	lower Tt																2		130	36				84	50	
268.68	268.70	29/3/138-140	lower Tt																1		84	2				32		
268.86	268.88	29/4/6-8	lower Tt																3		59	3				40		
269.28	269.30	29/4/48-50	lower Tt																6		43	5				59		
269.52	269.54	29/4/72-74	lower Tt																5		57	12		3		48		
269.75	269.77	29/4/95-97	lower Tt																4		67	9		1		66		
269.87	269.89	29/4/107-109	lower Tt																1		65	7		5		54		
270.15	270.17	29/4/135-137	lower Tt																8		110	13		1		55		
270.31	270.33	29/5/1-3	lower Tt																26		98	16		3		86		
270.45	270.47	29/5/15-17	lower Tt																6		66	8				51	18	
270.72	270.74	29/5/42-44	lower Tt																6		61	7		1		56		
270.91	270.93	29/5/61-63	lower Tt																16		112	3		1		35		
271.15	271.17	29/5/85-87	lower Tt																20		58	10		1		61		
271.34	271.36	29/5/104-106	lower Tt																4		76	4		6		47		
271.48	271.50	29/5/118-120	lower Tt																5		86	1		5		32		
271.72	271.74	29/5/142-144	lower Tt																1		62	7		1		61		
271.94	271.96	29/6/14-16	lower Tt																9		83	13		1		73		
272.19	272.21	29CC/17-19	lower Tt															1	45		136	28		3		86	32	
273.91	273.93	30/1/1-A7303	lower Tt																18		118	6		2		71		
274.04	274.06	30/1/14-16	lower Tt																2		53	11		1		58		
274.32	274.34	30/1/42-44	lower Tt																5		86	19		4		42		
274.48	274.50	30/1/58-60	lower Tt																5		46	12				71	22	
274.72	274.74	30/1/82-84	lower Tt																11		109	9		2		106		
274.93	274.95	30/1/103-105	lower Tt																2		99	12				60		
275.12	275.14	30/1/122-124	lower Tt																6		107	9		4		114		
275.31	275.33	30/1/141-143	lower Tt																1		153	11		2		97		
275.45	275.47	30/2/5-7	lower Tt																1		99	11		2		57		
275.93	275.95	30/2/53-55	lower Tt																8		100	11		3		100		

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Sphaeroidinellopsis paenedehiscens*	*Sphaeroidinellopsis seminulina*	*Sphaeroidinellopsis sp.?*	*Truncorotalia* aff. *crassaconica* dex	*Truncorotalia* aff. *crassaconica* sin	*Truncorotalia* cf. *crassaformis* sin	*Truncorotalia crassaformis* sin	*Truncorotalia juanai* dex	*Truncorotalia juanai* sin	*Truncorotalia juanai?* dex	*Truncorotalia juanai?* sin	*Truncorotalia neojuanai* dex	*Truncorotalia neojuanai* sin	*Truncorotalila neojuanai?* dex	*Truncorotalia neojuanai?* sin	*Zeaglobigerina nepenthes*	*Zeaglobigerina nepenthes?*	*Zeaglobigerina* sp.	*Zeaglobigerina woodi apertura*	*Zeaglobigerina woodi apertura?*	*Zeaglobigerina woodi decoraperta*	*Zeaglobigerina woodi decoraperta?*	*Zeaglobigerina woodi woodi*	*Zeaglobigerina woodi woodi?*	Misc: unidentified planktics
276.52	276.54	30/2/112-114	lower Tt																		138	48		5		204		
276.91	276.93	30/3/1-3	lower Tt																		109	6		1		91		
277.33	277.35	30/3/43-45	lower Tt																8		110	5		3		73		
277.74	277.76	30/3/84-86	lower Tt																5		103	7		4		72		
278.07	278.09	30/3/117-119	lower Tt																3		157	7		2		96		
278.49	278.51	30/4/9-11	lower Tt																11		101	42		3		165		
278.88	278.90	30/4/48-50	lower Tt																2		111	3		3		71		
279.33	279.35	30/4/93-95	lower Tt																		87	13		1		84		
279.75	279.77	30/4/135-137	lower Tt																		113	5		2		86		
280.05	280.07	30/5/15-17	lower Tt																4		150	12		9		143		
280.25	280.27	30/5/35-37	lower Tt																5		100	59		12		164		
280.92	280.94	30/5/102-104	lower Tt																2		88	11				58		
283.51	283.53	31/1/1-3	lower Tt																2		92	27		2		96		
283.94	283.96	31/1/44-46	lower Tt										1						1		123	2				83		
284.33	284.35	31/1/83-85	lower Tt																		128	4		1		87		
284.55	284.57	31/1/105-107	lower Tt																		70	27		1		78	98	
284.88	284.90	31/1/138-140	lower Tt																		123	15				114		
285.29	285.31	31/2/29-31	lower Tt																4		105	13		3		104		
285.73	285.75	31/2/73-75	lower Tt																		90	11		2		92		
286.10	286.12	31/2/110-112	lower Tt																1		117	9		6		105		
286.51	286.53	31/3/1-3	lower Tt																14		115	25		15		103	65	
286.88	286.90	31/3/38-40	lower Tt																		90	8		3		93		
287.32	287.34	31/3/82-84	lower Tt																		156	3		3		38		
287.67	287.69	31/3/117-119	lower Tt																1		211	10			5	34		
288.08	288.10	31/4/8-10	lower Tt																1		259	14		12		65		
288.55	288.57	31/4/55-57	lower Tt																12		150	29		4		160		
288.89	288.91	31/4/89-91	lower Tt																11		53	3		5		17		
289.34	289.36	31/4/134-136	lower Tt																3		137	8				94		
289.73	289.75	31/5/23-25	lower Tt																2		92	5				58		
290.12	290.14	31/5/62-64	lower Tt																		75	10		6		109		
290.51	290.53	31/5/101-103	lower Tt																1		100	37		2		134		
290.74	290.76	31CC/0-2	lower Tt																2		137	6		1		87		
293.11	293.13	32/1/1-3	lower Tt			1															89	8				90		
293.33	293.35	32/1/23-25	lower Tt																11		83	11		1		64		
293.71	293.73	32/1/61-63	lower Tt																1		93	8				59		
294.12	294.14	32/1/102-104	lower Tt																2		78	5		1		69		
294.51	294.53	32/1/141-143	lower Tt																1		189	33		3		209		
294.90	294.92	32/2/30-32	lower Tt																		112	7		1		115		
295.33	295.35	32/2/73-75	lower Tt																7		120	10		3		101		
295.73	295.75	32/2/113-115	lower Tt																		115	5				93		
295.93	295.95	32/2/133-135	lower Tt																		79	6				84		
296.50	296.52	32/3/40-42	lower Tt																3		80	12		1		127		
296.93	296.95	32/3/83-85	lower Tt																		79	9				77		
297.33	297.35	32/3/123-125	lower Tt																		51	1				51		
297.70	297.72	32/4/10-12	lower Tt																1		124	9				103		
298.08	298.10	32/4/48-50	lower Tt																4		91	8				95		
298.52	298.54	32/4/92-94	lower Tt																3		84	17			13	92		
298.93	298.95	32/4/133-135	lower Tt																		81	13		3		74		
299.38	299.40	32/5/28-30	lower Tt																22		106	7		4		95		
299.67	299.69	32CC/2-4	lower Tt																39		122	18		11		141		
302.71	302.73	33/1/1-3	lower Tt																21		90	11		4		95		
302.97	302.99	33/1/27-29	lower Tt																11		76	5		17		64		
303.29	303.31	33/1/59-61	lower Tt																8		79	5		30		60		
303.77	303.79	33/1/107-109	lower Tt																5		105	2		6		69		
304.13	304.15	33/1/143-145	lower Tt										1	5					5		84	1		7		44		
304.29	304.31	33/2/9-11	lower Tt										2	8							108	8		2		53		
304.47	304.49	33/2/27-29	lower Tt										1	19					19		157	10		8		116		
304.66	304.68	33/2/46-48	lower Tt										1	29					3		90	10				38		
305.02	305.04	33/2/82-84	lower Tt										1	33					2		107	4		9		55		
305.15	305.17	33/2/95-97	lower Tt										4	29					5		84			4		45		
305.34	305.36	33/2/114-116	lower Tt										1	8					8		81			7		47		
305.55	305.57	33/2/135-137	lower Tt										3	24					1		95	3		1		63		
305.71	305.73	33/3/1-3	lower Tt										1	6					4		74	4		2		35		
305.93	305.95	33/3/23-25	lower Tt										1	17					1		69	1				50		
306.11	306.13	33/3/41-43	lower Tt											6					3		74	5		7		58		
306.27	306.29	33/3/57-59	lower Tt											17					4		142			2		69		
306.54	306.56	33/3/84-86	lower Tt											31							128	5				108		
306.75	306.77	33/3/105-107	lower Tt										2	38					3		135	5				127		
306.86	306.88	33/3/116-118	lower Tt											12					2		77	1		2		32		
307.08	307.10	33/3/138-140	lower Tt											15						3	73	3		1		61		
307.30	307.32	33/4/10-12	lower Tt											11						2	34	2		2		25		
307.49	307.51	33/4/29-31	lower Tt											6							64			2		24		

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Sphaeroidinellopsis paenedehiscens*	*Sphaeroidinellopsis seminulina*	*Sphaeroidinellopsis sp.?*	*Truncorotalia* aff. *crassaconica* dex	*Truncorotalia* aff. *crassaconica* sin	*Truncorotalia* cf. *crassaformis* sin	*Truncorotalia crassaformis* sin	*Truncorotalia juanai* dex	*Truncorotalia juanai* sin	*Truncorotalia juanai?* dex	*Truncorotalia juanai?* sin	*Truncorotalia neojuanai* dex	*Truncorotalia neojuanai* sin	*Truncorotalia neojuanai?* dex	*Truncorotalia neojuanai?* sin	*Zeaglobigerina nepenthes*	*Zeaglobigerina nepenthes?*	*Zeaglobigerina* sp.	*Zeaglobigerina woodi apertura*	*Zeaglobigerina woodi apertura?*	*Zeaglobigerina woodi decoraperta*	*Zeaglobigerina woodi decoraperta?*	*Zeaglobigerina woodi woodi*	*Zeaglobigerina woodi woodi?*	Misc: unidentified planktics
307.70	307.72	33/4/50-52	lower Tt										1	11						4	66	2		7		17		
307.93	307.95	33/4/73-75	lower Tt											10							72	1				37		
308.14	308.16	33/4/94-96	lower Tt											26						2	96	4		6		51		
308.30	308.32	33/4/110-112	lower Tt										1	13					1		58					32		
308.53	308.55	33/4/133-135	lower Tt										1	13						1	70	3		2		71		
308.71	308.73	33/5/1-3	lower Tt											4							102	4		2		93		
308.99	309.01	33/5/29-31	lower Tt											9						3	74	4		3		36		
309.11	309.13	33/5/41-43	lower Tt																	2	64			2		67		
309.28	309.30	33/5/58-60	lower Tt																1		91	3				98		
309.54	309.56	33/5/84-86	lower Tt																9		129	13				129		
309.74	309.76	33/5/104-106	lower Tt																	1	162	5		1		75		
312.31	312.33	34/1/1-3	lower Tt																3		86	3		2		83		
312.54	312.56	34/1/24-26	lower Tt																	1	75	3		1		72		
312.67	312.69	34/1/37-39	lower Tt																	7	109	1		3		33		
312.87	312.89	34/1/57-59	lower Tt																		89	2		2		53		
313.07	313.09	34/1/77-79	lower Tt																	13	70			3		23		
313.31	313.33	34/1/101-103	lower Tt																	2	80	4		7		69		
313.53	313.55	34/1/123-125	lower Tt																	6	119	3		2		52		
313.71	313.73	34/1/141-143	lower Tt																	17	91	4		2		84		
313.90	313.92	34/2/10-12	lower Tt																	18	80	1			7	27		
314.09	314.11	34/2/29-31	lower Tt																	7	38			7		36		
314.29	314.31	34/2/49-51	lower Tt																	4	74			3		31		
314.45	314.47	34/2/65-67	lower Tt																	16	81			12		51		
314.69	314.71	34/2/89-91	lower Tt																	26	112	1		12		58		
314.90	314.92	34/2/110-112	lower Tt																		58	1		53		35		
315.13	315.15	34/2/133-135	lower Tt																	2	137	1			7	55		
315.30	315.32	34/3/0-2	upper Sw																		66			5		27		
315.52	315.54	34/3/22-24	upper Sw																	5	89				16	20		
315.71	315.73	34/3/41-43	upper Sw																		73	2		23		43		
316.06	316.08	34/3/76-78	upper Sw																	4	158	2			7	50		
316.27	316.29	34/3/97-99	upper Sw																7		178	12		4		122		
316.48	316.50	34/3/118-120	upper Sw																	4	72	1		15		56		
316.67	316.69	34/3/137-139	upper Sw																9		93				1	1		
317.10	317.12	34/4/30-32	upper Sw																	31	72			7		34		
317.50	317.52	34/4/70-72	upper Sw																	2	52	1			1	24		
317.90	317.92	34/4/110-112	upper Sw																		75	1				35		
318.35	318.37	34/5/5-7	upper Sw																		77				39	16		
318.60	318.62	34/5/30-32	upper Sw																		148	8		2		111		
321.91	321.93	35/1/1-3	upper Sw																		97	4		1		67		
322.33	322.35	35/1/43-45	upper Sw																	95	159				30	4		
322.72	322.74	35/1/82-84	upper Sw																	4	91	2			7	36		
323.09	323.11	35/1/119-121	upper Sw																	5	110				12	35		
323.48	323.50	35/2/8-10	upper Sw																	37	37				1	7		
323.91	323.93	35/2/51-53	upper Sw																	4	109	3		8		42		
324.50	324.52	35/2/110-112	upper Sw																	22	51				3	16		
324.91	324.93	35/3/1-3	upper Sw																	6	53					19		
325.33	325.35	35/3/43-45	upper Sw																		83	1				38		
325.71	325.73	35/3/81-83	upper Sw																11		120					75		
325.94	325.96	35/3/104-106	upper Sw																43		61	4				42		
326.28	326.30	35/3/138-140	upper Sw																	2	48					21		
326.70	326.72	35/4/30-32	upper Sw		1															2	109				2	42		
327.09	327.11	35/4/69-71	upper Sw																	2	43				1	11		
327.50	327.52	35/4/110-112	upper Sw																	1	100					40		
327.91	327.93	35/5/1-3	upper Sw																	2	77	3				50		
328.27	328.29	35/5/37-39	upper Sw	1																	88				1	46		
328.72	328.74	35/5/82-84	upper Sw																	2	88	5				62		
331.69	331.71	36/1/19-21	upper Sw																	2	86			2		59		
332.11	332.13	36/1/61-63	upper Sw																	3	82		2		2	47		
332.68	332.70	36/1/118-120	upper Sw																	1	74			1		45		
332.98	333.00	36/1/148-150	upper Sw																		57			2		36		
333.40	333.42	36/2/40-42	upper Sw																		38			1		24		
334.00	334.02	36/2/100-102	upper Sw																	12	40			5		23		
334.36	334.38	36/2/136-138	upper Sw																	10	39			1		29		
334.87	334.89	36/3/37-39	upper Sw																40		101	3				86		
335.47	335.49	36/3/97-99	upper Sw																19		89			2		54		
335.88	335.90	36/3/138-140	upper Sw																11		114	4		6		79		
336.20	336.22	36/4/20-22	upper Sw																14		107	2		4		41		
336.60	336.62	36/4/60-62	upper Sw																	11	143			3		53		

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	Census aliquot weight (g)	Picked aliquot weight (g)	Total Planktics (n)	Total benthics (n)	Planktics /gram >150 um	* *Globigerinoides pyramidalis*	* *Globoconella inflata* sin	* *Truncorotalia* sp.?	* *Truncorotalia crassaformis* sin?	* *Truncorotalia crassula* s.s. dex	* *Truncorotalia crassula viola* sin	* *Truncorotalia tosaensis* sin	Total Contaminants	Fragment count	Frag. proxy = Benthics/(Bnthics + Planktics)	Frag. index = (frag./8)/(frag./8 + whole)	*Bolboforma praeintermedia*	*Bolboforma metzmacheri ornta*	*Bolboforma metzmacheri* s.s.
120.30	120.33	14/1/0-3	lower Wo	0.2332	0.0038	308	22	81053								0	208	0.07	0.08			
120.51	120.54	14/1/21-24	lower Wo	0.3098	0.0048	371	16	77292								0	241	0.04	0.08			
120.69	120.72	14/1/39-42	lower Wo	0.2480	0.0043	338	24	78605								0	192	0.07	0.07			
120.90	120.93	14/1/60-63	lower Wo	0.2826	0.0045	363	23	80667								0	197	0.06	0.06			
121.11	121.14	14/1/81-84	lower Wo	0.2846	0.0048	346	21	72083								0	186	0.06	0.06			
121.26	121.29	14/1/96-99	lower Wo	0.3010	0.0046	345	11	75000								0	160	0.03	0.05			
121.49	121.52	14/1/119-122	lower Wo	0.3820	0.0032	264	11	82500								0	151	0.04	0.07			
121.69	121.72	14/1/139-142	lower Wo	0.3530	0.0053	399	22	75283								0	280	0.05	0.08			
121.90	121.93	14/2/10-13	lower Wo	0.3506	0.0052	394	22	75769								0	282	0.05	0.08			
122.09	122.12	14/2/29-32	lower Wo	0.3113	0.0043	365	14	84884								0	267	0.04	0.08			
122.26	122.29	14/2/46-49	lower Wo	0.3091	0.0044	345	22	78409								0	275	0.06	0.09			
122.51	122.55	14/2/71-75	lower Wo	0.2410	0.0037	328	18	88649								0	183	0.05	0.07			
122.71	122.74	14/2/91-94	lower Wo	0.3213	0.0051	552	31	108235								0	167	0.05	0.04			
122.92	122.95	14/2/112-115	lower Wo	0.2798	0.0044	427	29	97045								0	156	0.06	0.04			
123.10	123.13	14/2/130-133	upper Tk	0.3484	0.0049	479	22	97755								0	163	0.04	0.04			
123.30	123.33	14/3/0-3	upper Tk	0.2765	0.0034	358	13	105294								0	138	0.04	0.05			
123.53	123.56	14/3/23-26	upper Tk	0.1730	0.0052	479	18	92115								0	265	0.04	0.06			
123.69	123.72	14/3/39-42	upper Tk	0.2676	0.0040	365	12	91250								0	191	0.03	0.06			
123.88	123.91	14/3/58-61	upper Tk	0.2362	0.0033	320	11	96970								0	144	0.03	0.05			
124.11	124.14	14/3/81-84	upper Tk	0.3166	0.0047	391	20	83191								0	142	0.05	0.04			
124.30	124.33	14/3/100-103	upper Tk	0.3774	0.0056	511	13	91250								0	264	0.02	0.06			
124.50	124.53	14/3/120-123	upper Tk	0.3068	0.0048	357	30	74375								0	227	0.08	0.07			
124.68	124.71	14/3/138-141	upper Tk	0.2862	0.0046	369	21	80217								0	175	0.05	0.06			
124.90	124.93	14/4/10-13	upper Tk	0.3471	0.0057	484	27	84912								0	220	0.05	0.05			
125.10	125.13	14/4/30-33	upper Tk	0.3424	0.0055	454	24	82545								0	267	0.05	0.07			
125.30	125.33	14/4/50-53	upper Tk	0.3083	0.0046	491	20	106739								0	170	0.04	0.04			
125.48	125.51	14/4/68-71	upper Tk	0.1451	0.0043	477	26	110930								0	142	0.05	0.04			
125.71	125.74	14/4/91-94	upper Tk	0.2205	0.0036	314	22	87222								0	142	0.07	0.05			
125.91	125.94	14/4/111-114	upper Tk	0.1976	0.0059	674	29	114237								0	269	0.04	0.05			
126.10	126.13	14/4/130-133	upper Tk	0.2276	0.0036	359	15	99722								0	164	0.04	0.05			
126.30	126.33	14/5/0-3	upper Tk	0.2438	0.0034	302	24	88824								0	135	0.07	0.05			
126.56	126.59	14/5/26-29	upper Tk	0.2997	0.0038	398	28	104737								0	208	0.07	0.06			
126.70	126.73	14/5/40-43	upper Tk	0.2008	0.0037	303	23	81892								0	118	0.07	0.05			
126.90	126.93	14/5/60-63	upper Tk	0.2428	0.0032	407	29	127188								0	137	0.07	0.04			
127.12	127.15	14/5/82-85	upper Tk	0.2804	0.0043	487	26	113256								0	139	0.05	0.03			
127.30	127.33	14/5/100-103	upper Tk	0.2873	0.0044	420	15	95455								0	227	0.03	0.06			
127.51	127.54	14/5/121-124	upper Tk	0.5205	0.0033	397	14	120303								0	173	0.03	0.05			
127.70	127.73	14/5/140-143	upper Tk	0.3463	0.0044	472	38	107273								0	170	0.07	0.04			
127.90	127.93	14/6/10-13	upper Tk	0.2506	0.0041	509	26	124146								0	85	0.05	0.02			
128.29	128.32	14/6/49-52	upper Tk	0.3233	0.0039	419	21	107436								0	120	0.05	0.03			
128.72	128.75	14/6/92-95	upper Tk	0.4482	0.0035	374	14	106857								0	110	0.04	0.04			
129.10	129.13	14/6/130-133	upper Tk	0.3424	0.0036	344	7	95556								0	148	0.02	0.05			
129.50	129.53	14/7/20-23	upper Tk	0.3576	0.0054	555	29	102778								0	213	0.05	0.05			
129.90	129.93	15/1/0-3	upper Tk	0.3020	0.0030	279	19	93000								0	109	0.06	0.05			
130.29	130.32	15/1/39-42	upper Tk	0.2518	0.0035	383	23	109429								0	123	0.06	0.04			
130.69	130.72	15/1/79-82	upper Tk	0.2623	0.0035	448	16	128000								0	101	0.03	0.03			
131.10	131.13	15/1/120-123	upper Tk	0.2960	0.0032	393	16	122813								0	93	0.04	0.03			
131.51	131.54	15/2/11-14	upper Tk	0.2468	0.0033	401	12	121515								0	159	0.03	0.05			
131.91	131.93	15/2/51-53	upper Tk	0.2846	0.0042	428	15	101905								0	113	0.03	0.03			
132.33	132.36	15/2/93-96	upper Tk	0.3939	0.0032	397	8	124063								0	110	0.02	0.03			
132.74	132.76	15/2/134-136	upper Tk	0.3404	0.0031	295	26	95161								0	78	0.08	0.03			
133.07	133.10	15/3/17-20	upper Tk	0.3077	0.0038	362	15	95263								0	102	0.04	0.03			
133.46	133.49	15/3/56-59	upper Tk	0.3716	0.0053	519	15	97925								0	169	0.03	0.04			
133.89	133.92	15/3/99-102	upper Tk	0.3997	0.0032	351	13	109688								0	121	0.04	0.04			
134.30	134.33	15/3/140-143	upper Tk	0.3546	0.0040	439	15	109750								0	147	0.03	0.04			
134.70	134.73	15/4/30-33	upper Tk	0.2186	0.0033	391	18	118485								0	96	0.04	0.03			
135.10	135.13	15/4/70-73	upper Tk	0.5307	0.0036	332	5	92222								0	124	0.01	0.04			
135.30	135.33	15/4/90-93	upper Tk	0.4012	0.0055	456	13	82909								0	200	0.03	0.05			
135.50	135.53	15/4/110-113	upper Tk	0.4535	0.0040	349	14	87250								0	68	0.04	0.02			
135.70	135.73	15/4/130-133	upper Tk	0.4104	0.0040	453	9	113250								0	91	0.02	0.02			
135.90	135.93	15/5/0-3	upper Tk	0.2462	0.0043	432	15	100465								0	97	0.03	0.03			
136.06	136.09	15/5/16-19	upper Tk	0.3716	0.0034	340	6	100000								0	53	0.02	0.02			
136.32	136.35	15/5/42-45	upper Tk	0.4111	0.0039	403	10	103333								0	83	0.02	0.03			
136.51	136.53	15/5/61-63	upper Tk	0.3280	0.0043	532	14	123721								0	76	0.03	0.02			
136.92	136.95	15/5/102-105	upper Tk	0.3777	0.0044	397	25	90227								0	116	0.06	0.04			
137.13	137.16	15/5/123-126	upper Tk	0.4516	0.0036	351	12	97500								0	79	0.03	0.03			
137.52	137.55	15/6/12-15	upper Tk	0.3529	0.0052	454	21	87308								0	168	0.04	0.04			
137.91	137.94	15/6/51-54	upper Tk	0.2356	0.0037	393	19	106216								0	123	0.05	0.04			
138.27	138.30	15/6/87-90	upper Tk	0.3385	0.0040	356	16	89000								0	77	0.04	0.03			
138.66	138.69	15/6/126-129	upper Tk	0.2938	0.0044	413	23	93864								0	97	0.05	0.03			
139.07	139.10	15/7/17-20	upper Tk	0.0608	0.0035	465	17	132857								0	104	0.04	0.03			
139.50	139.53	16/1/0-3	upper Tk	0.1497	0.0038	302	21	79474								0	159	0.07	0.06			

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	Census aliquot weight (g)	Picked aliquot weight (g)	Total Planktics (n)	Total benthics (n)	Planktics /gram >150 um	* *Globigerinoides pyramidalis*	* *Globoconella inflata* sin	* *Truncorotalia* sp.?	* *Truncorotalia crassaformis* sin?	* *Truncorotalia crassula* s.s. dex	* *Truncorotalia crassula viola* sin	* *Truncorotalia tosaensis* sin	Total Contaminants	Fragment count	Frag. proxy = Benthics/(Bnthics + Planktics)	Frag. index = (frag./8)/(frag./8 + whole)	*Bolboforma praeintermedia*	*Bolboforma metzmacheri ornta*	*Bolboforma metzmacheri* s.s.
139.93	139.96	16/1/43-46	upper Tk	0.0451	0.0040	477	29	119250								0	114	0.06	0.03			
140.34	140.37	16/1/84-87	upper Tk	0.2642	0.0039	359	40	92051								0	88	0.10	0.03			
140.73	140.76	16/1/123-126	upper Tk	0.1783	0.0039	421	26	107949								0	165	0.06	0.05			
141.13	141.15	16/2/13-16	upper Tk	0.2066	0.0032	245	32	76563								0	104	0.12	0.05			
141.54	141.57	16/2/54-57	upper Tk	0.1922	0.0059	392	45	66441								0	210	0.10	0.06			
141.92	141.95	16/2/92-95	upper Tk	0.2170	0.0036	257	25	71389								0	86	0.09	0.04			
142.32	142.35	16/2/132-135	upper Tk	0.2047	0.0041	379	31	92439								0	85	0.08	0.03			
142.75	142.78	16/3/25-28	upper Tk	0.2360	0.0040	385	36	96250								0	91	0.09	0.03			
143.15	143.18	16/3/65-68	upper Tk	0.2916	0.0038	426	26	112105								0	126	0.06	0.04			
143.53	143.56	16/3/103-106	upper Tk	0.3601	0.0057	535	36	93860								0	225	0.06	0.05			
143.84	143.87	16/3/134-137	lower Tk	0.4341	0.0036	396	16	110000								0	98	0.04	0.03			
144.26	144.29	16/4/26-29	lower Tk	0.3394	0.0042	378	22	90000								0	78	0.06	0.03			
144.67	144.70	16/4/67-70	lower Tk	0.6858	0.0030	222	17	74000								0	83	0.07	0.04			
145.13	145.16	16/4/113-116	lower Tk	0.1883	0.0030	424	13	141333							1	1	57	0.03	0.02			
145.50	145.53	16/5/0-3	lower Tk	0.2209	0.0038	423	22	111316								0	130	0.05	0.04			
145.93	145.96	16/5/43-46	lower Tk	0.2005	0.0036	352	16	97778								0	118	0.04	0.04			
146.36	146.38	16/5/86-88	lower Tk	0.2260	0.0038	372	27	97895								0	76	0.07	0.02			
146.71	146.74	16/5/121-124	lower Tk	0.2241	0.0031	331	22	106774								0	105	0.06	0.04			
147.06	147.09	16/6/6-9	lower Tk	0.2652	0.0035	295	20	84286								0	113	0.06	0.05			
147.47	147.50	16/6/47-50	lower Tk	0.2926	0.0048	486	31	101250								0	106	0.06	0.03			
147.93	147.96	16/6/93-96	lower Tk	0.2947	0.0034	379	14	111471								0	83	0.04	0.03			
148.33	148.36	16/6/133-136	lower Tk	0.3144	0.0040	529	17	132250					1			1	48	0.03	0.01			
148.67	148.69	16/7/17-19	lower Tk	0.3678	0.0031	396	12	127742								0	65	0.03	0.02			
149.10	149.13	17/1/0-3	lower Tk	0.2529	0.0039	426	16	109231								0	120	0.04	0.03			
149.52	149.55	17/1/42-45	lower Tk	0.2761	0.0045	415	19	92222								0	224	0.04	0.06			
150.11	150.14	17/1/101-104	lower Tk	0.2699	0.0036	324	9	90000								0	136	0.03	0.05			
150.51	150.54	17/1/141-144	lower Tk	0.4010	0.0031	326	16	105161								0	102	0.05	0.04			
150.87	150.90	17/2/27-30	lower Tk	0.3085	0.0038	452	21	118947								0	105	0.04	0.03			
151.07	151.10	17/2/47-50	lower Tk	0.2467	0.0033	365	9	110606	1							1	82	0.02	0.03			
151.52	151.55	17/2/92-95	lower Tk	0.2716	0.0049	551	18	112449								0	190	0.03	0.04			
151.96	151.98	17/2/136-138	lower Tk	0.3433	0.0030	322	12	107333								0	104	0.04	0.04			
152.10	152.13	17/3/0-3	lower Tk	0.3420	0.0041	436	20	106341								0	164	0.04	0.04			
152.25	152.28	17/3/15-18	lower Tk	0.3029	0.0039	401	34	102821								0	114	0.08	0.03			
152.47	152.50	17/3/37-40	lower Tk	0.1937	0.0029	305	12	105172								0	166	0.04	0.06			
152.75	152.77	17/3/65-67	lower Tk	0.1930	0.0041	399	19	97317							1	1	276	0.05	0.08			
152.91	152.94	17/3/81-84	lower Tk	0.2905	0.0039	349	18	89487								0	126	0.05	0.04			
153.12	153.15	17/3/102-105	lower Tk	0.3009	0.0035	360	17	102857								0	122	0.05	0.04			
153.26	153.29	17/3/116-119	lower Tk	0.2578	0.0042	445	13	105952								0	126	0.03	0.03			
153.45	153.48	17/3/135-138	lower Tk	0.3344	0.0051	460	12	90196								0	249	0.03	0.06			
153.66	153.69	17/4/6-9	lower Tk	0.2447	0.0031	278	13	89677								0	143	0.04	0.06			
153.97	153.99	17/4/37-39	lower Tk	0.1425	0.0043	402	17	93488								0	216	0.04	0.06			
154.13	154.16	17/4/53-56	lower Tk	0.1804	0.0042	416	13	99048								0	155	0.03	0.04			
154.32	154.35	17/4/72-75	lower Tk	0.1859	0.0037	489	25	132162								0	130	0.05	0.03			
154.54	154.57	17/4/94-97	lower Tk	0.1764	0.0042	559	18	133095								0	150	0.03	0.03			
154.77	154.79	17/4/117-119	lower Tk	0.2599	0.0034	402	8	118235							1	1	88	0.02	0.03			
154.95	154.98	17/4/135-138	lower Tk	0.3009	0.0035	511	15	146000								0	122	0.03	0.03			
155.10	155.13	17/5/0-3	lower Tk	0.3251	0.0037	494	10	133514								0	88	0.02	0.02			
155.24	155.27	17/5/14-17	lower Tk	0.3674	0.0029	368	3	126897								0	66	0.01	0.02			
155.48	155.50	17/5/38-40	lower Tk	0.3672	0.0058	559	14	96379								0	238	0.02	0.05			
155.67	155.70	17/5/57-60	lower Tk	0.2272	0.0030	298	3	99333								0	92	0.01	0.04			
155.94	155.97	17/5/84-87	lower Tk	0.2021	0.0044	519	9	117955								0	107	0.02	0.03			
156.13	156.16	17/5/103-106	lower Tk	0.2765	0.0035	364	9	104000								0	133	0.02	0.04			
156.27	156.30	17/5/117-120	lower Tk	0.2597	0.0035	421	13	120286								0	143	0.03	0.04			
156.47	156.50	17/5/137-140	lower Tk	0.2405	0.0042	413	14	98333								0	140	0.03	0.04			
156.71	156.74	17/6/11-14	lower Tk	0.2290	0.0034	382	14	112353								0	122	0.04	0.04			
156.95	156.98	17/6/35-38	lower Tk	0.2442	0.0030	365	7	121667								0	81	0.02	0.03			
157.12	157.15	17/6/52-55	lower Tk	0.2419	0.0035	488	10	139429								0	120	0.02	0.03			
157.37	157.39	17/6/77-79	lower Tk	0.2441	0.0039	348	16	89231								0	219	0.04	0.07			
157.52	157.55	17/6/92-95	lower Tk	0.2769	0.0041	337	14	82195								0	178	0.04	0.06			
157.76	157.79	17/6/116-119	lower Tk	0.2852	0.0037	443	12	119730								0	78	0.03	0.02			
157.93	157.96	17/6/133-136	lower Tk	0.2526	0.0038	557	21	146579								0	93	0.04	0.02			
158.10	153.13	17/7/0-3	lower Tk	0.2541	0.0038	527	9	138684								0	123	0.02	0.03			
158.27	158.30	17/7/17-20	lower Tk	0.3086	0.0037	492	13	132973								0	141	0.03	0.03			
158.52	158.55	17CC/6-9	lower Tk	0.3084	0.0033	380	13	115152								0	136	0.03	0.04			
158.70	158.73	18/1/0-3	lower Tk	0.3266	0.0037	480	4	129730								0	93	0.01	0.02			
158.95	158.98	18/1/25-28	lower Tk	0.1582	0.0036	398	13	110556								0	171	0.03	0.05			
159.13	159.16	18/1/43-46	lower Tk	0.2139	0.0032	325	17	101563								0	152	0.05	0.06			
159.35	159.38	18/1/65-68	lower Tk	0.2688	0.0040	500	12	125000								0	165	0.02	0.04			
159.49	159.52	18/1/79-82	lower Tk	0.3704	0.0060	670	12	111667								0	257	0.02	0.05			
159.72	159.75	18/1/102-105	lower Tk	0.3983	0.0043	464	14	107907								0	130	0.03	0.03			
159.86	159.89	18/1/116-119	lower Tk	0.3193	0.0039	403	8	103333								0	135	0.02	0.04			
160.11	160.14	18/1/141-144	lower Tk	0.4142	0.0037	414	14	111892								0	114	0.03	0.03			

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	Census aliquot weight (g)	Picked aliquot weight (g)	Total Planktics (n)	Total benthics (n)	Planktics /gram >150 um	* *Globigerinoides pyramidalis*	* *Globoconella inflata* sin	* *Truncorotalia* sp.?	* *Truncorotalia crassaformis* sin?	* *Truncorotalia crassula* s.s. dex	* *Truncorotalia crassula viola* sin	* *Truncorotalia tosaensis* sin	Total Contaminants	Fragment count	Frag. proxy = Benthics/(Bnthics + Planktics)	Frag. index = (frag./8)/(frag./8 + whole)	*Bolboforma praeintermedia*	*Bolboforma metzmacheri ornta*	*Bolboforma metzmacheri* s.s.
160.33	160.36	18/2/13-16	lower Tk	0.4839	0.0041	543	22	132439								0	80	0.04	0.02			
160.73	160.76	18/2/53-56	lower Tk	0.5581	0.0036	368	19	102222								0	59	0.05	0.02			
161.16	161.19	18/2/96-99	lower Tk	0.2804	0.0046	506	21	110000								0	248	0.04	0.06			
161.53	161.56	18/2/133-136	lower Tk	0.3082	0.0044	520	21	118182								0	182	0.04	0.04			
161.84	161.87	18/3/14-17	lower Tk	0.3520	0.0045	441	14	98000								0	153	0.03	0.04			
162.26	162.29	18/3/56-59	lower Tk	0.2318	0.0038	394	16	103684								0	149	0.04	0.05			
162.87	162.90	18/3/117-120	lower Tk	0.2747	0.0043	379	16	88140								0	212	0.04	0.07			
163.33	163.36	18/4/13-16	lower Tk	0.3005	0.0038	333	6	87632								0	109	0.02	0.04			
163.56	163.59	18/4/36-39	lower Tk	0.3586	0.0054	656	10	121481								0	223	0.02	0.04			
163.93	163.96	18/4/73-76	lower Tk	0.4594	0.0032	325	11	101563								0	96	0.03	0.04			
164.31	164.33	18/4/111-113	lower Tk	0.2890	0.0034	346	8	101765								0	89	0.02	0.03			
164.70	164.73	18/5/0-3	lower Tk	0.3305	0.0038	417	9	109737								0	87	0.02	0.03			
165.13	165.16	18/5/43-46	lower Tk	0.3134	0.0046	567	19	123261								0	150	0.03	0.03			
165.50	165.53	18/5/80-83	lower Tk	0.3463	0.0052	621	16	119423								0	157	0.03	0.03			
165.95	165.97	18/5/125-127	lower Tk	0.2793	0.0045	459	16	102000								0	163	0.03	0.04			
166.26	166.29	18/6/6-9	lower Tk	0.4969	0.0036	395	6	109722								0	104	0.01	0.03			
166.66	166.69	18/6/46-49	lower Tk	0.3156	0.0039	418	5	107179								0	129	0.01	0.04			
167.06	167.09	18/6/86-89	lower Tk	0.3872	0.0046	487	14	105870								0	121	0.03	0.03			
167.44	167.47	18/6/124-127	upper Tt	0.3911	0.0058	622	15	107241								0	191	0.02	0.04			
168.30	168.33	19/1/0-3	upper Tt	0.2486	0.0036	399	25	110833								0	126	0.06	0.04			
168.71	168.74	19/1/41-44	upper Tt	0.3591	0.0045	538	23	119556			1					1	141	0.04	0.03			
169.13	169.15	19/1/83-85	upper Tt	0.3937	0.0037	421	7	113784								0	82	0.02	0.02			
169.51	169.54	19/1/121-124	upper Tt	0.4444	0.0038	461	11	121316								0	133	0.02	0.03			
169.85	169.88	19/2/5-8	upper Tt	0.4344	0.0037	410	15	110811								0	131	0.04	0.04			
170.32	170.35	19/2/52-55	upper Tt	0.3667	0.0044	443	9	100682								0	120	0.02	0.03			
170.73	170.76	19/2/93-96	upper Tt	0.2717	0.0038	476	16	125263								0	145	0.03	0.04			
171.15	171.18	19/2/135-138	upper Tt	0.3440	0.0044	465	8	105682								0	143	0.02	0.04			
171.57	171.59	19/3/27-29	upper Tt	0.2761	0.0041	476	15	116098								0	153	0.03	0.04			
171.92	171.94	19/3/62-64	upper Tt	0.2835	0.0032	304	18	95000								0	189	0.06	0.07			
172.32	172.35	19/3/102-105	upper Tt	0.3231	0.0040	445	12	111250								0	144	0.03	0.04			
172.66	172.68	19/3/136-138	upper Tt	0.4092	0.0033	312	13	94545								0	105	0.04	0.04			
173.07	173.09	19/4/27-29	upper Tt	0.4357	0.0033	354	8	107273								0	129	0.02	0.04			
173.52	173.54	19/4/72-74	upper Tt	0.4229	0.0032	244	17	76250								0	134	0.07	0.06			
173.93	173.95	19/4/113-115	upper Tt	0.2573	0.0036	382	15	106111								0	139	0.04	0.04			
174.30	174.33	19/5/0-3	upper Tt	0.2360	0.0042	379	26	90238								0	147	0.06	0.05			
174.72	174.75	19/5/42-45	upper Tt	0.1443	0.0036	393	22	109167								0	105	0.05	0.03			
175.26	175.28	19/5/96-99	upper Tt	0.1248	0.0039	343	30	87949								0	256	0.08	0.09			
175.71	175.74	19/5/141-144	upper Tt	0.1900	0.0031	283	21	91290								0	127	0.07	0.05			
176.06	176.09	19/6/26-29	upper Tt	0.2223	0.0035	300	24	85714								0	216	0.07	0.08			
176.47	176.49	19/6/67-69	upper Tt	0.2323	0.0034	342	16	100588								0	158	0.04	0.05			
176.92	176.94	19/6/112-114	upper Tt	0.1113	0.0035	258	19	73714								0	283	0.07	0.12			
177.30	177.33	19/7/0-3	upper Tt	0.1039	0.0033	295	28	89394								0	182	0.09	0.07			
177.52	177.55	19/7/22-25	upper Tt	0.1046	0.0059	894	37	151525								0	338	0.04	0.05			
177.90	177.93	20/1/0-3	upper Tt	0.1719	0.0040	320	24	80000		1						1	188	0.07	0.07			
178.27	178.30	20/1/37-40	upper Tt	0.1424	0.0036	371	29	103056								0	143	0.07	0.05			
178.68	178.70	20/1/78-80	upper Tt	0.1652	0.0038	386	29	101579								0	155	0.07	0.05			
179.08	179.10	20/1/118-120	upper Tt	0.1367	0.0040	353	30	88250								0	214	0.08	0.07			
179.45	179.47	20/2/5-7	upper Tt	0.0822	0.0047	493	35	104894								0	254	0.07	0.06			
179.86	179.88	20/2/46-48	upper Tt	0.1357	0.0037	437	22	118108								0	130	0.05	0.04			
180.33	180.35	20/2/93-95	upper Tt	0.1646	0.0040	378	17	94500								0	187	0.04	0.06			
180.73	180.75	20/2/133-135	upper Tt	0.2701	0.0035	332	13	94857								0	124	0.04	0.04			
181.14	181.16	20/3/24-26	upper Tt	0.1031	0.0034	256	22	75294								0	188	0.08	0.08			
181.57	181.59	20/3/67-69	upper Tt	0.1150	0.0035	314	32	89714								0	206	0.09	0.08			
181.86	181.88	20/3/96-98	upper Tt	0.0966	0.0033	393	25	119091								0	120	0.06	0.04			
182.23	182.25	20/3/133-135	upper Tt	0.0962	0.0035	318	40	90857								0	178	0.11	0.07			
182.68	182.70	20/4/28-30	upper Tt	0.1735	0.0028	268	15	95714								0	118	0.05	0.05			
183.08	183.10	20/4/68-70	upper Tt	0.1789	0.0028	292	21	104286								0	121	0.07	0.05			
183.45	183.47	20/4/105-107	upper Tt	0.1564	0.0048	540	27	112500								0	194	0.05	0.04			
183.91	183.93	20/5/1-3	upper Tt	0.1992	0.0032	405	14	126563								0	141	0.03	0.04			
184.32	184.34	20/5/42-44	upper Tt	0.1641	0.0027	380	14	140741								0	98	0.04	0.03			
184.72	184.74	20/5/82-84	upper Tt	0.2050	0.0030	386	16	128667								0	107	0.04	0.03			
185.07	185.09	20/5/117-119	upper Tt	0.2945	0.0037	458	11	123784								0	90	0.02	0.02			
185.47	185.49	20/6/7-9	upper Tt	0.2079	0.0031	362	15	116774								0	137	0.04	0.05			
185.92	185.94	20/6/52-54	upper Tt	0.1927	0.0032	414	9	129375								0	90	0.02	0.03			
186.32	186.34	20/6/92-94	upper Tt	0.2058	0.0033	423	33	128182								0	90	0.07	0.03			
186.72	186.74	20/6/132-134	upper Tt	0.1511	0.0031	428	13	138065								0	95	0.03	0.03			
187.07	187.09	20/7/17-19	upper Tt	0.2699	0.0035	486	31	138857								0	65	0.06	0.02			
187.51	187.53	21/1/1-3	upper Tt	0.2684	0.0045	551	25	122444		2						2	167	0.04	0.04			
187.93	187.95	21/1/43-45	upper Tt	0.1537	0.0039	567	29	145385		1				1		2	99	0.05	0.02			
188.32	188.34	21/182-84	upper Tt	0.1901	0.0026	335	13	128846								0	85	0.04	0.03			
188.67	188.69	21/1/117-119	upper Tt	0.1951	0.0035	426	13	121714								0	105	0.03	0.03			
189.08	189.10	21/2/8-10	upper Tt	0.1639	0.0026	307	30	118077								0	70	0.09	0.03			

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	Census aliquot weight (g)	Picked aliquot weight (g)	Total Planktics (n)	Total benthics (n)	Planktics /gram >150 um	* *Globigerinoides pyramidalis*	* *Globoconella inflata* sin	* *Truncorotalia* sp.?	* *Truncorotalia crassaformis* sin?	* *Truncorotalia crassula* s.s. dex	* *Truncorotalia crassula viola* sin	* *Truncorotalia tosaensis* sin	Total Contaminants	Fragment count	Frag. proxy = Benthics/(Bnthics + Planktics)	Frag. index = (frag./8)/(frag./8 + whole)	*Bolboforma praeintermedia*	*Bolboforma metzmacheri ornta*	*Bolboforma metzmacheri* s.s.
189.46	189.48	21/2/46-48	upper Tt	0.1180	0.0036	407	34	113056								0	100	0.08	0.03			
189.93	189.96	21/2/93-96	upper Tt	0.2086	0.0029	413	28	142414								0	67	0.06	0.02			
190.42	190.44	21/2/142-144	upper Tt	0.1107	0.0033	405	29	122727								0	128	0.07	0.04			
190.66	190.68	21/3/16-18	upper Tt	0.1410	0.0031	389	22	125484								0	105	0.05	0.03			
191.12	191.14	21/3/62-64	upper Tt	0.1999	0.0029	403	16	138966								0	115	0.04	0.03			
191.52	191.54	21/3/102-104	upper Tt	0.2607	0.0044	558	18	126818								0	132	0.03	0.03			
191.86	191.89	21/3/136-139	upper Tt	0.1779	0.0027	332	12	122963								0	127	0.03	0.05			
192.36	192.38	21/4/36-38	upper Tt	0.1504	0.0033	516	27	156364								0	123	0.05	0.03			
192.73	193.75	21/4/73-75	upper Tt	0.2460	0.0038	573	16	150789								0	78	0.03	0.02			
193.12	193.14	21/4/112-114	upper Tt	0.2870	0.0038	401	17	105526								0	63	0.04	0.02			
193.50	193.52	21/5/0-2	upper Tt	0.3569	0.0056	676	35	120714								0	124	0.05	0.02			
193.92	193.94	21/5/42-44	upper Tt	0.2755	0.0031	417	10	134516								0	38	0.02	0.01			
194.34	194.26	21/5/84-86	upper Tt	0.7561	0.0027	298	11	110370								0	103	0.04	0.04			
194.72	194.74	21/5/122-124	upper Tt	0.2565	0.0036	599	16	166389								0	99	0.03	0.02			
195.07	195.09	21/6/7-9	upper Tt	0.2942	0.0032	474	8	148125								0	65	0.02	0.02			
195.49	195.51	21/6/49-51	upper Tt	0.2866	0.0047	477	21	101489								0	159	0.04	0.04			
195.87	195.89	21/6/87-89	upper Tt	0.3016	0.0034	588	24	172941								0	134	0.04	0.03			
196.34	196.36	21/6/134-136	upper Tt	0.2719	0.0032	393	8	122813								0	134	0.02	0.04			
196.72	196.74	21/7/22-24	upper Tt	0.2093	0.0032	387	26	120938								0	98	0.06	0.03			
197.11	197.13	22/1/1-3	upper Tt	0.3294	0.0030	454	5	151333								0	70	0.01	0.02			
197.48	197.50	22/1/38-40	upper Tt	0.2614	0.0040	524	34	131000								0	152	0.06	0.03			
197.94	197.96	22/1/84-86	upper Tt	0.1615	0.0034	459	35	135000								0	72	0.07	0.02			
198.32	198.34	22/1/122-124	upper Tt	0.2841	0.0038	553	14	145526								0	103	0.02	0.02			
198.73	198.75	22/2/13-15	upper Tt	0.3006	0.0035	356	14	101714								0	101	0.04	0.03			
199.14	199.16	22/2/54-56	upper Tt	0.2757	0.0036	590	11	163889								0	84	0.02	0.02			
199.53	199.55	22/2/93-95	upper Tt	0.2737	0.0045	608	10	135111								0	152	0.02	0.03			
199.93	199.95	22/2/133-135	upper Tt	0.3348	0.0028	345	11	123214								0	70	0.03	0.02			
200.25	200.27	22/3/15-17	upper Tt	0.3204	0.0035	530	11	151429								0	70	0.02	0.02			
200.66	200.68	22/3/56-58	upper Tt	0.3618	0.0030	333	11	111000								0	90	0.03	0.03			
201.05	201.07	22/3/95-97	upper Tt	0.2977	0.0032	487	12	152188								0	96	0.02	0.02			
201.42	201.44	22/3/132-134	upper Tt	0.3524	0.0057	674	16	118246								0	189	0.02	0.03			
201.93	201.95	22/4/33-35	upper Tt	0.2969	0.0034	477	20	140294								0	97	0.04	0.02			
202.52	202.55	22/4/92-95	upper Tt	0.2248	0.0037	568	19	153514								0	105	0.03	0.02			
202.93	202.95	22/4/133-135	upper Tt	0.2195	0.0034	516	14	151765								0	94	0.03	0.02			
203.17	203.20	22CC/7-10	upper Tt	0.2243	0.0038	517	34	136053								0	160	0.06	0.04			
206.71	206.73	23/1/1-3	upper Tt	0.1412	0.0041	677	13	165122		3				1		4	176	0.02	0.03			
207.13	207.15	23/1/43-45	upper Tt	0.2462	0.0028	458	8	163571								0	110	0.02	0.03			
207.48	207.50	23/1/78-80	upper Tt	0.2887	0.0036	407	13	113056								0	143	0.03	0.04			
207.88	207.90	23/1/118-120	upper Tt	0.3054	0.0039	500	13	128205								0	127	0.03	0.03			
208.26	208.28	23/2/6-8	upper Tt	0.1425	0.0029	464	6	160000		1						1	114	0.01	0.03			
208.52	208.54	23/2/32-34	upper Tt	0.1625	0.0051	801	9	157059								0	240	0.01	0.04			
209.06	209.08	23/2/86-88	upper Tt	0.2051	0.0036	475	6	131944								0	134	0.01	0.03			
209.54	209.56	23/2/134-136	upper Tt	0.1924	0.0033	430	4	130303								0	111	0.01	0.03			
209.85	209.87	23/3/15-17	upper Tt	0.1300	0.0031	454	6	146452								0	110	0.01	0.03			
210.33	210.35	23/3/63-65	upper Tt	0.2082	0.0028	445	2	158929								0	66	0.00	0.02			
210.53	210.55	23/3/83-85	upper Tt	0.1477	0.0046	607	7	131957								0	158	0.01	0.03			
210.87	210.89	23/3/117-119	upper Tt	0.1733	0.0038	534	15	140526								0	163	0.03	0.04			
211.27	211.29	23/4/7-9	upper Tt	0.2049	0.0036	441	14	122500								0	109	0.03	0.03			
211.72	211.74	23/4/52-54	upper Tt	0.2434	0.0034	505	10	148529								0	107	0.02	0.03			
212.13	212.15	23/4/93-95	upper Tt	0.3393	0.0029	399	8	137586								0	45	0.02	0.01			
212.32	212.34	23/4/112-114	upper Tt	0.3206	0.0046	634	7	137826							1	1	130	0.01	0.02			
212.71	212.73	23/5/1-3	upper Tt	0.2341	0.0028	408	13	145714								0	127	0.03	0.04			
213.12	213.14	23/5/42-44	upper Tt	0.1576	0.0033	603	15	182727								0	97	0.02	0.02			
213.72	213.74	23/5/102-104	upper Tt	0.3162	0.0023	346	5	150435								0	90	0.01	0.03			
214.12	214.14	23/5/142-144	upper Tt	0.3079	0.0025	386	6	154400								0	61	0.02	0.02			
214.51	214.53	23/6/31-33	upper Tt	0.3063	0.0055	745	14	135455								0	135	0.02	0.02			
215.05	215.07	23/6/85-87	upper Tt	0.1706	0.0026	364	9	140000								0	116	0.02	0.04			
215.53	215.55	23/6/133-135	upper Tt	0.2289	0.0035	487	10	139143								0	122	0.02	0.03			
215.93	215.95	23/7/23-25	upper Tt	0.2508	0.0030	439	15	146333								0	84	0.03	0.02			
216.31	216.33	24/1/1-3	upper Tt	0.1989	0.0027	375	12	138889				1				1	74	0.03	0.02			
216.57	216.59	24/1/27-29	upper Tt	0.1995	0.0057	942	37	165263								0	180	0.04	0.02			
216.94	216.96	24/1/64-66	upper Tt	0.4296	0.0030	473	6	157667								0	88	0.01	0.02			
217.34	217.36	24/1/104-106	upper Tt	0.3994	0.0028	402	4	143571								0	65	0.01	0.02			
217.72	217.74	24/1/142-144	upper Tt	0.2530	0.0028	428	6	152857								0	67	0.01	0.02			
218.08	218.10	24/2/28-30	upper Tt	0.2355	0.0027	461	7	170741								0	64	0.01	0.02			
218.52	218.54	24/2/72-74	upper Tt	0.1698	0.0048	868	13	180833								0	161	0.01	0.02			
218.87	218.89	24/2/107-109	upper Tt	0.2328	0.0036	599	6	166389								0	126	0.01	0.03			
219.31	219.33	24/3/1-3	upper Tt	0.2378	0.0037	619	15	167297		1						1	83	0.02	0.02			
219.72	219.74	24/3/42-44	upper Tt	0.2428	0.0034	567	5	166765								0	98	0.01	0.02			
220.12	220.14	24/3/82-84	upper Tt	0.2120	0.0034	590	6	173529								0	93	0.01	0.02			
220.46	220.48	24/3/116-118	upper Tt	0.2531	0.0037	619	8	167297								0	95	0.01	0.02			
220.87	220.89	24/4/7-9	upper Tt	0.3552	0.0030	456	4	152000								0	68	0.01	0.02			

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	Census aliquot weight (g)	Picked aliquot weight (g)	Total Planktics (n)	Total benthics (n)	Planktics /gram >150 um	*Globigerinoides pyramidalis*	*Globoconella inflata* sin	*Truncorotalia* sp.?	*Truncorotalia crassaformis* sin?	*Truncorotalia crassula* s.s. dex	*Truncorotalia crassula viola* sin	*Truncorotalia tosaensis* sin	Total Contaminants	Fragment count	Frag. proxy = Benthics/(Bnthics + Planktics)	Frag. index = (frag./8)/(frag./8 + whole)	*Bolboforma praeintermedia*	*Bolboforma metzmacheri ornta*	*Bolboforma metzmacheri* s.s.
221.27	221.29	24/4/47-49	upper Tt	0.2441	0.0037	655	9	177027								0	67	0.01	0.01			
221.66	221.68	24/4/86-88	upper Tt	0.2132	0.0036	552	10	153333								0	97	0.02	0.02			
222.13	222.15	24/4/133-135	upper Tt	0.4464	0.0037	535	5	144595								0	71	0.01	0.02			
222.45	222.47	24/5/15-17	upper Tt	0.4415	0.0033	589	7	178485								0	41	0.01	0.01			
222.93	222.95	24/5/63-65	upper Tt	0.4368	0.0030	484	4	161333								0	57	0.01	0.01			
223.33	223.35	24/5/103-105	upper Tt	0.3382	0.0027	421	7	155926								0	37	0.02	0.01			
223.72	223.74	24/5/142-144	upper Tt	0.2714	0.0039	489	9	125385								0	70	0.02	0.02			
224.07	224.09	24/6/27-29	upper Tt	0.4424	0.0026	399	10	153462								0	67	0.02	0.02			
224.47	224.49	24/6/67-69	upper Tt	0.2737	0.0044	704	9	160000								0	83	0.01	0.01			
224.87	224.89	24/6/107-109	upper Tt	0.1543	0.0021	317	7	150952								0	51	0.02	0.02			
225.36	225.38	24CC/9-11	upper Tt	0.4932	0.0032	405	6	126563								0	67	0.01	0.02			
226.13	226.15	25/1/23-25	upper Tt	0.4539	0.0029	432	7	148966								0	49	0.02	0.01			
226.53	226.55	25/1/63-65	upper Tt	0.3889	0.0058	823	21	141897								0	106	0.02	0.02			
226.93	226.95	25/1/103-105	upper Tt	0.3652	0.0028	389	9	138929								0	50	0.02	0.02			
227.34	227.36	25/1/144-146	upper Tt	0.3721	0.0028	404	5	144286								0	55	0.01	0.02			
227.72	227.74	25/2/-32-34	upper Tt	0.3032	0.0025	353	5	141200								0	70	0.01	0.02			
228.12	228.14	25/2/72-74	upper Tt	0.4397	0.0036	547	5	151944								0	58	0.01	0.01			
228.52	228.54	25/2/112-114	upper Tt	0.5460	0.0041	628	9	153171								0	73	0.01	0.01			
228.90	228.92	25/3/0-2	upper Tt	0.6166	0.0023	342	5	148696								0	56	0.01	0.02			
229.33	229.35	25/3/43-45	upper Tt	0.4739	0.0036	566	2	157222								0	60	0.00	0.01			
229.85	229.87	25/3/95-97	upper Tt	0.4634	0.0037	491	4	132703								0	86	0.01	0.02			
230.27	230.29	25/3/137-139	upper Tt	0.3576	0.0026	366	3	140769								0	68	0.01	0.02			
230.47	230.49	25/4/7-9	upper Tt	0.2583	0.0041	774	9	188780								0	99	0.01	0.02			
230.93	230.95	25/4/53-55	upper Tt	0.2574	0.0021	382	2	181905								0	58	0.01	0.02			
231.33	231.35	25/4/93-95	upper Tt	0.1970	0.0029	574	6	197931								0	112	0.01	0.02			
231.73	231.75	25/4/133-135	upper Tt	0.1623	0.0025	501	9	200400								0	69	0.02	0.02			
232.06	232.08	25/5/16-18	upper Tt	0.3150	0.0025	412	3	164800								0	54	0.01	0.02			
232.52	232.54	25/5/62-64	upper Tt	0.2677	0.0038	612	9	161053								0	86	0.01	0.02			
232.92	232.94	25/5/102-104	upper Tt	0.2920	0.0022	335	7	152273								0	76	0.02	0.03			
233.27	233.29	25/5137-139	upper Tt	0.2944	0.0022	391	4	177727								0	40	0.01	0.01			
233.67	233.69	25/6/27-29	upper Tt	0.3563	0.0028	472	8	168571								0	47	0.02	0.01			
234.15	234.17	25/6/75-77	upper Tt	0.4992	0.0037	568	6	153514								0	69	0.01	0.01			
234.52	234.54	25/6/112-114	upper Tt	0.3440	0.0046	672	4	146087								0	97	0.01	0.02			
234.91	234.93	25/7/1-3	upper Tt	0.3236	0.0028	465	3	166071								0	75	0.01	0.02			
235.26	235.28	25CC/10-22	upper Tt	0.3622	0.0031	426	5	137419								0	53	0.01	0.02			
235.73	235.75	26/1/23-25	upper Tt	0.1344	0.0022	303	7	137727								0	98	0.02	0.04			
236.08	236.10	26/1/58-60	upper Tt	0.1240	0.0037	431	6	116486								0	151	0.01	0.04			
236.52	236.54	26/1/102-104	upper Tt	0.2459	0.0034	469	3	137941								0	90	0.01	0.02			
236.92	236.94	26/1/142-144	upper Tt	0.2842	0.0024	291	4	121250								0	70	0.01	0.03			
237.32	237.34	26/2/32-34	upper Tt	0.2186	0.0032	490	7	153125								0	108	0.01	0.03			
237.93	237.95	26/2/93-95	upper Tt	0.1775	0.0028	353	8	126071								0	66	0.02	0.02			
238.33	238.35	26/2/133-135	upper Tt	0.3200	0.0025	377	2	150800								0	73	0.01	0.02			
238.51	238.53	26/3/1-3	upper Tt	0.2097	0.0033	580	11	175758								0	89	0.02	0.02			
238.93	238.95	26/3/43-45	upper Tt	0.3720	0.0030	459	4	153000								0	92	0.01	0.02	4		
239.32	239.34	26/3/82-84	upper Tt	0.2144	0.0040	514	11	128500								0	155	0.02	0.04	2		
239.67	239.69	26/3/117-119	upper Tt	0.3612	0.0031	380	8	122581								0	63	0.02	0.02			
240.07	240.09	26/4/7-9	upper Tt	0.3700	0.0034	465	10	136765								0	96	0.02	0.03			
240.52	240.54	26/4/52-54	upper Tt	0.1568	0.0048	664	5	138333								0	98	0.01	0.02			
240.92	240.94	26/4/92-94	upper Tt	0.5282	0.0041	586	2	142927								0	93	0.00	0.02			
241.32	241.34	26/4/132-134	upper Tt	0.2267	0.0038	457	11	120263								0	95	0.02	0.03		2	
241.65	241.67	26/5/15-17	upper Tt	0.2656	0.0039	468	12	120000								0	186	0.03	0.05		3	
242.13	242.15	26/5/63-65	upper Tt	0.2054	0.0031	316	21	101935								0	155	0.06	0.06			
242.52	242.54	26/5/102-104	upper Tt	0.0968	0.0053	400	44	75472								0	380	0.10	0.11		22	
242.92	242.94	26/5/142-144	upper Tt	0.2874	0.0049	505	8	103061								0	302	0.02	0.07		14	
243.26	243.28	26/6/26-28	upper Tt	0.4994	0.0038	388	6	102105								0	101	0.02	0.03		19	
243.63	243.65	26/6/63-65	upper Tt	0.3127	0.0025	339	8	135600								0	64	0.02	0.02		2	
243.86	243.88	26CC/13-15	upper Tt	0.4836	0.0034	386	4	113529								0	101	0.01	0.03			
245.11	245.13	27/1/1-3	upper Tt	0.2842	0.0042	468	9	111429								0	134	0.02	0.03			
245.53	245.55	27/1/43-45	upper Tt	0.2314	0.0035	459	8	131143								0	148	0.02	0.04			
245.91	245.93	27/1/81-83	upper Tt	0.1763	0.0025	322	13	128800								0	143	0.04	0.05			
246.27	246.29	27/1/117-119	upper Tt	0.2363	0.0036	442	7	122778								0	157	0.02	0.04			
246.52	246.54	27/1/142-144	upper Tt	0.1673	0.0052	632	24	121538								0	273	0.04	0.05			
246.87	246.89	27/2/27-29	upper Tt	0.2377	0.0037	544	14	147027								0	176	0.03	0.04			
247.33	247.35	27/2/73-76	upper Tt	0.6042	0.0027	366	7	135556								0	61	0.02	0.02			
247.67	247.69	27/2/107-109	upper Tt	0.4527	0.0034	529	7	155588								0	100	0.01	0.02			
248.11	248.13	27/3/1-3	upper Tt	0.5716	0.0023	350	5	152174								0	51	0.01	0.02			
248.47	248.49	27/3/37-39	upper Tt	0.5457	0.0041	605	8	147561								0	91	0.01	0.02			
248.93	248.95	27/3/83-85	upper Tt	0.5133	0.0023	276	7	120000								0	45	0.02	0.02			
249.27	249.27	27/3/117-119	upper Tt	0.4186	0.0036	474	8	131667								0	128	0.02	0.03			
249.67	249.69	27/4/7-9	upper Tt	0.4518	0.0039	603	7	154615								0	140	0.01	0.03			
250.12	250.14	27/4/52-54	upper Tt	0.2780	0.0045	464	14	103111								0	212	0.03	0.05			
250.46	250.48	27/4/86-88	upper Tt	0.2223	0.0032	327	12	102188								0	257	0.04	0.09			

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	Census aliquot weight (g)	Picked aliquot weight (g)	Total Planktics (n)	Total benthics (n)	Planktics /gram >150 um	* *Globigerinoides pyramidalis*	* *Globoconella inflata* sin	* *Truncorotalia* sp.?	* *Truncorotalia crassaformis* sin?	* *Truncorotalia crassula* s.s. dex	* *Truncorotalia crassula viola* sin	* *Truncorotalia tosaensis* sin	Total Contaminants	Fragment count	Frag. proxy = Benthics/(Bnthics + Planktics)	Frag. index = (frag./8)/(frag./8 + whole)	*Bolboforma praeintermedia*	*Bolboforma metzmacheri ornta*	*Bolboforma metzmacheri* s.s.
250.92	250.94	27/4/132-134	upper Tt	0.2883	0.0044	467	12	106136								0	169	0.03	0.04			
251.33	251.36	27/5/23-26	upper Tt	0.5442	0.0041	447	6	109024								0	204	0.01	0.05			
251.67	251.69	27/5/57-59	upper Tt	0.3741	0.0029	406	7	140000								0	163	0.02	0.05			
252.13	252.15	27/5/103-105	upper Tt	0.4662	0.0041	480	6	117073								0	184	0.01	0.05			
252.53	252.55	27/5/143-145	upper Tt	0.4027	0.0033	398	13	120606								0	139	0.03	0.04			
252.92	252.94	27/6/32-34	upper Tt	0.4554	0.0039	418	17	107179								0	191	0.04	0.05			
253.33	253.35	27/6/73-75	upper Tt	0.2943	0.0024	266	7	110833								0	127	0.03	0.06			
253.67	253.69	27/6/107-109	upper Tt	0.5140	0.0046	503	5	109348								0	126	0.01	0.03			
254.10	254.12	27/7/0-2	upper Tt	0.2580	0.0039	428	15	109744								0	176	0.03	0.05			
254.49	254.51	27CC/10-12	lower Tt	0.2712	0.0039	582	9	149231								0	173	0.02	0.04			2
254.93	254.95	28/4/23-25	lower Tt	0.2407	0.0038	455	10	119737								0	168	0.02	0.04			4
255.28	255.30	28/1/58-60	lower Tt	0.2902	0.0045	464	11	103111								0	238	0.02	0.06			2
255.73	255.75	28/1/103-105	lower Tt	0.2628	0.0041	394	9	96098								0	208	0.02	0.06			8
256.11	256.13	28/1/141-143	lower Tt	0.1853	0.0029	296	8	102069								0	145	0.03	0.06			11
256.53	256.55	28/2/33-35	lower Tt	0.2526	0.0032	377	11	117813								0	170	0.03	0.05			12
257.03	257.05	28/2/83-85	lower Tt	0.2389	0.0037	295	8	79730								0	179	0.03	0.07			3
257.33	257.35	28/2/113-115	lower Tt	0.2025	0.0031	281	7	90645								0	172	0.02	0.07			1
257.71	257.73	28/3/1-3	lower Tt	0.3946	0.0034	313	11	92059								0	139	0.03	0.05			3
258.12	258.14	28/3/42-44	lower Tt	0.2420	0.0036	388	7	107778								0	188	0.02	0.06			2
258.54	258.56	28/3/84-86	lower Tt	0.2122	0.0032	258	12	80625								0	139	0.04	0.06			2
259.07	259.09	28/3/137-139	lower Tt	0.1606	0.0026	274	7	105385								0	142	0.02	0.06			
259.53	259.55	28/4/33-35	lower Tt	0.2430	0.0036	435	5	120833								0	175	0.01	0.05			1
259.86	259.88	28/4/66-68	lower Tt	0.2644	0.0043	536	12	124651								0	171	0.02	0.04			
260.28	260.30	28/4/108-110	lower Tt	0.2467	0.0037	453	10	122432								0	170	0.02	0.04			
260.54	260.56	28/4/134-136	lower Tt	0.2679	0.0037	440	9	118919								0	126	0.02	0.03			
260.86	260.88	28/5/16-18	lower Tt	0.1784	0.0026	316	4	121538								0	116	0.01	0.04			
261.31	261.33	28/5/61-63	lower Tt	0.2255	0.0037	447	9	120811								0	125	0.02	0.03			
261.72	261.74	28/5/102-104	lower Tt	0.2820	0.0044	516	10	117273								0	154	0.02	0.04			
262.11	262.13	28/5/141-143	lower Tt	0.3772	0.0030	336	5	112000								0	117	0.01	0.04			
262.45	262.47	28CC/8-10	lower Tt	0.3296	0.0053	589	15	111132								0	187	0.02	0.04			
264.30	264.32	29/1/0-2	lower Tt	0.3369	0.0025	250	4	100000								0	80	0.02	0.04			
264.64	264.66	29/1/34-36	lower Tt	0.3085	0.0044	438	10	99545								0	186	0.02	0.05			
264.88	264.90	29/1/58-60	lower Tt	0.3148	0.0041	419	11	102195								0	165	0.03	0.05			
265.26	265.28	29/1/96-98	lower Tt	0.4406	0.0034	436	17	128235								0	151	0.04	0.04			
265.72	265.74	29/1/142-144	lower Tt	0.5132	0.0044	389	5	88409								0	176	0.01	0.05			
266.12	266.14	29/2/32-34	lower Tt	0.3592	0.0044	362	16	82273								0	205	0.04	0.07			
266.44	266.46	29/2/64-66	lower Tt	0.1950	0.0030	320	9	106667								0	179	0.03	0.07			
266.87	266.89	29/2/107-109	lower Tt	0.3028	0.0031	291	12	93871								0	162	0.04	0.07			
267.31	267.33	29/3/1-3	lower Tt	0.1606	0.0037	302	18	81622								0	167	0.06	0.06			
267.53	267.55	29/3/23-25	lower Tt	0.1642	0.0039	386	15	98974								0	191	0.04	0.06			
267.72	267.74	29/3/42-44	lower Tt	0.1508	0.0045	479	9	106444								0	267	0.02	0.07			
267.87	267.89	29/3/57-59	lower Tt	0.1326	0.0035	400	24	114286								0	202	0.06	0.06			
268.14	268.16	29/3/84-86	lower Tt	0.1855	0.0029	378	10	130345								0	132	0.03	0.04			
268.34	268.36	29/3/104-106	lower Tt	0.2758	0.0043	402	9	93488								0	153	0.02	0.05			
268.47	268.49	29/3/117-119	lower Tt	0.1815	0.0055	641	19	116545								0	228	0.03	0.04			
268.68	268.70	29/3/138-140	lower Tt	0.1597	0.0024	266	3	110833								0	133	0.01	0.06			
268.86	268.88	29/4/6-8	lower Tt	0.2787	0.0024	238	5	99167								0	113	0.02	0.06			
269.28	269.30	29/4/48-50	lower Tt	0.3003	0.0023	239	6	103913								0	95	0.02	0.05			
269.52	269.54	29/4/72-74	lower Tt	0.1541	0.0024	290	6	120833								0	84	0.02	0.03			
269.75	269.77	29/4/95-97	lower Tt	0.2296	0.0037	399	17	107838								0	125	0.04	0.04			
269.87	269.89	29/4/107-109	lower Tt	0.2171	0.0038	354	14	93158								0	116	0.04	0.04			
270.15	270.17	29/4/135-137	lower Tt	0.2156	0.0035	404	15	115429								0	140	0.04	0.04			
270.31	270.33	29/5/1-3	lower Tt	0.2251	0.0037	458	11	123784								0	133	0.02	0.04			
270.45	270.47	29/5/15-17	lower Tt	0.3916	0.0032	295	8	92188								0	59	0.03	0.02			
270.72	270.74	29/5/42-44	lower Tt	0.1812	0.0027	312	2	115556								0	94	0.01	0.04			
270.91	270.93	29/5/61-63	lower Tt	0.2974	0.0039	391	9	100256								0	127	0.02	0.04			
271.15	271.17	29/5/85-87	lower Tt	0.1320	0.0041	393	11	95854								0	183	0.03	0.06			
271.34	271.36	29/5/104-106	lower Tt	0.1290	0.0041	363	16	88537								0	184	0.04	0.06			
271.48	271.50	29/5/118-120	lower Tt	0.2325	0.0037	379	9	102432								0	177	0.02	0.06			
271.72	271.74	29/5/142-144	lower Tt	0.3590	0.0023	253	2	110000								0	70	0.01	0.03			
271.94	271.96	29/6/14-16	lower Tt	0.3746	0.0031	362	7	116774								0	104	0.02	0.03			
272.19	272.21	29CC/17-19	lower Tt	0.3043	0.0045	613	13	136222								0	205	0.02	0.04			
273.91	273.93	30/1/1-A7303	lower Tt	0.2183	0.0033	391	6	118485								0	113	0.02	0.03			1
274.04	274.06	30/1/14-16	lower Tt	0.1829	0.0032	321	9	100313								0	122	0.03	0.05			6
274.32	274.34	30/1/42-44	lower Tt	0.1160	0.0033	420	13	128440								0	150	0.03	0.04			14
274.48	274.50	30/1/58-60	lower Tt	0.1692	0.0032	334	9	104375								0	145	0.03	0.05			8
274.72	274.74	30/1/82-84	lower Tt	0.1307	0.0043	484	13	112558								0	261	0.03	0.06			21
274.93	274.95	30/1/103-105	lower Tt	0.1204	0.0035	444	13	126857								0	156	0.03	0.04			22
275.12	275.14	30/1/122-124	lower Tt	0.1832	0.0039	507	9	130000								0	137	0.02	0.03			6
275.31	275.33	30/1/141-143	lower Tt	0.3696	0.0037	476	5	128649								0	80	0.01	0.02			16
275.45	275.47	30/2/5-7	lower Tt	0.3656	0.0029	384	5	132414								0	51	0.01	0.02			7
275.93	275.95	30/2/53-55	lower Tt	0.2828	0.0034	388	10	114118								0	113	0.03	0.04			2

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	Census aliquot weight (g)	Picked aliquot weight (g)	Total Planktics (n)	Total benthics (n)	Planktics /gram >150 um	* *Globigerinoides pyramidalis*	* *Globoconella inflata* sin	* *Truncorotalia* sp.?	* *Truncorotalia crassaformis* sin?	* *Truncorotalia crassula* s.s. dex	* *Truncorotalia crassula viola* sin	* *Truncorotalia tosaensis* sin	Total Contaminants	Fragment count	Frag. proxy = Benthics/(Bnthics + Planktics)	Frag. index = (frag./8)/(frag./8 + whole)	*Bolboforma praeintermedia*	*Bolboforma metzmacheri ornta*	*Bolboforma metzmacheri* s.s.
276.52	276.54	30/2/112-114	lower Tt	0.1531	0.0052	654	16	125769								0	268	0.02	0.05			2
276.91	276.93	30/3/1-3	lower Tt	0.1938	0.0030	380	12	126667								0	130	0.03	0.04			
277.33	277.35	30/3/43-45	lower Tt	0.2326	0.0033	455	10	137879								0	214	0.02	0.06			
277.74	277.76	30/3/84-86	lower Tt	0.2235	0.0034	449	4	132059								0	215	0.01	0.06			
278.07	278.09	30/3/117-119	lower Tt	0.2724	0.0036	491	7	136389								0	118	0.01	0.03			
278.49	278.51	30/4/9-11	lower Tt	0.2553	0.0039	575	12	147436								0	136	0.02	0.03			
278.88	278.90	30/4/48-50	lower Tt	0.1956	0.0032	424	11	132500								0	180	0.03	0.05			
279.33	279.35	30/4/93-95	lower Tt	0.1760	0.0030	349	10	116333								0	138	0.03	0.05			
279.75	279.77	30/4/135-137	lower Tt	0.1466	0.0032	373	19	116563								0	170	0.05	0.05			
280.05	280.07	30/5/15-17	lower Tt	0.1563	0.0035	496	7	141714								0	156	0.01	0.04			
280.25	280.27	30/5/35-37	lower Tt	0.1307	0.0047	604	16	128511								0	113	0.03	0.02			
280.92	280.94	30/5/102-104	lower Tt	0.1758	0.0028	401	17	143214								0	112	0.04	0.03			
283.51	283.53	31/1/1-3	lower Tt	0.2060	0.0031	464	9	149677								0	86	0.02	0.02			
283.94	283.96	31/1/44-46	lower Tt	0.3148	0.0031	459	6	148065								0	102	0.01	0.03			
284.33	284.35	31/1/83-85	lower Tt	0.1954	0.0029	432	5	148966								0	148	0.01	0.04			
284.55	284.57	31/1/105-107	lower Tt	0.2679	0.0044	571	14	129773								0	169	0.02	0.04			
284.88	284.90	31/1/138-140	lower Tt	0.2084	0.0029	491	11	169310								0	102	0.02	0.03			
285.29	285.31	31/2/29-31	lower Tt	0.2524	0.0027	411	6	152222								0	92	0.01	0.03			
285.73	285.75	31/2/73-75	lower Tt	0.3711	0.0028	396	4	141429								0	65	0.01	0.02			
286.10	286.12	31/2/110-112	lower Tt	0.2140	0.0034	462	23	135882								0	117	0.05	0.03			
286.51	286.53	31/3/1-3	lower Tt	0.2791	0.0044	605	14	137500								0	148	0.02	0.03			
286.88	286.90	31/3/38-40	lower Tt	0.2984	0.0029	364	6	125517								0	75	0.02	0.03			
287.32	287.34	31/3/82-84	lower Tt	0.2005	0.0029	366	9	126207								0	128	0.02	0.04			
287.67	287.69	31/3/117-119	lower Tt	0.1524	0.0040	580	18	145000								0	99	0.03	0.02			
288.08	288.10	31/4/8-10	lower Tt	0.1842	0.0038	603	12	158684								0	121	0.02	0.02			
288.55	288.57	31/4/55-57	lower Tt	0.1507	0.0049	613	23	125102								0	212	0.04	0.04			
288.89	288.91	31/4/89-91	lower Tt	0.1382	0.0039	282	10	72308								0	113	0.03	0.05			
289.34	289.36	31/4/134-136	lower Tt	0.1494	0.0033	594	13	180000								0	176	0.02	0.04			
289.73	289.75	31/5/23-25	lower Tt	0.1268	0.0031	513	9	165484								0	142	0.02	0.03			
290.12	290.14	31/5/62-64	lower Tt	0.2089	0.0036	417	10	115833								0	94	0.02	0.03			
290.51	290.53	31/5/101-103	lower Tt	0.2467	0.0037	535	7	144595								0	89	0.01	0.02			
290.74	290.76	31CC/0-2	lower Tt	0.1557	0.0038	554	13	145789								0	106	0.02	0.02			
293.11	293.13	32/1/1-3	lower Tt	0.1940	0.0031	429	6	138387								0	87	0.01	0.02			
293.33	293.35	32/1/23-25	lower Tt	0.1185	0.0035	511	10	146000								0	79	0.02	0.02			
293.71	293.73	32/1/61-63	lower Tt	0.1156	0.0034	442	12	130000								0	174	0.03	0.05			
294.12	294.14	32/1/102-104	lower Tt	0.1419	0.0032	416	6	130000								0	152	0.01	0.04			
294.51	294.53	32/1/141-143	lower Tt	0.1600	0.0053	824	19	155472								0	176	0.02	0.03			
294.90	294.92	32/2/30-32	lower Tt	0.0899	0.0043	578	8	134419								0	89	0.01	0.02			
295.33	295.35	32/2/73-75	lower Tt	0.1323	0.0036	496	16	137778								0	127	0.03	0.03			
295.73	295.75	32/2/113-115	lower Tt	0.0961	0.0034	374	26	110000								0	167	0.07	0.05			
295.93	295.95	32/2/133-135	lower Tt	0.2430	0.0062	330	9	53226								0	75	0.03	0.03			
296.50	296.52	32/3/40-42	lower Tt	0.2581	0.0038	405	6	106579								0	143	0.01	0.04			
296.93	296.95	32/3/83-85	lower Tt	0.2194	0.0037	428	18	115676								0	129	0.04	0.04			
297.33	297.35	32/3/123-125	lower Tt	0.2213	0.0035	247	12	70571								0	113	0.05	0.05			
297.70	297.72	32/4/10-12	lower Tt	0.1586	0.0055	470	22	85455								0	308	0.04	0.08			
298.08	298.10	32/4/48-50	lower Tt	0.1085	0.0038	415	8	109211								0	166	0.02	0.05			
298.52	298.54	32/4/92-94	lower Tt	0.2113	0.0035	375	9	107143								0	92	0.02	0.03			
298.93	298.95	32/4/133-135	lower Tt	0.1739	0.0040	449	15	112250								0	95	0.03	0.03			
299.38	299.40	32/5/28-30	lower Tt	0.2265	0.0038	481	7	126579								0	78	0.01	0.02			
299.67	299.69	32CC/2-4	lower Tt	0.1715	0.0050	626	13	125200								0	186	0.02	0.04			
302.71	302.73	33/1/1-3	lower Tt	0.1171	0.0033	395	11	119697								0	132	0.03	0.04			
302.97	302.99	33/1/27-29	lower Tt	0.0877	0.0039	385	19	98718								0	192	0.05	0.06			
303.29	303.31	33/1/59-61	lower Tt	0.0641	0.0044	442	29	100455								0	204	0.06	0.05			
303.77	303.79	33/1/107-109	lower Tt	0.0988	0.0044	414	22	94091								0	185	0.05	0.05			
304.13	304.15	33/1/143-145	lower Tt	0.0726	0.0040	372	16	93000								0	193	0.04	0.06			
304.29	304.31	33/2/9-11	lower Tt	0.0786	0.0039	392	29	100513								0	192	0.07	0.06			
304.47	304.49	33/2/27-29	lower Tt	0.0953	0.0057	653	29	114561								0	254	0.04	0.05			
304.66	304.68	33/2/46-48	lower Tt	0.1021	0.0035	424	28	121143								0	153	0.06	0.04			
305.02	305.04	33/2/82-84	lower Tt	0.0995	0.0035	440	13	125714								0	104	0.03	0.03			
305.15	305.17	33/2/95-97	lower Tt	0.1247	0.0036	326	30	90556								0	151	0.08	0.05			
305.34	305.36	33/2/114-116	lower Tt	0.1963	0.0031	339	10	109355								0	120	0.03	0.04			
305.55	305.57	33/2/135-137	lower Tt	0.0832	0.0042	398	33	94762								0	188	0.08	0.06			
305.71	305.73	33/3/1-3	lower Tt	0.1373	0.0035	361	6	103143								0	49	0.02	0.02			
305.93	305.95	33/3/23-25	lower Tt	0.1098	0.0035	325	17	92857								0	113	0.05	0.04			
306.11	306.13	33/3/41-43	lower Tt	0.1003	0.0027	359	16	132963								0	134	0.04	0.04			
306.27	306.29	33/3/57-59	lower Tt	0.1366	0.0037	479	8	129459								0	122	0.02	0.03			
306.54	306.56	33/3/84-86	lower Tt	0.1007	0.0031	416	18	134194								0	91	0.04	0.03			
306.75	306.77	33/3/105-107	lower Tt	0.0844	0.0062	649	35	104677								0	202	0.05	0.04			
306.86	306.88	33/3/116-118	lower Tt	0.0794	0.0035	344	22	98286								0	129	0.06	0.04			
307.08	307.10	33/3/138-140	lower Tt	0.0921	0.0038	347	34	91316								0	190	0.09	0.06			
307.30	307.32	33/4/10-12	lower Tt	0.1262	0.0040	323	20	80750								0	118	0.06	0.04			
307.49	307.51	33/4/29-31	lower Tt	0.0866	0.0034	246	27	72353								0	128	0.10	0.06			

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	Census aliquot weight (g)	Picked aliquot weight (g)	Total Planktics (n)	Total benthics (n)	Planktics /gram >150 um	* *Globigerinoides pyramidalis*	* *Globoconella inflata* sin	* *Truncorotalia* sp.?	* *Truncorotalia crassaformis* sin?	* *Truncorotalia crassula* s.s. dex	* *Truncorotalia crassula viola* sin	* *Truncorotalia tosaensis* sin	Total Contaminants	Fragment count	Frag. proxy = Benthics/(Bnthics + Planktics)	Frag. index = (frag./8)/(frag./8 + whole)	*Bolboforma praeintermedia*	*Bolboforma metzmacheri ornta*	*Bolboforma metzmacheri* s.s.
307.70	307.72	33/4/50-52	lower Tt	0.1152	0.0039	303	17	77692								0	151	0.05	0.06			
307.93	307.95	33/4/73-75	lower Tt	0.1702	0.0038	404	21	106316								0	102	0.05	0.03			
308.14	308.16	33/4/94-96	lower Tt	0.0805	0.0039	459	22	117692								0	114	0.05	0.03			
308.30	308.32	33/4/110-112	lower Tt	0.0862	0.0035	353	19	100857								0	161	0.05	0.05			
308.53	308.55	33/4/133-135	lower Tt	0.1239	0.0040	430	25	107500								0	134	0.05	0.04			
308.71	308.73	33/5/1-3	lower Tt	0.1765	0.0039	454	16	116410								0	157	0.03	0.04			
308.99	309.01	33/5/29-31	lower Tt	0.1190	0.0036	349	21	96944								0	157	0.06	0.05			
309.11	309.13	33/5/41-43	lower Tt	0.2067	0.0032	354	11	110625								0	113	0.03	0.04			
309.28	309.30	33/5/58-60	lower Tt	0.1899	0.0043	460	26	106977								0	118	0.05	0.03			
309.54	309.56	33/5/84-86	lower Tt	0.1455	0.0046	533	18	115870								0	137	0.03	0.03			
309.74	309.76	33/5/104-106	lower Tt	0.1281	0.0040	510	10	127500								0	137	0.02	0.03			
312.31	312.33	34/1/1-3	lower Tt	0.1153	0.0042	381	17	90714								0	137	0.04	0.04			
312.54	312.56	34/1/24-26	lower Tt	0.1006	0.0039	354	12	90769								0	120	0.03	0.04			
312.67	312.69	34/1/37-39	lower Tt	0.1379	0.0032	321	9	100313								0	141	0.03	0.05			
312.87	312.89	34/1/57-59	lower Tt	0.1018	0.0028	294	16	105000								0	164	0.05	0.07			
313.07	313.09	34/1/77-79	lower Tt	0.0873	0.0044	357	17	81136								0	222	0.05	0.07			
313.31	313.33	34/1/101-103	lower Tt	0.2148	0.0032	328	15	102500								0	123	0.04	0.04			
313.53	313.55	34/1/123-125	lower Tt	0.1796	0.0041	407	6	99268								0	158	0.01	0.05			
313.71	313.73	34/1/141-143	lower Tt	0.1601	0.0033	439	6	133030								0	134	0.01	0.04			
313.90	313.92	34/2/10-12	lower Tt	0.1278	0.0037	370	18	100000								0	144	0.05	0.05			
314.09	314.11	34/2/29-31	lower Tt	0.1000	0.0036	289	14	80278								0	175	0.05	0.07			
314.29	314.31	34/2/49-51	lower Tt	0.1060	0.0035	290	11	82857								0	159	0.04	0.06			
314.45	314.47	34/2/65-67	lower Tt	0.1706	0.0035	518	3	148000								0	113	0.01	0.03			
314.69	314.71	34/2/89-91	lower Tt	0.1262	0.0043	543	9	126279								0	96	0.02	0.02			
314.90	314.92	34/2/110-112	lower Tt	0.1598	0.0023	332	7	144348								0	75	0.02	0.03			
315.13	315.15	34/2/133-135	lower Tt	0.1405	0.0041	495	7	120732								0	139	0.01	0.03			
315.30	315.32	34/3/0-2	upper Sw	0.1599	0.0029	260	8	89655								0	60	0.03	0.03			
315.52	315.54	34/3/22-24	upper Sw	0.1117	0.0031	351	15	113226								0	132	0.04	0.04			
315.71	315.73	34/3/41-43	upper Sw	0.1435	0.0027	322	4	119259								0	98	0.01	0.04			
316.06	316.08	34/3/76-78	upper Sw	0.0796	0.0038	475	13	125000								0	119	0.03	0.03			
316.27	316.29	34/3/97-99	upper Sw	0.0815	0.0055	650	22	118182								0	206	0.03	0.04			
316.48	316.50	34/3/118-120	upper Sw	0.0808	0.0034	381	10	112059								0	127	0.03	0.04			
316.67	316.69	34/3/137-139	upper Sw	0.1000	0.0035	338	15	96571								0	91	0.04	0.03			
317.10	317.12	34/4/30-32	upper Sw	0.0943	0.0034	393	9	115588								0	159	0.02	0.05			
317.50	317.52	34/4/70-72	upper Sw	0.1194	0.0039	335	10	85897								0	180	0.03	0.06			
317.90	317.92	34/4/110-112	upper Sw	0.0925	0.0031	293	8	94516								0	143	0.03	0.06			
318.35	318.37	34/5/5-7	upper Sw	0.0714	0.0037	357	12	96486								0	200	0.03	0.07			
318.60	318.62	34/5/30-32	upper Sw	0.0633	0.0045	554	21	123111								0	212	0.04	0.05			
321.91	321.93	35/1/1-3	upper Sw	0.1047	0.0037	452	6	122162								0	122	0.01	0.03			
322.33	322.35	35/1/43-45	upper Sw	0.1285	0.0043	688	17	160000								0	145	0.02	0.03			
322.72	322.74	35/1/82-84	upper Sw	0.0771	0.0026	360	14	138462								0	109	0.04	0.04			
323.09	323.11	35/1/119-121	upper Sw	0.1197	0.0029	364	21	125517								0	111	0.05	0.04			
323.48	323.50	35/2/8-10	upper Sw	0.0630	0.0031	289	12	93226								0	172	0.04	0.07			
323.91	323.93	35/2/51-53	upper Sw	0.0912	0.0053	763	36	143962								0	227	0.05	0.04			
324.50	324.52	35/2/110-112	upper Sw	0.0329	0.0033	335	28	101515								0	239	0.08	0.08			
324.91	324.93	35/3/1-3	upper Sw	0.0430	0.0026	261	19	100385								0	127	0.07	0.06			
325.33	325.35	35/3/43-45	upper Sw	0.0571	0.0038	491	18	129211								0	160	0.04	0.04			
325.71	325.73	35/3/81-83	upper Sw	0.0830	0.0037	540	15	145946								0	122	0.03	0.03			
325.94	325.96	35/3/104-106	upper Sw	0.0306	0.0040	583	17	145750								0	174	0.03	0.04			
326.28	326.30	35/3/138-140	upper Sw	0.0644	0.0032	363	14	113438								0	166	0.04	0.05			
326.70	326.72	35/4/30-32	upper Sw	0.0728	0.0032	405	12	126563								0	86	0.03	0.03			
327.09	327.11	35/4/69-71	upper Sw	0.0911	0.0031	202	16	65161								0	145	0.07	0.08			
327.50	327.52	35/4/110-112	upper Sw	0.0634	0.0042	524	18	124762								0	167	0.03	0.04			
327.91	327.93	35/5/1-3	upper Sw	0.2370	0.0035	462	6	132000								0	105	0.01	0.03			
328.27	328.29	35/5/37-39	upper Sw	0.1600	0.0043	577	26	134186								0	136	0.04	0.03			
328.72	328.74	35/5/82-84	upper Sw	0.1555	0.0048	767	9	159792								0	157	0.01	0.02			
331.69	331.71	36/1/19-21	upper Sw	0.1348	0.0040	530	11	132500								0	98	0.02	0.02			
332.11	332.13	36/1/61-63	upper Sw	0.1800	0.0035	391	7	111714								0	119	0.02	0.04			
332.68	332.70	36/1/118-120	upper Sw	0.0363	0.0036	344	20	95556								0	80	0.05	0.03			
332.98	333.00	36/1/148-150	upper Sw	0.1074	0.0033	359	15	108788								0	83	0.04	0.03			
333.40	333.42	36/2/40-42	upper Sw	0.1076	0.0037	500	16	135135								0	98	0.03	0.02			
334.00	334.02	36/2/100-102	upper Sw	0.0639	0.0035	431	24	123143								0	124	0.05	0.03			
334.36	334.38	36/2/136-138	upper Sw	0.1070	0.0028	356	10	127143								0	74	0.03	0.03			
334.87	334.89	36/3/37-39	upper Sw	0.2059	0.0030	393	5	131000								0	51	0.01	0.02			
335.47	335.49	36/3/97-99	upper Sw	0.0878	0.0026	385	13	148077								0	65	0.03	0.02			
335.88	335.90	36/3/138-140	upper Sw	0.1150	0.0025	377	10	150800								0	76	0.03	0.02			
336.20	336.22	36/4/20-22	upper Sw	0.1229	0.0029	434	5	149655								0	94	0.01	0.03			
336.60	336.62	36/4/60-62	upper Sw	0.0614	0.0027	457	6	169259								0	60	0.01	0.02			

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Bolboforma gracilireticulata* s.l.	*Bolboforma pentispinosa*	*Bolboforma capsula*	*Bolboforma gruetzmacheri*	*Bolboforma subfragoris* s.l.	Echinoid spines	Fish teeth	Fish bones? (fragments)	Mollusc fragments	Mollusc fragments?	Ostracods	Dolomite?	Dolomite? (burrows)	Gypsum	Pyrite	Biotite	Volcanic glass shards
120.30	120.33	14/1/0-3	lower Wo											1						
120.51	120.54	14/1/21-24	lower Wo											1						
120.69	120.72	14/1/39-42	lower Wo											2						
120.90	120.93	14/1/60-63	lower Wo											2						
121.11	121.14	14/1/81-84	lower Wo											2						
121.26	121.29	14/1/96-99	lower Wo											2						
121.49	121.52	14/1/119-122	lower Wo											2						
121.69	121.72	14/1/139-142	lower Wo						1					2						
121.90	121.93	14/2/10-13	lower Wo											2						
122.09	122.12	14/2/29-32	lower Wo						1					1						
122.26	122.29	14/2/46-49	lower Wo											3						
122.51	122.55	14/2/71-75	lower Wo						1		1			1						
122.71	122.74	14/2/91-94	lower Wo						1											
122.92	122.95	14/2/112-115	lower Wo											1						
123.10	123.13	14/2/130-133	upper Tk											2						
123.30	123.33	14/3/0-3	upper Tk								1									
123.53	123.56	14/3/23-26	upper Tk											2						
123.69	123.72	14/3/39-42	upper Tk											3						
123.88	123.91	14/3/58-61	upper Tk											4						
124.11	124.14	14/3/81-84	upper Tk											3						
124.30	124.33	14/3/100-103	upper Tk						1	1				1						
124.50	124.53	14/3/120-123	upper Tk																	
124.68	124.71	14/3/138-141	upper Tk								1			2						
124.90	124.93	14/4/10-13	upper Tk											2						
125.10	125.13	14/4/30-33	upper Tk						3											
125.30	125.33	14/4/50-53	upper Tk						2					3						
125.48	125.51	14/4/68-71	upper Tk						1					2						
125.71	125.74	14/4/91-94	upper Tk											2						
125.91	125.94	14/4/111-114	upper Tk							2				5						
126.10	126.13	14/4/130-133	upper Tk											1						
126.30	126.33	14/5/0-3	upper Tk							1				2						
126.56	126.59	14/5/26-29	upper Tk											6						
126.70	126.73	14/5/40-43	upper Tk											1						
126.90	126.93	14/5/60-63	upper Tk											2						
127.12	127.15	14/5/82-85	upper Tk											1						
127.30	127.33	14/5/100-103	upper Tk						2					2						
127.51	127.54	14/5/121-124	upper Tk																	
127.70	127.73	14/5/140-143	upper Tk						2					2						
127.90	127.93	14/6/10-13	upper Tk																	
128.29	128.32	14/6/49-52	upper Tk																	
128.72	128.75	14/6/92-95	upper Tk											1						
129.10	129.13	14/6/130-133	upper Tk						1											
129.50	129.53	14/7/20-23	upper Tk						1					1						
129.90	129.93	15/1/0-3	upper Tk											1						
130.29	130.32	15/1/39-42	upper Tk																	
130.69	130.72	15/1/79-82	upper Tk																	
131.10	131.13	15/1/120-123	upper Tk																	
131.51	131.54	15/2/11-14	upper Tk						1					2						
131.91	131.93	15/2/51-53	upper Tk							1				2						
132.33	132.36	15/2/93-96	upper Tk																	
132.74	132.76	15/2/134-136	upper Tk											2						
133.07	133.10	15/3/17-20	upper Tk																	
133.46	133.49	15/3/56-59	upper Tk							3				1						
133.89	133.92	15/3/99-102	upper Tk											1						
134.30	134.33	15/3/140-143	upper Tk											1						
134.70	134.73	15/4/30-33	upper Tk											2						
135.10	135.13	15/4/70-73	upper Tk											3						
135.30	135.33	15/4/90-93	upper Tk											1						
135.50	135.53	15/4/110-113	upper Tk											1						
135.70	135.73	15/4/130-133	upper Tk											1						
135.90	135.93	15/5/0-3	upper Tk						1					1						
136.06	136.09	15/5/16-19	upper Tk											1						
136.32	136.35	15/5/42-45	upper Tk																	
136.51	136.53	15/5/61-63	upper Tk											1						
136.92	136.95	15/5/102-105	upper Tk											2						
137.13	137.16	15/5/123-126	upper Tk											1						
137.52	137.55	15/6/12-15	upper Tk											1						
137.91	137.94	15/6/51-54	upper Tk											1						
138.27	138.30	15/6/87-90	upper Tk											1						
138.66	138.69	15/6/126-129	upper Tk																	
139.07	139.10	15/7/17-20	upper Tk																	
139.50	139.53	16/1/0-3	upper Tk						2					1		1				

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Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Bolboforma gracilireticulata* s.l.	*Bolboforma pentispinosa*	*Bolboforma capsula*	*Bolboforma gruetzmacheri*	*Bolboforma subfragoris* s.l.	Echinoid spines	Fish teeth	Fish bones? (fragments)	Mollusc fragments	Mollusc fragments?	Ostracods	Dolomite?	Dolomite? (burrows)	Gypsum	Pyrite	Biotite	Volcanic glass shards
139.93	139.96	16/1/43-46	upper Tk						2											
140.34	140.37	16/1/84-87	upper Tk																	
140.73	140.76	16/1/123-126	upper Tk						1					2						
141.13	141.15	16/2/13-16	upper Tk																	
141.54	141.57	16/2/54-57	upper Tk						1					4				1		
141.92	141.95	16/2/92-95	upper Tk									1		1				1		
142.32	142.35	16/2/132-135	upper Tk																	
142.75	142.78	16/3/25-28	upper Tk																	
143.15	143.18	16/3/65-68	upper Tk											1						
143.53	143.56	16/3/103-106	upper Tk						1					5						
143.84	143.87	16/3/134-137	lower Tk																	
144.26	144.29	16/4/26-29	lower Tk											2				1		
144.67	144.70	16/4/67-70	lower Tk											1						
145.13	145.16	16/4/113-116	lower Tk																	
145.50	145.53	16/5/0-3	lower Tk											1						
145.93	145.96	16/5/43-46	lower Tk								1			1		2		1		
146.36	146.38	16/5/86-88	lower Tk																	
146.71	146.74	16/5/121-124	lower Tk											1						
147.06	147.09	16/6/6-9	lower Tk																	
147.47	147.50	16/6/47-50	lower Tk											1						
147.93	147.96	16/6/93-96	lower Tk											1						
148.33	148.36	16/6/133-136	lower Tk											1						
148.67	148.69	16/7/17-19	lower Tk											2						
149.10	149.13	17/1/0-3	lower Tk											2						
149.52	149.55	17/1/42-45	lower Tk						1					2						
150.11	150.14	17/1/101-104	lower Tk																	
150.51	150.54	17/1/141-144	lower Tk											2						
150.87	150.90	17/2/27-30	lower Tk											1						
151.07	151.10	17/2/47-50	lower Tk											2						
151.52	151.55	17/2/92-95	lower Tk						1		1			1				1		
151.96	151.98	17/2/136-138	lower Tk								1									
152.10	152.13	17/3/0-3	lower Tk											2						
152.25	152.28	17/3/15-18	lower Tk																	
152.47	152.50	17/3/37-40	lower Tk																	
152.75	152.77	17/3/65-67	lower Tk											3						
152.91	152.94	17/3/81-84	lower Tk											1						
153.12	153.15	17/3/102-105	lower Tk																	
153.26	153.29	17/3/116-119	lower Tk																	
153.45	153.48	17/3/135-138	lower Tk								1									
153.66	153.69	17/4/6-9	lower Tk													1				
153.97	153.99	17/4/37-39	lower Tk																	
154.13	154.16	17/4/53-56	lower Tk																	
154.32	154.35	17/4/72-75	lower Tk																	
154.54	154.57	17/4/94-97	lower Tk																	
154.77	154.79	17/4/117-119	lower Tk																	
154.95	154.98	17/4/135-138	lower Tk											1						
155.10	155.13	17/5/0-3	lower Tk																	
155.24	155.27	17/5/14-17	lower Tk																	
155.48	155.50	17/5/38-40	lower Tk								1									
155.67	155.70	17/5/57-60	lower Tk															1		
155.94	155.97	17/5/84-87	lower Tk											2						
156.13	156.16	17/5/103-106	lower Tk																	
156.27	156.30	17/5/117-120	lower Tk						1											
156.47	156.50	17/5/137-140	lower Tk											2						
156.71	156.74	17/6/11-14	lower Tk																	
156.95	156.98	17/6/35-38	lower Tk						1											
157.12	157.15	17/6/52-55	lower Tk																	
157.37	157.39	17/6/77-79	lower Tk																	
157.52	157.55	17/6/92-95	lower Tk							2				1						
157.76	157.79	17/6/116-119	lower Tk											1				1		
157.93	157.96	17/6/133-136	lower Tk																	
158.10	153.13	17/7/0-3	lower Tk											2						
158.27	158.30	17/7/17-20	lower Tk							1				1						
158.52	158.55	17CC/6-9	lower Tk						1							1				
158.70	158.73	18/1/0-3	lower Tk																	
158.95	158.98	18/1/25-28	lower Tk						1											
159.13	159.16	18/1/43-46	lower Tk																	
159.35	159.38	18/1/65-68	lower Tk											1						
159.49	159.52	18/1/79-82	lower Tk											1						
159.72	159.75	18/1/102-105	lower Tk																	
159.86	159.89	18/1/116-119	lower Tk																	
160.11	160.14	18/1/141-144	lower Tk																	

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Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Bolboforma gracilireticulata* s.l.	*Bolboforma pentispinosa*	*Bolboforma capsula*	*Bolboforma gruetzmacheri*	*Bolboforma subfragoris* s.l.	Echinoid spines	Fish teeth	Fish bones? (fragments)	Mollusc fragments	Mollusc fragments?	Ostracods	Dolomite?	Dolomite? (burrows)	Gypsum	Pyrite	Biotite	Volcanic glass shards
160.33	160.36	18/2/13-16	lower Tk											1						
160.73	160.76	18/2/53-56	lower Tk																	
161.16	161.19	18/2/96-99	lower Tk											1		1				
161.53	161.56	18/2/133-136	lower Tk																	
161.84	161.87	18/3/14-17	lower Tk																	
162.26	162.29	18/3/56-59	lower Tk						1											
162.87	162.90	18/3/117-120	lower Tk						2					1						
163.33	163.36	18/4/13-16	lower Tk																	
163.56	163.59	18/4/36-39	lower Tk						2											
163.93	163.96	18/4/73-76	lower Tk																	
164.31	164.33	18/4/111-113	lower Tk													1				
164.70	164.73	18/5/0-3	lower Tk											1						
165.13	165.16	18/5/43-46	lower Tk						1											
165.50	165.53	18/5/80-83	lower Tk						1											
165.95	165.97	18/5/125-127	lower Tk											1						
166.26	166.29	18/6/6-9	lower Tk						1											
166.66	166.69	18/6/46-49	lower Tk																	
167.06	167.09	18/6/86-89	lower Tk																	
167.44	167.47	18/6/124-127	upper Tt											1						
168.30	168.33	19/1/0-3	upper Tt																	
168.71	168.74	19/1/41-44	upper Tt						1					3						
169.13	169.15	19/1/83-85	upper Tt																	
169.51	169.54	19/1/121-124	upper Tt						1											
169.85	169.88	19/2/5-8	upper Tt						2	1										
170.32	170.35	19/2/52-55	upper Tt						2					1						
170.73	170.76	19/2/93-96	upper Tt						1					1						
171.15	171.18	19/2/135-138	upper Tt											1						
171.57	171.59	19/3/27-29	upper Tt																	
171.92	171.94	19/3/62-64	upper Tt																	
172.32	172.35	19/3/102-105	upper Tt																	
172.66	172.68	19/3/136-138	upper Tt						1					2						
173.07	173.09	19/4/27-29	upper Tt																	
173.52	173.54	19/4/72-74	upper Tt																	
173.93	173.95	19/4/113-115	upper Tt						1											
174.30	174.33	19/5/0-3	upper Tt											3						
174.72	174.75	19/5/42-45	upper Tt																	
175.26	175.28	19/5/96-99	upper Tt						1	1						1				
175.71	175.74	19/5/141-144	upper Tt						2	1				1				1		
176.06	176.09	19/6/26-29	upper Tt											1						
176.47	176.49	19/6/67-69	upper Tt						1									1		
176.92	176.94	19/6/112-114	upper Tt						1											
177.30	177.33	19/7/0-3	upper Tt											1				1		
177.52	177.55	19/7/22-25	upper Tt						1											
177.90	177.93	20/1/0-3	upper Tt						1	1			1	1						
178.27	178.30	20/1/37-40	upper Tt											1				1		
178.68	178.70	20/1/78-80	upper Tt						3					1		3				
179.08	179.10	20/1/118-120	upper Tt						3							7		1		
179.45	179.47	20/2/5-7	upper Tt						2					1						
179.86	179.88	20/2/46-48	upper Tt						1											
180.33	180.35	20/2/93-95	upper Tt						1											
180.73	180.75	20/2/133-135	upper Tt																	
181.14	181.16	20/3/24-26	upper Tt						7											
181.57	181.59	20/3/67-69	upper Tt						2					1				1		
181.86	181.88	20/3/96-98	upper Tt											2						
182.23	182.25	20/3/133-135	upper Tt						7					1						
182.68	182.70	20/4/28-30	upper Tt						5					2						
183.08	183.10	20/4/68-70	upper Tt						2					1				1		
183.45	183.47	20/4/105-107	upper Tt						7											
183.91	183.93	20/5/1-3	upper Tt						1	2				2						
184.32	184.34	20/5/42-44	upper Tt																	
184.72	184.74	20/5/82-84	upper Tt						1					1						
185.07	185.09	20/5/117-119	upper Tt																	
185.47	185.49	20/6/7-9	upper Tt																	
185.92	185.94	20/6/52-54	upper Tt											1						
186.32	186.34	20/6/92-94	upper Tt																	
186.72	186.74	20/6/132-134	upper Tt						2											
187.07	187.09	20/7/17-19	upper Tt																	
187.51	187.53	21/1/1-3	upper Tt						1					2						
187.93	187.95	21/1/43-45	upper Tt						1					1		1				
188.32	188.34	21/182-84	upper Tt																	
188.67	188.69	21/1/117-119	upper Tt											2						
189.08	189.10	21/2/8-10	upper Tt						1					2						

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Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Bolboforma gracilireticulata* s.l.	*Bolboforma pentispinosa*	*Bolboforma capsula*	*Bolboforma gruetzmacheri*	*Bolboforma subfragoris* s.l.	Echinoid spines	Fish teeth	Fish bones? (fragments)	Mollusc fragments	Mollusc fragments?	Ostracods	Dolomite?	Dolomite? (burrows)	Gypsum	Pyrite	Biotite	Volcanic glass shards
189.46	189.48	21/2/46-48	upper Tt																	
189.93	189.96	21/2/93-96	upper Tt											1						
190.42	190.44	21/2/142-144	upper Tt						1											
190.66	190.68	21/3/16-18	upper Tt																	
191.12	191.14	21/3/62-64	upper Tt																	
191.52	191.54	21/3/102-104	upper Tt						1											
191.86	191.89	21/3/136-139	upper Tt						2											
192.36	192.38	21/4/36-38	upper Tt							1				1		1				
192.73	193.75	21/4/73-75	upper Tt						1											
193.12	193.14	21/4/112-114	upper Tt								1			1				1		
193.50	193.52	21/5/0-2	upper Tt							1										
193.92	193.94	21/5/42-44	upper Tt						1											
194.34	194.26	21/5/84-86	upper Tt																	
194.72	194.74	21/5/122-124	upper Tt																	
195.07	195.09	21/6/7-9	upper Tt													2				
195.49	195.51	21/6/49-51	upper Tt																	
195.87	195.89	21/6/87-89	upper Tt						2					1						
196.34	196.36	21/6/134-136	upper Tt																	
196.72	196.74	21/7/22-24	upper Tt						1											
197.11	197.13	22/1/1-3	upper Tt						2											
197.48	197.50	22/1/38-40	upper Tt																	
197.94	197.96	22/1/84-86	upper Tt																	
198.32	198.34	22/1/122-124	upper Tt																	
198.73	198.75	22/2/13-15	upper Tt							1						1				
199.14	199.16	22/2/54-56	upper Tt							1										
199.53	199.55	22/2/93-95	upper Tt																	
199.93	199.95	22/2/133-135	upper Tt							1				1		1				
200.25	200.27	22/3/15-17	upper Tt												2					
200.66	200.68	22/3/56-58	upper Tt																	
201.05	201.07	22/3/95-97	upper Tt																	
201.42	201.44	22/3/132-134	upper Tt																	
201.93	201.95	22/4/33-35	upper Tt																	
202.52	202.55	22/4/92-95	upper Tt																	
202.93	202.95	22/4/133-135	upper Tt							1				1						
203.17	203.20	22CC/7-10	upper Tt																	
206.71	206.73	23/1/1-3	upper Tt							1				1		5				
207.13	207.15	23/1/43-45	upper Tt											1						
207.48	207.50	23/1/78-80	upper Tt																	
207.88	207.90	23/1/118-120	upper Tt											4	1					
208.26	208.28	23/2/6-8	upper Tt											2						
208.52	208.54	23/2/32-34	upper Tt						1					1						
209.06	209.08	23/2/86-88	upper Tt											1						
209.54	209.56	23/2/134-136	upper Tt											2						
209.85	209.87	23/3/15-17	upper Tt											2						
210.33	210.35	23/3/63-65	upper Tt							1										
210.53	210.55	23/3/83-85	upper Tt						1					1						
210.87	210.89	23/3/117-119	upper Tt											1						
211.27	211.29	23/4/7-9	upper Tt											1	2					
211.72	211.74	23/4/52-54	upper Tt											1						
212.13	212.15	23/4/93-95	upper Tt																	
212.32	212.34	23/4/112-114	upper Tt																	
212.71	212.73	23/5/1-3	upper Tt						1											
213.12	213.14	23/5/42-44	upper Tt						1					1						
213.72	213.74	23/5/102-104	upper Tt																	
214.12	214.14	23/5/142-144	upper Tt											1						
214.51	214.53	23/6/31-33	upper Tt											3						
215.05	215.07	23/6/85-87	upper Tt																	
215.53	215.55	23/6/133-135	upper Tt											2						
215.93	215.95	23/7/23-25	upper Tt																	
216.31	216.33	24/1/1-3	upper Tt																	
216.57	216.59	24/1/27-29	upper Tt																	
216.94	216.96	24/1/64-66	upper Tt											1						
217.34	217.36	24/1/104-106	upper Tt											1						
217.72	217.74	24/1/142-144	upper Tt							1										
218.08	218.10	24/2/28-30	upper Tt																	
218.52	218.54	24/2/72-74	upper Tt											1						
218.87	218.89	24/2/107-109	upper Tt						1											
219.31	219.33	24/3/1-3	upper Tt						1					1						
219.72	219.74	24/3/42-44	upper Tt											1						
220.12	220.14	24/3/82-84	upper Tt											2						
220.46	220.48	24/3/116-118	upper Tt																	
220.87	220.89	24/4/7-9	upper Tt						1					1						

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Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Bolboforma gracilireticulata* s.l.	*Bolboforma pentispinosa*	*Bolboforma capsula*	*Bolboforma gruetzmacheri*	*Bolboforma subfragoris* s.l.	Echinoid spines	Fish teeth	Fish bones? (fragments)	Mollusc fragments	Mollusc fragments?	Ostracods	Dolomite?	Dolomite? (burrows)	Gypsum	Pyrite	Biotite	Volcanic glass shards
221.27	221.29	24/4/47-49	upper Tt																	
221.66	221.68	24/4/86-88	upper Tt											3						
222.13	222.15	24/4/133-135	upper Tt																	
222.45	222.47	24/5/15-17	upper Tt																	
222.93	222.95	24/5/63-65	upper Tt																	
223.33	223.35	24/5/103-105	upper Tt											1						
223.72	223.74	24/5/142-144	upper Tt																	
224.07	224.09	24/6/27-29	upper Tt																	
224.47	224.49	24/6/67-69	upper Tt						1											
224.87	224.89	24/6/107-109	upper Tt																	
225.36	225.38	24CC/9-11	upper Tt																	
226.13	226.15	25/1/23-25	upper Tt													1				
226.53	226.55	25/1/63-65	upper Tt								1									
226.93	226.95	25/1/103-105	upper Tt								1									
227.34	227.36	25/1/144-146	upper Tt											1						
227.72	227.74	25/2/-32-34	upper Tt																	
228.12	228.14	25/2/72-74	upper Tt																	
228.52	228.54	25/2/112-114	upper Tt																	
228.90	228.92	25/3/0-2	upper Tt						1											
229.33	229.35	25/3/43-45	upper Tt											1						
229.85	229.87	25/3/95-97	upper Tt																	
230.27	230.29	25/3/137-139	upper Tt						1											
230.47	230.49	25/4/7-9	upper Tt						1					4						
230.93	230.95	25/4/53-55	upper Tt						1											
231.33	231.35	25/4/93-95	upper Tt											1						
231.73	231.75	25/4/133-135	upper Tt											1						
232.06	232.08	25/5/16-18	upper Tt						1					1						
232.52	232.54	25/5/62-64	upper Tt							1				1						
232.92	232.94	25/5/102-104	upper Tt																	
233.27	233.29	25/5137-139	upper Tt																	
233.67	233.69	25/6/27-29	upper Tt											1						
234.15	234.17	25/6/75-77	upper Tt											1						
234.52	234.54	25/6/112-114	upper Tt																	
234.91	234.93	25/7/1-3	upper Tt						1											
235.26	235.28	25CC/10-22	upper Tt						2					1				3		
235.73	235.75	26/1/23-25	upper Tt																	
236.08	236.10	26/1/58-60	upper Tt															1		
236.52	236.54	26/1/102-104	upper Tt																	
236.92	236.94	26/1/142-144	upper Tt							1										
237.32	237.34	26/2/32-34	upper Tt						1											
237.93	237.95	26/2/93-95	upper Tt											1						
238.33	238.35	26/2/133-135	upper Tt						1					1						
238.51	238.53	26/3/1-3	upper Tt																	
238.93	238.95	26/3/43-45	upper Tt																	
239.32	239.34	26/3/82-84	upper Tt											1						
239.67	239.69	26/3/117-119	upper Tt						1											
240.07	240.09	26/4/7-9	upper Tt																	
240.52	240.54	26/4/52-54	upper Tt											1						
240.92	240.94	26/4/92-94	upper Tt																	
241.32	241.34	26/4/132-134	upper Tt							1				1						
241.65	241.67	26/5/15-17	upper Tt						1	2										
242.13	242.15	26/5/63-65	upper Tt						1	1				2						
242.52	242.54	26/5/102-104	upper Tt						1											
242.92	242.94	26/5/142-144	upper Tt											1						
243.26	243.28	26/6/26-28	upper Tt															1		
243.63	243.65	26/6/63-65	upper Tt						1					2						
243.86	243.88	26CC/13-15	upper Tt											1				1		
245.11	245.13	27/1/1-3	upper Tt																	
245.53	245.55	27/1/43-45	upper Tt						1					1				1		
245.91	245.93	27/1/81-83	upper Tt																	
246.27	246.29	27/1/117-119	upper Tt						1					2						
246.52	246.54	27/1/142-144	upper Tt						1		2			1						
246.87	246.89	27/2/27-29	upper Tt						1									5		
247.33	247.35	27/2/73-76	upper Tt																	
247.67	247.69	27/2/107-109	upper Tt																	
248.11	248.13	27/3/1-3	upper Tt											2						
248.47	248.49	27/3/37-39	upper Tt						2					1						
248.93	248.95	27/3/83-85	upper Tt						1											
249.27	249.27	27/3/117-119	upper Tt							1										
249.67	249.69	27/4/7-9	upper Tt							1				1						
250.12	250.14	27/4/52-54	upper Tt						1					1						
250.46	250.48	27/4/86-88	upper Tt							1										

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Bolboforma gracilireticulata* s.l.	*Bolboforma pentispinosa*	*Bolboforma capsula*	*Bolboforma gruetzmacheri*	*Bolboforma subfragoris* s.l.	Echinoid spines	Fish teeth	Fish bones? (fragments)	Mollusc fragments	Mollusc fragments?	Ostracods	Dolomite?	Dolomite? (burrows)	Gypsum	Pyrite	Biotite	Volcanic glass shards
250.92	250.94	27/4/132-134	upper Tt						5											
251.33	251.36	27/5/23-26	upper Tt							1	1			1						
251.67	251.69	27/5/57-59	upper Tt						2											
252.13	252.15	27/5/103-105	upper Tt							1				1						
252.53	252.55	27/5/143-145	upper Tt								1									
252.92	252.94	27/6/32-34	upper Tt						1		1			3						
253.33	253.35	27/6/73-75	upper Tt											2						
253.67	253.69	27/6/107-109	upper Tt											1						
254.10	254.12	27/7/0-2	upper Tt						3					1						
254.49	254.51	27CC/10-12	lower Tt						1											
254.93	254.95	28/4/23-25	lower Tt											1						
255.28	255.30	28/1/58-60	lower Tt						1											
255.73	255.75	28/1/103-105	lower Tt																	
256.11	256.13	28/1/141-143	lower Tt								2									
256.53	256.55	28/2/33-35	lower Tt						2											
257.03	257.05	28/2/83-85	lower Tt																	
257.33	257.35	28/2/113-115	lower Tt							1								1		
257.71	257.73	28/3/1-3	lower Tt																	
258.12	258.14	28/3/42-44	lower Tt							1										
258.54	258.56	28/3/84-86	lower Tt																	
259.07	259.09	28/3/137-139	lower Tt								1									
259.53	259.55	28/4/33-35	lower Tt							1	2			1		1				
259.86	259.88	28/4/66-68	lower Tt							1				1						
260.28	260.30	28/4/108-110	lower Tt																	
260.54	260.56	28/4/134-136	lower Tt						1					1						1
260.86	260.88	28/5/16-18	lower Tt							1										
261.31	261.33	28/5/61-63	lower Tt											1				1		
261.72	261.74	28/5/102-104	lower Tt						1											
262.11	262.13	28/5/141-143	lower Tt									1								
262.45	262.47	28CC/8-10	lower Tt																	
264.30	264.32	29/1/0-2	lower Tt																	
264.64	264.66	29/1/34-36	lower Tt																	
264.88	264.90	29/1/58-60	lower Tt																	
265.26	265.28	29/1/96-98	lower Tt											1						
265.72	265.74	29/1/142-144	lower Tt							1										
266.12	266.14	29/2/32-34	lower Tt																	
266.44	266.46	29/2/64-66	lower Tt						1											
266.87	266.89	29/2/107-109	lower Tt																	
267.31	267.33	29/3/1-3	lower Tt																	
267.53	267.55	29/3/23-25	lower Tt																	
267.72	267.74	29/3/42-44	lower Tt																	
267.87	267.89	29/3/57-59	lower Tt												1					
268.14	268.16	29/3/84-86	lower Tt						1	1										
268.34	268.36	29/3/104-106	lower Tt																	
268.47	268.49	29/3/117-119	lower Tt								1									
268.68	268.70	29/3/138-140	lower Tt							1										
268.86	268.88	29/4/6-8	lower Tt							1				1						
269.28	269.30	29/4/48-50	lower Tt											1				1		
269.52	269.54	29/4/72-74	lower Tt						1											
269.75	269.77	29/4/95-97	lower Tt																	
269.87	269.89	29/4/107-109	lower Tt							1				1	3					
270.15	270.17	29/4/135-137	lower Tt																	
270.31	270.33	29/5/1-3	lower Tt								1									
270.45	270.47	29/5/15-17	lower Tt																	
270.72	270.74	29/5/42-44	lower Tt										1							
270.91	270.93	29/5/61-63	lower Tt											2						
271.15	271.17	29/5/85-87	lower Tt											1					1	
271.34	271.36	29/5/104-106	lower Tt															2	3	
271.48	271.50	29/5/118-120	lower Tt															4		
271.72	271.74	29/5/142-144	lower Tt										1				1			
271.94	271.96	29/6/14-16	lower Tt											1						
272.19	272.21	29CC/17-19	lower Tt						3	1	1									
273.91	273.93	30/1/1-A7303	lower Tt						1		1			1						
274.04	274.06	30/1/14-16	lower Tt																	
274.32	274.34	30/1/42-44	lower Tt											1				1		
274.48	274.50	30/1/58-60	lower Tt								2									
274.72	274.74	30/1/82-84	lower Tt											1						
274.93	274.95	30/1/103-105	lower Tt											2						
275.12	275.14	30/1/122-124	lower Tt						1					1						
275.31	275.33	30/1/141-143	lower Tt						2					1						
275.45	275.47	30/2/5-7	lower Tt											1						
275.93	275.95	30/2/53-55	lower Tt																	

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Bolboforma gracilireticulata* s.l.	*Bolboforma pentispinosa*	*Bolboforma capsula*	*Bolboforma gruetzmacheri*	*Bolboforma subfragoris* s.l.	Echinoid spines	Fish teeth	Fish bones? (fragments)	Mollusc fragments	Mollusc fragments?	Ostracods	Dolomite?	Dolomite? (burrows)	Gypsum	Pyrite	Biotite	Volcanic glass shards
276.52	276.54	30/2/112-114	lower Tt																	
276.91	276.93	30/3/1-3	lower Tt																	
277.33	277.35	30/3/43-45	lower Tt						1											
277.74	277.76	30/3/84-86	lower Tt											1						
278.07	278.09	30/3/117-119	lower Tt						1	1										
278.49	278.51	30/4/9-11	lower Tt								4									
278.88	278.90	30/4/48-50	lower Tt											4						
279.33	279.35	30/4/93-95	lower Tt																	
279.75	279.77	30/4/135-137	lower Tt	1														1		
280.05	280.07	30/5/15-17	lower Tt															1		
280.25	280.27	30/5/35-37	lower Tt											1				4		
280.92	280.94	30/5/102-104	lower Tt																	
283.51	283.53	31/1/1-3	lower Tt								1									
283.94	283.96	31/1/44-46	lower Tt	1																
284.33	284.35	31/1/83-85	lower Tt						1											
284.55	284.57	31/1/105-107	lower Tt								1									
284.88	284.90	31/1/138-140	lower Tt															1		
285.29	285.31	31/2/29-31	lower Tt																	
285.73	285.75	31/2/73-75	lower Tt																	
286.10	286.12	31/2/110-112	lower Tt							1										
286.51	286.53	31/3/1-3	lower Tt						1		1									
286.88	286.90	31/3/38-40	lower Tt						1	2				1						
287.32	287.34	31/3/82-84	lower Tt		1					3								1		
287.67	287.69	31/3/117-119	lower Tt						2					1						
288.08	288.10	31/4/8-10	lower Tt		2				1					1						
288.55	288.57	31/4/55-57	lower Tt		2				1		1			1						
288.89	288.91	31/4/89-91	lower Tt		8					1										
289.34	289.36	31/4/134-136	lower Tt		45				1	1										
289.73	289.75	31/5/23-25	lower Tt		6	2														
290.12	290.14	31/5/62-64	lower Tt			6				1										
290.51	290.53	31/5/101-103	lower Tt			10			1									3		
290.74	290.76	31CC/0-2	lower Tt			2														
293.11	293.13	32/1/1-3	lower Tt			8					2									
293.33	293.35	32/1/23-25	lower Tt																	
293.71	293.73	32/1/61-63	lower Tt						1											
294.12	294.14	32/1/102-104	lower Tt											1						
294.51	294.53	32/1/141-143	lower Tt								1									
294.90	294.92	32/2/30-32	lower Tt																	
295.33	295.35	32/2/73-75	lower Tt						1						1			2		
295.73	295.75	32/2/113-115	lower Tt				3			1										
295.93	295.95	32/2/133-135	lower Tt				12		1								1			
296.50	296.52	32/3/40-42	lower Tt								1			1						
296.93	296.95	32/3/83-85	lower Tt				1													
297.33	297.35	32/3/123-125	lower Tt				1													
297.70	297.72	32/4/10-12	lower Tt				2											9		
298.08	298.10	32/4/48-50	lower Tt				10			1										
298.52	298.54	32/4/92-94	lower Tt						1											
298.93	298.95	32/4/133-135	lower Tt																	
299.38	299.40	32/5/28-30	lower Tt											1				2		
299.67	299.69	32CC/2-4	lower Tt						1					1						
302.71	302.73	33/1/1-3	lower Tt																	
302.97	302.99	33/1/27-29	lower Tt																	
303.29	303.31	33/1/59-61	lower Tt											2				1		
303.77	303.79	33/1/107-109	lower Tt																	
304.13	304.15	33/1/143-145	lower Tt							1										
304.29	304.31	33/2/9-11	lower Tt											1		1				
304.47	304.49	33/2/27-29	lower Tt						1		2									
304.66	304.68	33/2/46-48	lower Tt											1				1		
305.02	305.04	33/2/82-84	lower Tt																	
305.15	305.17	33/2/95-97	lower Tt																	
305.34	305.36	33/2/114-116	lower Tt																	
305.55	305.57	33/2/135-137	lower Tt													1				
305.71	305.73	33/3/1-3	lower Tt							1						1				
305.93	305.95	33/3/23-25	lower Tt					1												
306.11	306.13	33/3/41-43	lower Tt																	
306.27	306.29	33/3/57-59	lower Tt					3										2		
306.54	306.56	33/3/84-86	lower Tt					4		1				2						
306.75	306.77	33/3/105-107	lower Tt					16						1						
306.86	306.88	33/3/116-118	lower Tt					12								1		2		
307.08	307.10	33/3/138-140	lower Tt					12												
307.30	307.32	33/4/10-12	lower Tt					4						1						
307.49	307.51	33/4/29-31	lower Tt												1					

Data Appendix 1.1

Census data: DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section/Interval	NZ Stage	*Bolboforma graciliireticulata* s.l.	*Bolboforma pentispinosa*	*Bolboforma capsula*	*Bolboforma gruetzmacheri*	*Bolboforma subfragoris* s.l.	Echinoid spines	Fish teeth	Fish bones? (fragments)	Mollusc fragments	Mollusc fragments?	Ostracods	Dolomite?	Dolomite? (burrows)	Gypsum	Pyrite	Biotite	Volcanic glass shards
307.70	307.72	33/4/50-52	lower Tt							2										
307.93	307.95	33/4/73-75	lower Tt							1						1		1		
308.14	308.16	33/4/94-96	lower Tt							1				1				2		
308.30	308.32	33/4/110-112	lower Tt																	
308.53	308.55	33/4/133-135	lower Tt								1							1		
308.71	308.73	33/5/1-3	lower Tt											1						
308.99	309.01	33/5/29-31	lower Tt							1										
309.11	309.13	33/5/41-43	lower Tt							1								1		
309.28	309.30	33/5/58-60	lower Tt							1						1				
309.54	309.56	33/5/84-86	lower Tt								1							1		
309.74	309.76	33/5/104-106	lower Tt							2										
312.31	312.33	34/1/1-3	lower Tt						2											
312.54	312.56	34/1/24-26	lower Tt																	
312.67	312.69	34/1/37-39	lower Tt																	
312.87	312.89	34/1/57-59	lower Tt								4									
313.07	313.09	34/1/77-79	lower Tt															1		
313.31	313.33	34/1/101-103	lower Tt															6		
313.53	313.55	34/1/123-125	lower Tt															4		
313.71	313.73	34/1/141-143	lower Tt																	
313.90	313.92	34/2/10-12	lower Tt						1											
314.09	314.11	34/2/29-31	lower Tt											1				2		
314.29	314.31	34/2/49-51	lower Tt								2							2		
314.45	314.47	34/2/65-67	lower Tt																	
314.69	314.71	34/2/89-91	lower Tt							1										
314.90	314.92	34/2/110-112	lower Tt																	
315.13	315.15	34/2/133-135	lower Tt					1	1	1										
315.30	315.32	34/3/0-2	upper Sw															8		
315.52	315.54	34/3/22-24	upper Sw					2		1				1						
315.71	315.73	34/3/41-43	upper Sw					1												
316.06	316.08	34/3/76-78	upper Sw							1				1						
316.27	316.29	34/3/97-99	upper Sw															2		
316.48	316.50	34/3/118-120	upper Sw						1											
316.67	316.69	34/3/137-139	upper Sw							1				1						
317.10	317.12	34/4/30-32	upper Sw								1									
317.50	317.52	34/4/70-72	upper Sw						1											
317.90	317.92	34/4/110-112	upper Sw																	
318.35	318.37	34/5/5-7	upper Sw																	
318.60	318.62	34/5/30-32	upper Sw						3		1									
321.91	321.93	35/1/1-3	upper Sw																	
322.33	322.35	35/1/43-45	upper Sw															1		
322.72	322.74	35/1/82-84	upper Sw					1	1											
323.09	323.11	35/1/119-121	upper Sw						1											
323.48	323.50	35/2/8-10	upper Sw																	
323.91	323.93	35/2/51-53	upper Sw					1						1	1					
324.50	324.52	35/2/110-112	upper Sw						1											
324.91	324.93	35/3/1-3	upper Sw						1	2								9		
325.33	325.35	35/3/43-45	upper Sw						1	1										
325.71	325.73	35/3/81-83	upper Sw						2											
325.94	325.96	35/3/104-106	upper Sw														1	1		
326.28	326.30	35/3/138-140	upper Sw												1					
326.70	326.72	35/4/30-32	upper Sw						1											
327.09	327.11	35/4/69-71	upper Sw					20			1					4		8		
327.50	327.52	35/4/110-112	upper Sw					1	1					1				12		
327.91	327.93	35/5/1-3	upper Sw															3		
328.27	328.29	35/5/37-39	upper Sw					1		1										
328.72	328.74	35/5/82-84	upper Sw						1											
331.69	331.71	36/1/19-21	upper Sw																	
332.11	332.13	36/1/61-63	upper Sw							1										
332.68	332.70	36/1/118-120	upper Sw						1											
332.98	333.00	36/1/148-150	upper Sw																	
333.40	333.42	36/2/40-42	upper Sw																	
334.00	334.02	36/2/100-102	upper Sw															1		
334.36	334.38	36/2/136-138	upper Sw																	
334.87	334.89	36/3/37-39	upper Sw																	
335.47	335.49	36/3/97-99	upper Sw							1										
335.88	335.90	36/3/138-140	upper Sw						1											
336.20	336.22	36/4/20-22	upper Sw						1											
336.60	336.62	36/4/60-62	upper Sw							1				1						

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	NZ Stage	*Globigerina bulloides*	*Globigerina eamesi*	*Globigerina falconensis*	*Globigerina* sp.	***Gg. bulloides* gp**	*Globigerina cf. angustiumbilicata*	*Globigerina quinqueloba*	***Gg. quinqueloba* gp**	*Globigerinella aequilateralis*	*Globigerinella aequilateralis?*	***Globigerinella***	*Globigerinita glutinata*	*Globigerinita uvula*	*Globigerinita uvula?*	***Globigerinita***	*Globigerinoides obliquus*	*Globigerinoides obliquus?*
120.30	120.33	14/1/0-3	lower Wo	1.27	0.00	0.76	8.63	10.66	0.00	0.00	0.00	0.00	0.00	0.00	1.78	0.00	0.00	1.78	0.00	0.00
120.51	120.54	14/1/21-24	lower Wo	2.45	0.00	0.82	9.61	12.88	0.00	0.00	0.00	0.00	0.00	0.00	1.43	0.00	0.00	1.43	0.00	0.00
120.69	120.72	14/1/39-42	lower Wo	0.45	0.00	1.36	14.51	16.33	0.00	0.23	0.23	0.00	0.00	0.00	1.36	0.00	0.00	1.36	0.23	0.00
120.90	120.93	14/1/60-63	lower Wo	5.40	0.00	1.30	11.23	17.93	0.00	0.22	0.22	0.00	0.00	0.00	1.08	0.00	0.00	1.08	2.38	0.00
121.11	121.14	14/1/81-84	lower Wo	3.94	0.00	1.86	16.01	21.81	0.00	0.23	0.23	0.00	0.23	0.23	0.70	0.00	0.00	0.70	0.23	0.00
121.26	121.29	14/1/96-99	lower Wo	3.86	0.00	1.72	9.23	14.81	0.00	0.21	0.21	0.00	0.00	0.00	0.43	0.00	0.00	0.43	0.21	0.00
121.49	121.52	14/1/119-122	lower Wo	2.02	0.00	1.45	15.32	18.79	0.00	0.00	0.00	0.00	0.00	0.00	1.16	0.00	0.00	1.16	0.29	0.00
121.69	121.72	14/1/139-142	lower Wo	1.30	0.00	0.56	10.41	12.27	0.00	0.00	0.00	0.00	0.00	0.00	1.49	0.00	0.00	1.49	0.00	0.00
121.90	121.93	14/2/10-13	lower Wo	2.43	0.00	0.40	11.74	14.57	0.00	0.00	0.00	0.00	0.00	0.00	1.42	0.00	0.00	1.42	0.00	0.00
122.09	122.12	14/2/29-32	lower Wo	3.13	0.00	0.45	11.63	15.21	0.00	0.00	0.00	0.00	0.00	0.00	1.12	0.00	0.00	1.12	0.22	0.00
122.26	122.29	14/2/46-49	lower Wo	3.01	0.00	1.39	7.87	12.27	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.69	0.00	0.00
122.51	122.55	14/2/71-75	lower Wo	0.93	0.00	0.93	10.98	12.85	0.00	0.47	0.47	0.00	0.00	0.00	0.93	0.00	0.00	0.93	0.00	0.00
122.71	122.74	14/2/91-94	lower Wo	2.12	0.00	0.71	8.18	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.00	0.00	0.99	0.00	0.00
122.92	122.95	14/2/112-115	lower Wo	0.90	0.00	0.36	6.86	8.12	0.00	0.00	0.00	0.00	0.00	0.00	0.72	0.00	0.00	0.72	0.18	0.00
123.10	123.13	14/2/130-133	upper Tk	2.42	0.00	0.48	12.40	15.30	0.00	0.00	0.00	0.16	0.00	0.16	1.13	0.00	0.00	1.13	0.00	0.00
123.30	123.33	14/3/0-3	upper Tk	1.33	0.00	1.78	17.56	20.67	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.44	0.00	0.00
123.53	123.56	14/3/23-26	upper Tk	1.29	0.00	0.32	9.49	11.09	0.00	0.32	0.32	0.00	0.00	0.00	1.29	0.00	0.00	1.29	0.00	0.00
123.69	123.72	14/3/39-42	upper Tk	0.81	0.00	1.83	11.38	14.02	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.00	0.00	0.61	0.00	0.00
123.88	123.91	14/3/58-61	upper Tk	1.96	0.00	0.73	11.74	14.43	0.00	0.00	0.00	0.00	0.00	0.00	2.20	0.00	0.00	2.20	0.00	0.00
124.11	124.14	14/3/81-84	upper Tk	0.99	0.00	0.79	14.00	15.78	0.00	0.00	0.00	0.00	0.00	0.00	0.79	0.00	0.00	0.79	0.00	0.00
124.30	124.33	14/3/100-103	upper Tk	2.09	0.00	1.34	12.09	15.52	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.30	0.00	0.00
124.50	124.53	14/3/120-123	upper Tk	1.31	0.00	0.65	13.07	15.03	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.65	0.00	0.00
124.68	124.71	14/3/138-141	upper Tk	0.84	0.00	0.21	12.84	13.89	0.00	0.00	0.00	0.00	0.00	0.00	0.84	0.00	0.00	0.84	0.00	0.00
124.90	124.93	14/4/10-13	upper Tk	0.98	0.00	1.46	12.03	14.47	0.00	0.00	0.00	0.00	0.00	0.00	0.98	0.00	0.00	0.98	0.00	0.00
125.10	125.13	14/4/30-33	upper Tk	1.04	0.00	0.87	11.63	13.54	0.00	0.00	0.00	0.00	0.00	0.00	1.74	0.00	0.00	1.74	0.00	0.00
125.30	125.33	14/4/50-53	upper Tk	1.83	0.00	1.07	8.52	11.42	0.00	0.00	0.00	0.00	0.00	0.00	1.83	0.00	0.00	1.83	0.00	0.00
125.48	125.51	14/4/68-71	upper Tk	1.22	0.00	0.61	7.93	9.76	0.00	0.00	0.00	0.00	0.00	0.00	0.91	0.00	0.00	0.91	0.00	0.00
125.71	125.74	14/4/91-94	upper Tk	1.90	0.00	0.95	7.82	10.66	0.00	0.00	0.00	0.00	0.00	0.00	1.18	0.00	0.00	1.18	0.00	0.00
125.91	125.94	14/4/111-114	upper Tk	2.02	0.00	0.78	12.21	15.01	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.67	0.00	0.00
126.10	126.13	14/4/130-133	upper Tk	1.77	0.00	0.66	13.25	15.67	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.22	0.00	0.00
126.30	126.33	14/5/0-3	upper Tk	1.29	0.00	1.03	10.34	12.66	0.00	0.26	0.26	0.00	0.00	0.00	0.26	0.00	0.00	0.26	0.00	0.00
126.56	126.59	14/5/26-29	upper Tk	2.92	0.00	0.58	11.70	15.20	0.00	0.00	0.00	0.00	0.00	0.00	0.78	0.00	0.00	0.78	0.00	0.00
126.70	126.73	14/5/40-43	upper Tk	2.61	0.00	1.04	12.27	15.93	0.00	0.00	0.00	0.00	0.26	0.26	1.57	0.00	0.00	1.57	0.00	0.00
126.90	126.93	14/5/60-63	upper Tk	4.97	0.00	1.10	10.50	16.57	0.00	0.00	0.00	0.00	0.00	0.00	2.21	0.00	0.55	2.76	0.18	0.00
127.12	127.15	14/5/82-85	upper Tk	1.57	0.00	0.31	12.54	14.42	0.00	0.00	0.00	0.00	0.00	0.00	1.72	0.00	0.00	1.72	0.63	0.00
127.30	127.33	14/5/100-103	upper Tk	2.17	0.00	0.18	13.54	15.88	0.00	0.00	0.00	0.00	0.00	0.00	0.90	0.00	0.00	0.90	0.00	0.00
127.51	127.54	14/5/121-124	upper Tk	1.93	0.00	0.97	18.96	21.86	0.00	0.58	0.58	0.00	0.00	0.00	0.58	0.00	0.00	0.58	0.00	0.00
127.70	127.73	14/5/140-143	upper Tk	1.62	0.00	1.13	20.87	23.62	0.00	0.00	0.00	0.00	0.00	0.00	1.13	0.00	0.00	1.13	0.00	0.00
127.90	127.93	14/6/10-13	upper Tk	1.35	0.00	1.35	19.61	22.31	0.00	0.00	0.00	0.00	0.00	0.00	1.80	0.00	0.00	1.80	0.30	0.00
128.29	128.32	14/6/49-52	upper Tk	2.31	0.00	0.36	16.90	19.57	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.36	0.00	0.00
128.72	128.75	14/6/92-95	upper Tk	2.09	0.00	0.21	15.87	18.16	0.00	0.00	0.00	0.00	0.00	0.00	2.09	0.00	0.00	2.09	0.00	0.00
129.10	129.13	14/6/130-133	upper Tk	1.34	0.00	0.00	16.04	17.37	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.00	0.00	0.89	0.00	0.00
129.50	129.53	14/7/20-23	upper Tk	1.64	0.00	0.27	16.96	18.88	0.00	0.00	0.00	0.00	0.00	0.00	1.37	0.00	0.00	1.37	0.00	0.00
129.90	129.93	15/1/0-3	upper Tk	0.77	0.00	0.26	14.18	15.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
130.29	130.32	15/1/39-42	upper Tk	0.55	0.00	0.37	11.42	12.34	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.00	0.00	0.74	0.00	0.00
130.69	130.72	15/1/79-82	upper Tk	0.78	0.00	0.47	11.56	12.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
131.10	131.13	15/1/120-123	upper Tk	2.66	0.00	0.53	13.14	16.34	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.18	0.00	0.53	0.00	0.00
131.51	131.54	15/2/11-14	upper Tk	1.37	0.00	0.00	14.24	15.61	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.69	0.00	0.00
131.91	131.93	15/2/51-53	upper Tk	0.49	0.00	0.66	13.61	14.75	0.00	0.00	0.00	0.00	0.00	0.00	0.82	0.00	0.00	0.82	0.00	0.00
132.33	132.36	15/2/93-96	upper Tk	0.70	0.00	0.00	13.09	13.79	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0.00
132.74	132.76	15/2/134-136	upper Tk	1.36	0.00	0.23	10.91	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.45	0.00	0.00
133.07	133.10	15/3/17-20	upper Tk	0.58	0.00	0.39	10.44	11.41	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.58	0.00	0.00
133.46	133.49	15/3/56-59	upper Tk	1.73	0.00	0.13	9.85	11.72	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.67	0.00	0.00
133.89	133.92	15/3/99-102	upper Tk	0.62	0.00	0.00	12.55	13.17	0.00	0.00	0.00	0.00	0.00	0.00	0.62	0.00	0.00	0.62	0.00	0.00
134.30	134.33	15/3/140-143	upper Tk	2.75	0.00	0.17	12.74	15.66	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.52	0.00	0.00
134.70	134.73	15/4/30-33	upper Tk	1.27	0.00	0.36	12.86	14.49	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.36	0.00	0.00
135.10	135.13	15/4/70-73	upper Tk	0.68	0.00	0.00	9.52	10.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
135.30	135.33	15/4/90-93	upper Tk	2.10	0.00	0.00	11.89	13.99	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.52	0.00	0.00
135.50	135.53	15/4/110-113	upper Tk	1.34	0.00	0.89	11.63	13.87	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.45	0.00	0.00
135.70	135.73	15/4/130-133	upper Tk	0.97	0.00	0.32	12.01	13.31	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.00	0.00	0.49	0.00	0.00
135.90	135.93	15/5/0-3	upper Tk	1.73	0.00	0.35	10.55	12.63	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.35	0.00	0.00
136.06	136.09	15/5/16-19	upper Tk	2.17	0.00	0.22	10.43	12.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
136.32	136.35	15/5/42-45	upper Tk	1.49	0.00	0.56	10.61	12.66	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.37	0.00	0.00
136.51	136.53	15/5/61-63	upper Tk	1.54	0.00	0.42	12.76	14.73	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.28	0.00	0.00
136.92	136.95	15/5/102-105	upper Tk	1.37	0.00	0.39	8.61	10.37	0.00	0.00	0.00	0.00	0.20	0.20	0.98	0.00	0.00	0.98	0.00	0.00
137.13	137.16	15/5/123-126	upper Tk	0.65	0.00	0.22	9.37	10.24	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.44	0.00	0.00
137.52	137.55	15/6/12-15	upper Tk	0.85	0.00	0.00	11.09	11.95	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0.00
137.91	137.94	15/6/51-54	upper Tk	0.94	0.00	0.00	13.32	14.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
138.27	138.30	15/6/87-90	upper Tk	0.61	0.00	0.20	10.86	11.68	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.20	0.00	0.00
138.66	138.69	15/6/126-129	upper Tk	0.35	0.00	0.35	11.60	12.30	0.00	0.00	0.00	0.00	0.00	0.00	0.88	0.00	0.00	0.88	0.18	0.00
139.07	139.10	15/7/17-20	upper Tk	1.40	0.00	0.62	15.06	17.08	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.31	0.00	0.00
139.50	139.53	16/1/0-3	upper Tk	1.19	0.00	0.00	13.81	15.00	0.00	0.24	0.24	0.00	0.00	0.00	0.24	0.00	0.00	0.24	0.00	0.00
139.93	139.96	16/1/43-46	upper Tk	0.78	0.00	0.31	13.84	14.93	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.00	0.47	0.00	0.00
140.34	140.37	16/1/84-87	upper Tk	0.66	0.00	0.44	13.10	14.19	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.22	0.00	0.00
140.73	140.76	16/1/123-126	upper Tk	0.17	0.00	0.69	10.34	11.21	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.52	0.00	0.00
141.13	141.15	16/2/13-16	upper Tk	0.00	0.00	0.31	12.54	12.85	0.00	0.00	0.00	0.00	0.00	0.00	0.63	0.00	0.00	0.63	0.00	0.00
141.54	141.57	16/2/54-57	upper Tk	3.09	0.00	0.21	10.08	13.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.21	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	NZ Stage	*Globigerina bulloides*	*Globigerina eamesi*	*Globigerina falconensis*	*Globigerina* sp.	***Gg. bulloides* gp**	*Globigerina cf. angustiumbilicata*	*Globigerina quinqueloba*	***Gg. quinqueloba* gp**	*Globigerinella aequilateralis*	*Globigerinella aequilateralis?*	***Globigerinella***	*Globigerinita glutinata*	*Globigerinita uvula*	*Globigerinita uvula?*	***Globigerinita***	*Globigerinoides obliquus*	*Globigerinoides obliquus?*
141.92	141.95	16/2/92-95	upper Tk	2.24	0.00	0.00	11.82	14.06	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.32	0.00	0.00
142.32	142.35	16/2/132-135	upper Tk	0.81	0.00	0.20	10.28	11.29	0.00	0.00	0.00	0.00	0.00	0.00	0.81	0.00	0.00	0.81	0.00	0.00
142.75	142.78	16/3/25-28	upper Tk	1.30	0.00	0.00	12.80	14.10	0.00	0.19	0.19	0.00	0.00	0.00	0.37	0.00	0.00	0.37	0.00	0.00
143.15	143.18	16/3/65-68	upper Tk	1.18	0.00	1.18	16.58	18.95	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.34	0.00	0.00
143.53	143.56	16/3/103-106	upper Tk	1.23	0.00	0.14	13.56	14.93	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.55	0.00	0.00
143.84	143.87	16/3/134-137	lower Tk	0.72	0.00	0.18	13.46	14.36	0.00	0.00	0.00	0.00	0.00	0.00	0.90	0.00	0.00	0.90	0.00	0.00
144.26	144.29	16/4/26-29	lower Tk	1.18	0.00	1.18	12.60	14.96	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.20	0.00	0.00
144.67	144.70	16/4/67-70	lower Tk	1.08	0.00	0.72	14.08	15.88	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.36	0.00	0.00
145.13	145.16	16/4/113-116	lower Tk	1.68	0.00	1.17	10.22	13.07	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.67	0.00	0.00
145.50	145.53	16/5/0-3	lower Tk	1.32	0.00	0.66	8.22	10.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
145.93	145.96	16/5/43-46	lower Tk	1.49	0.00	0.64	13.19	15.32	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.43	0.00	0.00
146.36	146.38	16/5/86-88	lower Tk	1.93	0.00	0.58	10.21	12.72	0.00	0.00	0.00	0.00	0.00	0.00	0.77	0.00	0.00	0.77	0.00	0.00
146.71	146.74	16/5/121-124	lower Tk	1.98	0.00	0.20	7.91	10.08	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.20	0.00	0.00
147.06	147.09	16/6/6-9	lower Tk	1.21	0.00	0.00	8.96	10.17	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.48	0.00	0.00
147.47	147.50	16/6/47-50	lower Tk	1.20	0.00	0.45	11.86	13.51	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.30	0.00	0.00
147.93	147.96	16/6/93-96	lower Tk	1.34	0.00	0.57	12.81	14.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
148.33	148.36	16/6/133-136	lower Tk	0.77	0.00	1.53	16.33	18.62	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.13	0.00	0.00
148.67	148.69	16/7/17-19	lower Tk	1.19	0.00	1.69	14.24	17.12	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.51	0.00	0.00
149.10	149.13	17/1/0-3	lower Tk	1.34	0.00	0.34	12.40	14.07	0.00	0.17	0.17	0.00	0.00	0.00	0.50	0.00	0.00	0.50	0.00	0.00
149.52	149.55	17/1/42-45	lower Tk	1.68	0.00	0.00	11.62	13.30	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.51	0.00	0.00
150.11	150.14	17/1/101-104	lower Tk	0.64	0.00	0.43	10.43	11.49	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.21	0.00	0.00
150.51	150.54	17/1/141-144	lower Tk	1.74	0.00	0.00	13.23	14.97	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.22	0.00	0.00
150.87	150.90	17/2/27-30	lower Tk	1.82	0.00	0.66	17.58	20.07	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
151.07	151.10	17/2/47-50	lower Tk	1.71	0.00	1.33	11.81	14.86	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.38	0.38	0.00
151.52	151.55	17/2/92-95	lower Tk	1.09	0.00	0.24	10.30	11.64	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.36	0.00	0.00
151.96	151.98	17/2/136-138	lower Tk	1.29	0.00	0.00	9.46	10.75	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.65	0.00	0.00
152.10	152.13	17/3/0-3	lower Tk	2.08	0.00	0.00	12.80	14.88	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.48	0.00	0.00
152.25	152.28	17/3/15-18	lower Tk	1.01	0.00	0.00	9.46	10.47	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0.00
152.47	152.50	17/3/37-40	lower Tk	0.65	0.00	0.00	9.33	9.98	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.43	0.00	0.00
152.75	152.77	17/3/65-67	lower Tk	2.29	0.00	0.00	8.80	11.09	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.35	0.00	0.00
152.91	152.94	17/3/81-84	lower Tk	1.81	0.00	0.00	7.83	9.64	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.40	0.00	0.00
153.12	153.15	17/3/102-105	lower Tk	2.61	0.00	0.20	12.22	15.03	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.40	0.00	0.00
153.26	153.29	17/3/116-119	lower Tk	0.31	0.00	0.00	10.95	11.27	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.16	0.16	0.00
153.45	153.48	17/3/135-138	lower Tk	1.93	0.00	0.00	9.79	11.72	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.45	0.00	0.00
153.66	153.69	17/4/6-9	lower Tk	0.72	0.00	0.00	9.81	10.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
153.97	153.99	17/4/37-39	lower Tk	0.16	0.00	0.00	8.28	8.44	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.32	0.00	0.00
154.13	154.16	17/4/53-56	lower Tk	0.63	0.00	0.00	8.07	8.70	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.00	0.47	0.00	0.00
154.32	154.35	17/4/72-75	lower Tk	0.13	0.00	0.00	6.06	6.19	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.27	0.00	0.00
154.54	154.57	17/4/94-97	lower Tk	0.46	0.00	0.46	5.46	6.37	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.11	0.00	0.00
154.77	154.79	17/4/117-119	lower Tk	0.49	0.00	0.49	4.40	5.38	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.16	0.16	0.00
154.95	154.98	17/4/135-138	lower Tk	0.40	0.00	0.53	6.12	7.05	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.40	0.00	0.00
155.10	155.13	17/5/0-3	lower Tk	0.54	0.00	0.00	5.53	6.06	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.13	0.00	0.00
155.24	155.27	17/5/14-17	lower Tk	0.70	0.00	0.18	5.45	6.33	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.18	0.35	0.00
155.48	155.50	17/5/38-40	lower Tk	1.21	0.00	0.12	9.58	10.91	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.36	0.00	0.00
155.67	155.70	17/5/57-60	lower Tk	0.00	0.00	0.48	11.59	12.08	0.00	0.00	0.00	0.00	0.00	0.00	0.97	0.00	0.00	0.97	0.00	0.00
155.94	155.97	17/5/84-87	lower Tk	0.64	0.00	0.13	9.23	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.64	0.00	0.00
156.13	156.16	17/5/103-106	lower Tk	1.34	0.00	0.38	9.98	11.71	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.38	0.00	0.00
156.27	156.30	17/5/117-120	lower Tk	1.09	0.00	0.00	7.50	8.59	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.00	0.47	0.00	0.00
156.47	156.50	17/5/137-140	lower Tk	0.49	0.00	0.00	7.69	8.18	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.33	0.00	0.00
156.71	156.74	17/6/11-14	lower Tk	0.54	0.00	0.18	10.47	11.19	0.00	0.00	0.00	0.00	0.00	0.00	0.90	0.00	0.00	0.90	0.00	0.00
156.95	156.98	17/6/35-38	lower Tk	1.29	0.00	1.48	9.04	11.81	0.00	0.00	0.00	0.00	0.00	0.00	0.92	0.00	0.00	0.92	0.55	0.00
157.12	157.15	17/6/52-55	lower Tk	1.29	0.00	1.43	12.29	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.29	0.00	1.00	0.71	0.00
157.37	157.39	17/6/77-79	lower Tk	0.61	0.00	0.20	10.30	11.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
157.52	157.55	17/6/92-95	lower Tk	1.66	0.00	0.21	4.77	6.64	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00	0.00	0.41	0.00	0.00
157.76	157.79	17/6/116-119	lower Tk	0.30	0.00	0.46	7.00	7.76	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.15	0.00	0.00
157.93	157.96	17/6/133-136	lower Tk	0.67	0.00	0.78	6.10	7.54	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.11	0.00	1.00	0.00	0.00
158.10	158.13	17/7/0-3	lower Tk	0.49	0.00	0.12	8.52	9.12	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.36	0.00	0.00
158.27	158.30	17/7/17-20	lower Tk	0.27	0.00	0.00	6.25	6.52	0.00	0.00	0.00	0.00	0.00	0.00	0.82	0.00	0.00	0.82	0.00	0.00
158.52	158.55	17CC/6-9	lower Tk	0.36	0.00	0.90	9.69	10.95	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.18	0.00	0.72	0.00	0.00
158.70	158.73	18/1/0-3	lower Tk	0.29	0.00	1.00	11.48	12.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.14	0.00	0.00
158.95	158.98	18/1/25-28	lower Tk	0.00	0.00	0.00	7.17	7.17	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0.00
159.13	159.16	18/1/43-46	lower Tk	0.00	0.00	0.42	8.03	8.46	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.42	0.00	0.00
159.35	159.38	18/1/65-68	lower Tk	0.69	0.00	0.41	6.48	7.59	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00	0.00	0.41	0.00	0.00
159.49	159.52	18/1/79-82	lower Tk	1.43	0.00	0.41	6.73	8.56	0.00	0.00	0.00	0.00	0.10	0.10	0.71	0.00	0.00	0.71	0.00	0.00
159.72	159.75	18/1/102-105	lower Tk	1.17	0.00	0.00	8.64	9.81	0.00	0.00	0.00	0.00	0.00	0.00	0.88	0.00	0.00	0.88	0.00	0.00
159.86	159.89	18/1/116-119	lower Tk	0.72	0.00	0.00	9.76	10.49	0.00	0.00	0.00	0.00	0.00	0.00	1.08	0.00	0.00	1.08	0.00	0.00
160.11	160.14	18/1/141-144	lower Tk	1.43	0.00	0.54	9.66	11.63	0.00	0.00	0.00	0.00	0.00	0.00	1.61	0.00	0.00	1.61	0.00	0.00
160.33	160.36	18/2/13-16	lower Tk	0.73	0.00	0.12	9.41	10.27	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.12	0.00	0.49	0.00	0.00
160.73	160.76	18/2/53-56	lower Tk	2.12	0.00	0.39	9.25	11.75	0.00	0.00	0.00	0.00	0.00	0.00	0.77	0.00	0.00	0.77	0.00	0.00
161.16	161.19	18/2/96-99	lower Tk	1.27	0.00	0.00	8.16	9.42	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.14	0.00	0.56	0.00	0.00
161.53	161.56	18/2/133-136	lower Tk	1.15	0.00	0.00	5.99	7.14	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.26	0.00	0.00
161.84	161.87	18/3/14-17	lower Tk	1.34	0.00	0.17	12.06	13.57	0.00	0.00	0.00	0.00	0.00	0.00	1.01	0.00	0.00	1.01	0.00	0.00
162.26	162.29	18/3/56-59	lower Tk	0.17	0.00	0.00	5.15	5.33	0.00	0.00	0.00	0.00	0.00	0.00	1.20	0.00	0.00	1.20	0.00	0.00
162.87	162.90	18/3/117-120	lower Tk	1.93	0.00	0.58	5.78	8.29	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.19	0.00	0.00
163.33	163.36	18/4/13-16	lower Tk	1.79	0.00	0.45	9.87	12.11	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.22	0.00	0.00
163.56	163.59	18/4/36-39	lower Tk	0.32	0.00	0.22	7.98	8.52	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.65	0.32	0.00
163.93	163.96	18/4/73-76	lower Tk	1.63	0.00	0.00	7.46	9.09	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.70	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	NZ Stage	*Globigerina bulloides*	*Globigerina eamesi*	*Globigerina falconensis*	*Globigerina* sp.	***Gg. bulloides* gp**	*Globigerina cf. angustiumbilicata*	*Globigerina quinqueloba*	***Gg. quinqueloba* gp**	*Globigerinella aequilateralis*	*Globigerinella aequilateralis?*	***Globigerinella***	*Globigerinita glutinata*	*Globigerinita uvula*	*Globigerinita uvula?*	***Globigerinita***	*Globigerinoides obliquus*	*Globigerinoides obliquus?*
164.31	164.33	18/4/111-113	lower Tk	0.66	0.00	0.22	8.33	9.21	0.00	0.22	0.22	0.00	0.00	0.00	0.66	0.00	0.00	0.66	0.00	0.00
164.70	164.73	18/5/0-3	lower Tk	2.23	0.00	0.17	5.67	8.08	0.00	0.00	0.00	0.00	0.00	0.00	1.37	0.00	0.00	1.37	0.00	0.00
165.13	165.16	18/5/43-46	lower Tk	2.15	0.00	0.51	9.22	11.87	0.00	0.13	0.13	0.00	0.00	0.00	0.38	0.00	0.00	0.38	0.00	0.00
165.50	165.53	18/5/80-83	lower Tk	1.60	0.00	0.23	7.53	9.36	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.00	0.00	0.68	0.34	0.00
165.95	165.97	18/5/125-127	lower Tk	1.43	0.00	0.00	10.33	11.76	0.00	0.16	0.16	0.00	0.00	0.00	0.64	0.00	0.00	0.64	0.00	0.00
166.26	166.29	18/6/6-9	lower Tk	0.71	0.00	0.35	9.40	10.46	0.00	0.00	0.00	0.00	0.00	0.00	1.60	0.18	0.00	1.77	0.00	0.00
166.66	166.69	18/6/46-49	lower Tk	2.35	0.00	0.34	6.21	8.89	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0.00
167.06	167.09	18/6/86-89	lower Tk	0.99	0.00	0.00	6.64	7.63	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.14	0.00	0.99	0.00	0.00
167.44	167.47	18/6/124-127	upper Tt	1.22	0.00	0.33	6.22	7.77	0.00	0.00	0.00	0.00	0.00	0.00	0.78	0.00	0.00	0.78	0.00	0.00
168.30	168.33	19/1/0-3	upper Tt	2.16	0.00	0.36	9.71	12.23	0.00	0.00	0.00	0.00	0.00	0.00	0.72	0.18	0.00	0.90	0.00	0.00
168.71	168.74	19/1/41-44	upper Tt	1.03	0.00	1.03	9.77	11.83	0.00	0.00	0.00	0.00	0.00	0.00	0.77	0.00	0.00	0.77	0.00	0.00
169.13	169.15	19/1/83-85	upper Tt	1.32	0.00	1.15	10.36	12.83	0.00	0.00	0.00	0.00	0.00	0.00	0.66	0.00	0.00	0.66	0.00	0.00
169.51	169.54	19/1/121-124	upper Tt	1.72	0.00	0.14	8.17	10.03	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.14	0.00	1.15	0.00	0.00
169.85	169.88	19/2/5-8	upper Tt	1.19	0.00	0.17	8.67	10.03	0.00	0.00	0.00	0.00	0.00	0.00	1.19	0.00	0.00	1.19	0.00	0.00
170.32	170.35	19/2/52-55	upper Tt	1.83	0.00	0.83	10.30	12.96	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.50	0.00	0.00
170.73	170.76	19/2/93-96	upper Tt	1.06	0.00	1.21	11.53	13.81	0.00	0.00	0.00	0.00	0.00	0.00	1.37	0.00	0.00	1.37	0.00	0.00
171.15	171.18	19/2/135-138	upper Tt	2.78	0.00	1.31	11.11	15.20	0.00	0.00	0.00	0.00	0.00	0.00	0.82	0.00	0.00	0.82	0.00	0.00
171.57	171.59	19/3/27-29	upper Tt	1.05	0.00	0.75	9.62	11.43	0.00	0.00	0.00	0.00	0.00	0.00	1.20	0.00	0.00	1.20	0.00	0.00
171.92	171.94	19/3/62-64	upper Tt	1.41	0.00	0.47	8.69	10.56	0.00	0.00	0.00	0.00	0.00	0.00	0.94	0.00	0.00	0.94	0.00	0.00
172.32	172.35	19/3/102-105	upper Tt	1.08	0.00	0.00	6.96	8.04	0.00	0.00	0.00	0.00	0.00	0.00	1.55	0.00	0.00	1.55	0.00	0.00
172.66	172.68	19/3/136-138	upper Tt	2.04	0.00	1.53	14.54	18.11	0.00	0.00	0.00	0.00	0.00	0.00	0.77	0.26	0.00	1.02	0.00	0.00
173.07	173.09	19/4/27-29	upper Tt	2.08	0.00	0.00	15.59	17.67	0.00	0.00	0.00	0.00	0.00	0.00	1.04	0.00	0.00	1.04	0.00	0.00
173.52	173.54	19/4/72-74	upper Tt	1.56	0.00	0.31	7.79	9.66	0.00	0.00	0.00	0.00	0.00	0.00	1.56	0.00	0.00	1.56	0.00	0.00
173.93	173.95	19/4/113-115	upper Tt	1.01	0.00	0.61	11.36	12.98	0.00	0.00	0.00	0.00	0.00	0.00	1.01	0.20	0.00	1.22	0.00	0.00
174.30	174.33	19/5/0-3	upper Tt	2.34	0.00	1.06	16.35	19.75	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.42	0.00	0.00
174.72	174.75	19/5/42-45	upper Tt	2.37	0.00	1.18	14.79	18.34	0.00	0.00	0.00	0.00	0.00	0.00	1.18	0.20	0.00	1.38	0.00	0.00
175.26	175.28	19/5/96-99	upper Tt	1.03	0.00	0.21	6.60	7.84	0.00	0.41	0.41	0.00	0.00	0.00	1.03	0.00	0.00	1.03	0.00	0.00
175.71	175.74	19/5/141-144	upper Tt	2.10	0.00	0.00	11.81	13.91	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.52	0.00	0.00
176.06	176.09	19/6/26-29	upper Tt	1.16	0.00	0.23	8.12	9.51	0.00	0.00	0.00	0.00	0.00	0.00	1.39	0.00	0.00	1.39	0.00	0.00
176.47	176.49	19/6/67-69	upper Tt	0.38	0.00	0.19	10.69	11.26	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.38	0.00	0.00
176.92	176.94	19/6/112-114	upper Tt	0.00	0.00	0.00	8.04	8.04	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00	0.54	0.00	0.00
177.30	177.33	19/7/0-3	upper Tt	1.92	0.00	0.24	11.54	13.70	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.48	0.00	0.00
177.52	177.55	19/7/22-25	upper Tt	0.75	0.00	0.45	11.21	12.41	0.45	0.00	0.45	0.00	0.07	0.07	1.20	0.00	0.00	1.20	0.00	0.00
177.90	177.93	20/1/0-3	upper Tt	1.85	0.00	0.69	10.88	13.43	0.00	0.00	0.00	0.00	0.00	0.00	1.16	0.00	0.00	1.16	0.00	0.00
178.27	178.30	20/1/37-40	upper Tt	2.78	0.00	1.19	9.92	13.89	0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.00	0.00	0.99	0.00	0.00
178.68	178.70	20/1/78-80	upper Tt	1.05	0.00	0.84	10.25	12.13	0.21	0.00	0.21	0.00	0.00	0.00	1.26	0.00	0.00	1.26	0.00	0.00
179.08	179.10	20/1/118-120	upper Tt	0.41	0.00	0.00	8.51	8.92	0.00	0.00	0.00	0.00	0.00	0.00	1.04	0.21	0.00	1.24	0.00	0.00
179.45	179.47	20/2/5-7	upper Tt	1.16	0.00	0.29	7.23	8.67	0.14	0.00	0.14	0.00	0.00	0.00	1.45	0.14	0.00	1.59	0.00	0.00
179.86	179.88	20/2/46-48	upper Tt	1.84	0.00	1.17	9.68	12.69	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.33	0.00	1.00	0.00	0.00
180.33	180.35	20/2/93-95	upper Tt	1.60	0.00	0.60	9.42	11.62	1.20	0.00	1.20	0.00	0.00	0.00	0.60	0.00	0.00	0.60	0.00	0.00
180.73	180.75	20/2/133-135	upper Tt	0.43	0.00	1.08	6.49	8.01	0.22	0.00	0.22	0.00	0.00	0.00	1.52	0.00	0.00	1.52	0.00	0.00
181.14	181.16	20/3/24-26	upper Tt	1.13	0.00	0.57	5.67	7.37	0.00	0.00	0.00	0.00	0.00	0.00	1.13	0.00	0.00	1.13	0.00	0.00
181.57	181.59	20/3/67-69	upper Tt	0.89	0.00	0.22	5.82	6.94	0.22	0.00	0.22	0.00	0.00	0.00	3.13	0.00	0.00	3.13	0.00	0.00
181.86	181.88	20/3/96-98	upper Tt	0.55	0.00	0.37	6.62	7.54	0.00	0.00	0.00	0.00	0.00	0.00	1.29	0.00	0.00	1.29	0.00	0.00
182.23	182.25	20/3/133-135	upper Tt	0.96	0.00	1.44	9.33	11.72	0.00	0.00	0.00	0.00	0.00	0.00	1.20	0.24	0.00	1.44	0.00	0.00
182.68	182.70	20/4/28-30	upper Tt	0.81	0.00	0.27	7.57	8.65	0.00	0.00	0.00	0.00	0.00	0.00	0.81	0.00	0.00	0.81	0.00	0.00
183.08	183.10	20/4/68-70	upper Tt	1.22	0.00	0.24	7.07	8.54	0.49	0.00	0.49	0.00	0.00	0.00	0.49	0.49	0.00	0.98	0.00	0.00
183.45	183.47	20/4/105-107	upper Tt	0.65	0.00	0.13	5.82	6.60	0.26	0.00	0.26	0.00	0.00	0.00	1.42	0.00	0.00	1.42	0.00	0.00
183.91	183.93	20/5/1-3	upper Tt	1.25	0.00	0.71	7.47	9.43	0.71	0.00	0.71	0.00	0.00	0.00	2.67	0.18	0.00	2.85	0.00	0.00
184.32	184.34	20/5/42-44	upper Tt	0.55	0.00	1.28	9.36	11.19	0.18	0.00	0.18	0.00	0.00	0.00	0.73	0.18	0.00	0.92	0.00	0.00
184.72	184.74	20/5/82-84	upper Tt	1.60	0.00	0.80	12.80	15.20	0.60	0.00	0.60	0.00	0.00	0.00	1.40	0.20	0.00	1.60	0.00	0.00
185.07	185.09	20/5/117-119	upper Tt	1.46	0.00	0.65	8.77	10.88	0.81	0.00	0.81	0.00	0.00	0.00	0.49	0.65	0.00	1.14	0.00	0.00
185.47	185.49	20/6/7-9	upper Tt	0.56	0.00	0.19	4.08	4.82	0.74	0.00	0.74	0.00	0.00	0.00	1.48	0.00	0.00	1.48	0.00	0.00
185.92	185.94	20/6/52-54	upper Tt	2.30	0.00	1.15	10.34	13.79	0.38	0.00	0.38	0.00	0.00	0.00	2.11	0.00	0.00	2.11	0.00	0.00
186.32	186.34	20/6/92-94	upper Tt	1.97	0.00	1.26	8.08	11.31	0.36	0.00	0.36	0.00	0.00	0.00	1.26	0.00	0.00	1.26	0.00	0.00
186.72	186.74	20/6/132-134	upper Tt	1.70	0.00	0.00	7.82	9.52	0.17	0.00	0.17	0.00	0.00	0.00	1.70	0.00	0.00	1.70	0.00	0.00
187.07	187.09	20/7/17-19	upper Tt	0.42	0.00	0.14	4.92	5.49	0.42	0.00	0.42	0.00	0.00	0.00	1.69	0.14	0.00	1.83	0.00	0.00
187.51	187.53	21/1/1-3	upper Tt	0.90	0.00	0.26	5.15	6.31	0.13	0.13	0.26	0.00	0.00	0.00	2.06	0.00	0.00	2.06	0.13	0.00
187.93	187.95	21/1/43-45	upper Tt	0.61	0.00	0.12	6.06	6.79	0.12	0.00	0.12	0.00	0.00	0.00	2.06	0.36	0.00	2.42	0.00	0.00
188.32	188.34	21/182-84	upper Tt	0.41	0.00	0.20	5.74	6.35	0.20	0.00	0.20	0.00	0.00	0.00	0.82	0.61	0.00	1.43	0.00	0.00
188.67	188.69	21/1/117-119	upper Tt	0.65	0.00	0.65	7.62	8.91	0.16	0.00	0.16	0.00	0.00	0.00	1.46	0.00	0.00	1.46	0.00	0.00
189.08	189.10	21/2/8-10	upper Tt	1.38	0.00	0.46	6.68	8.53	0.46	0.00	0.46	0.00	0.00	0.00	1.61	0.46	0.00	2.07	0.00	0.00
189.46	189.48	21/2/46-48	upper Tt	1.32	0.00	0.00	8.10	9.42	0.33	0.00	0.33	0.00	0.00	0.00	0.17	0.17	0.00	0.33	0.00	0.00
189.93	189.96	21/2/93-96	upper Tt	0.31	0.00	0.47	6.40	7.18	0.16	0.00	0.16	0.00	0.00	0.00	0.78	0.00	0.00	0.78	0.00	0.00
190.42	190.44	21/2/142-144	upper Tt	0.85	0.00	0.00	6.10	6.95	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.51	0.00	1.53	0.00	0.00
190.66	190.68	21/3/16-18	upper Tt	0.87	0.00	0.17	6.62	7.67	0.70	0.00	0.70	0.00	0.00	0.00	1.22	0.52	0.00	1.74	0.00	0.00
191.12	191.14	21/3/62-64	upper Tt	4.38	0.00	0.00	11.56	15.94	0.18	0.00	0.18	0.00	0.00	0.00	1.93	0.35	0.00	2.28	0.00	0.00
191.52	191.54	21/3/102-104	upper Tt	0.78	0.00	0.39	6.99	8.15	0.13	0.00	0.13	0.00	0.00	0.00	1.94	0.13	0.00	2.07	0.00	0.00
191.86	191.89	21/3/136-139	upper Tt	1.31	0.00	1.31	7.44	10.07	0.22	0.00	0.22	0.00	0.00	0.00	1.09	0.44	0.00	1.53	0.00	0.00
192.36	192.38	21/4/36-38	upper Tt	2.52	0.00	0.26	7.15	9.93	0.40	0.00	0.40	0.00	0.00	0.00	1.59	0.40	0.00	1.99	0.00	0.00
192.73	192.75	21/4/73-75	upper Tt	1.26	0.00	1.77	9.34	12.37	0.13	0.00	0.13	0.00	0.00	0.00	1.52	0.25	0.00	1.77	0.00	0.00
193.12	193.14	21/4/112-114	upper Tt	2.08	0.00	0.52	11.61	14.21	0.00	0.00	0.00	0.00	0.00	0.00	1.73	0.17	0.00	1.91	0.00	0.00
193.50	193.52	21/5/0-2	upper Tt	1.62	0.00	0.10	7.98	9.70	0.10	0.00	0.10	0.00	0.00	0.00	1.92	0.00	0.00	1.92	0.00	0.00
193.92	193.94	21/5/42-44	upper Tt	1.27	0.00	0.16	5.71	7.14	0.00	0.00	0.00	0.00	0.00	0.00	1.11	0.48	0.00	1.59	0.00	0.00
194.34	194.26	21/5/84-86	upper Tt	1.33	0.00	0.67	6.67	8.67	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.44	0.00	1.11	0.00	0.00
194.72	194.74	21/5/122-124	upper Tt	1.49	0.00	0.00	10.40	11.89	0.11	0.00	0.11	0.00	0.00	0.00	1.71	0.23	0.00	1.94	0.00	0.00
195.07	195.09	21/6/7-9	upper Tt	2.08	0.00	0.83	10.94	13.85	0.28	0.00	0.28	0.00	0.00	0.00	1.11	0.14	0.00	1.25	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	NZ Stage	*Globigerina bulloides*	*Globigerina eamesi*	*Globigerina falconensis*	*Globigerina* sp.	***Gg. bulloides* gp**	*Globigerina cf. angustiumbilicata*	*Globigerina quinqueloba*	***Gg. quinqueloba* gp**	*Globigerinella aequilateralis*	*Globigerinella aequilateralis?*	***Globigerinella***	*Globigerinita glutinata*	*Globigerinita uvula*	*Globigerinita uvula?*	***Globigerinita***	*Globigerinoides obliquus*	*Globigerinoides obliquus?*
195.49	195.51	21/6/49-51	upper Tt	0.94	0.00	0.00	4.72	5.67	0.40	0.00	0.40	0.00	0.00	0.00	1.48	0.00	0.00	1.48	0.00	0.00
195.87	195.89	21/6/87-89	upper Tt	1.65	0.00	0.55	8.02	10.22	0.44	0.00	0.44	0.00	0.00	0.00	0.77	0.33	0.00	1.10	0.00	0.00
196.34	196.36	21/6/134-136	upper Tt	2.23	0.00	0.93	15.46	18.62	0.37	0.00	0.37	0.00	0.00	0.00	1.12	0.37	0.00	1.49	0.00	0.00
196.72	196.74	21/7/22-24	upper Tt	1.97	0.00	0.90	12.39	15.26	0.00	0.00	0.00	0.00	0.00	0.00	2.15	0.00	0.00	2.15	0.00	0.00
197.11	197.13	22/1/1-3	upper Tt	0.15	0.00	0.91	7.40	8.46	0.15	0.00	0.15	0.00	0.00	0.00	0.60	0.00	0.00	0.60	0.00	0.00
197.48	197.50	22/1/38-40	upper Tt	0.34	0.00	0.11	2.03	2.48	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.11	0.00	0.79	0.00	0.00
197.94	197.96	22/1/84-86	upper Tt	1.28	0.00	1.00	6.69	8.96	0.28	0.00	0.28	0.00	0.00	0.00	1.00	0.14	0.00	1.14	0.00	0.00
198.32	198.34	22/1/122-124	upper Tt	1.64	0.00	0.88	8.70	11.22	0.63	0.00	0.63	0.00	0.00	0.00	0.50	0.13	0.00	0.63	0.00	0.00
198.73	198.75	22/2/13-15	upper Tt	1.72	0.00	0.38	6.13	8.24	0.38	0.00	0.38	0.00	0.00	0.00	0.57	0.00	0.00	0.57	0.00	0.00
199.14	199.16	22/2/54-56	upper Tt	0.46	0.00	1.04	7.84	9.34	0.12	0.00	0.12	0.00	0.00	0.00	0.92	0.00	0.00	0.92	0.00	0.00
199.53	199.55	22/2/93-95	upper Tt	0.22	0.00	1.21	6.80	8.22	0.00	0.00	0.00	0.00	0.00	0.00	1.64	0.11	0.00	1.75	0.00	0.00
199.93	199.95	22/2/133-135	upper Tt	0.39	0.00	0.99	7.50	8.88	0.39	0.00	0.39	0.00	0.00	0.00	0.79	0.20	0.00	0.99	0.00	0.00
200.25	200.27	22/3/15-17	upper Tt	0.51	0.00	0.26	6.14	6.91	0.13	0.00	0.13	0.00	0.00	0.00	0.90	0.38	0.00	1.28	0.00	0.00
200.66	200.68	22/3/56-58	upper Tt	1.64	0.00	0.20	6.75	8.59	0.00	0.00	0.00	0.00	0.00	0.00	0.82	0.20	0.00	1.02	0.00	0.00
201.05	201.07	22/3/95-97	upper Tt	2.09	0.00	0.45	9.72	12.26	0.00	0.00	0.00	0.00	0.00	0.00	1.20	0.45	0.00	1.64	0.00	0.00
201.42	201.44	22/3/132-134	upper Tt	0.80	0.00	0.60	7.32	8.73	0.10	0.00	0.10	0.00	0.00	0.00	1.00	0.10	0.00	1.10	0.10	0.00
201.93	201.95	22/4/33-35	upper Tt	2.48	0.00	0.29	15.33	18.10	0.00	0.00	0.00	0.00	0.00	0.00	1.17	0.15	0.00	1.31	0.00	0.00
202.52	202.55	22/4/92-95	upper Tt	0.94	0.00	0.12	8.08	9.13	0.00	0.00	0.00	0.00	0.00	0.00	1.41	0.00	0.00	1.41	0.00	0.00
202.93	202.95	22/4/133-135	upper Tt	0.40	0.00	0.93	6.88	8.20	0.13	0.00	0.13	0.00	0.00	0.00	0.93	0.40	0.00	1.32	0.00	0.00
203.17	203.20	22CC/7-10	upper Tt	0.82	0.00	0.47	4.47	5.76	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.00	0.00	0.59	0.00	0.00
206.71	206.73	23/1/1-3	upper Tt	0.79	0.00	0.35	2.91	4.05	0.09	0.09	0.18	0.00	0.00	0.00	0.26	0.00	0.00	0.26	0.00	0.00
207.13	207.15	23/1/43-45	upper Tt	0.95	0.00	0.95	6.40	8.31	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.14	0.00	0.54	0.00	0.00
207.48	207.50	23/1/78-80	upper Tt	0.50	0.00	0.83	11.06	12.38	0.33	0.00	0.33	0.00	0.00	0.00	0.50	0.00	0.00	0.50	0.00	0.00
207.88	207.90	23/1/118-120	upper Tt	0.77	0.00	0.77	10.04	11.58	0.13	0.00	0.13	0.00	0.00	0.00	0.26	0.00	0.13	0.39	0.00	0.00
208.26	208.28	23/2/6-8	upper Tt	0.64	0.00	0.13	6.19	6.96	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.26	0.00	0.00
208.52	208.54	23/2/32-34	upper Tt	1.63	0.00	0.37	4.22	6.22	0.07	0.00	0.07	0.00	0.00	0.00	0.30	0.00	0.00	0.30	0.00	0.00
209.06	209.08	23/2/86-88	upper Tt	0.52	0.00	0.13	5.19	5.84	0.13	0.00	0.13	0.00	0.00	0.00	0.26	0.00	0.13	0.39	0.00	0.00
209.54	209.56	23/2/134-136	upper Tt	0.86	0.00	0.43	7.88	9.17	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.00	0.29	0.00	0.00
209.85	209.87	23/3/15-17	upper Tt	0.42	0.00	0.56	8.44	9.42	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.14	0.00	0.56	0.00	0.00
210.33	210.35	23/3/63-65	upper Tt	0.15	0.00	0.44	7.56	8.14	1.02	0.00	1.02	0.00	0.00	0.00	0.15	0.00	0.00	0.15	0.00	0.00
210.53	210.55	23/3/83-85	upper Tt	1.54	0.00	0.72	3.38	5.64	0.51	0.00	0.51	0.00	0.00	0.00	0.00	0.20	0.00	0.20	0.00	0.00
210.87	210.89	23/3/117-119	upper Tt	1.07	0.00	0.00	8.35	9.43	0.24	0.00	0.24	0.00	0.00	0.00	0.36	0.12	0.00	0.48	0.00	0.00
211.27	211.29	23/4/7-9	upper Tt	0.46	0.00	0.31	11.75	12.52	0.46	0.00	0.46	0.00	0.00	0.00	0.46	0.15	0.00	0.62	0.00	0.00
211.72	211.74	23/4/52-54	upper Tt	0.12	0.00	0.49	6.92	7.54	0.37	0.00	0.37	0.00	0.00	0.00	0.62	0.00	0.00	0.62	0.00	0.00
212.13	212.15	23/4/93-95	upper Tt	0.63	0.00	0.32	7.28	8.23	0.47	0.00	0.47	0.00	0.00	0.00	0.16	0.00	0.00	0.16	0.00	0.00
212.32	212.34	23/4/112-114	upper Tt	1.61	0.00	0.20	4.42	6.23	0.20	0.00	0.20	0.00	0.00	0.00	0.60	0.00	0.00	0.60	0.00	0.00
212.71	212.73	23/5/1-3	upper Tt	0.59	0.00	0.00	3.12	3.71	0.30	0.00	0.30	0.00	0.00	0.00	0.15	0.00	0.00	0.15	0.00	0.00
213.12	213.14	23/5/42-44	upper Tt	1.33	0.00	0.21	8.51	10.05	0.21	0.00	0.21	0.00	0.00	0.00	0.21	0.00	0.00	0.21	0.00	0.00
213.72	213.74	23/5/102-104	upper Tt	2.01	0.00	0.92	4.58	7.51	0.73	0.00	0.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
214.12	214.14	23/5/142-144	upper Tt	1.71	0.00	0.00	5.29	7.00	0.16	0.00	0.16	0.00	0.00	0.00	0.16	0.31	0.00	0.47	0.00	0.00
214.51	214.53	23/6/31-33	upper Tt	1.46	0.00	0.09	6.18	7.73	1.29	0.00	1.29	0.00	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0.00
215.05	215.07	23/6/85-87	upper Tt	1.73	0.00	0.00	10.40	12.14	0.39	0.00	0.39	0.00	0.00	0.00	0.58	0.39	0.00	0.96	0.00	0.00
215.53	215.55	23/6/133-135	upper Tt	1.56	0.00	1.56	10.67	13.80	0.14	0.00	0.14	0.00	0.14	0.14	0.43	0.43	0.00	0.85	0.00	0.00
215.93	215.95	23/7/23-25	upper Tt	3.14	0.00	0.31	11.79	15.25	0.16	0.00	0.16	0.00	0.00	0.00	0.31	0.00	0.00	0.31	0.00	0.00
216.31	216.33	24/1/1-3	upper Tt	1.25	0.00	0.54	9.50	11.29	0.36	0.00	0.36	0.00	0.00	0.00	0.54	0.00	0.00	0.54	0.00	0.00
216.57	216.59	24/1/27-29	upper Tt	0.77	0.00	0.42	3.87	5.06	0.07	0.00	0.07	0.00	0.00	0.00	0.07	0.14	0.00	0.21	0.00	0.00
216.94	216.96	24/1/64-66	upper Tt	0.75	0.00	1.94	11.18	13.86	0.15	0.15	0.30	0.00	0.00	0.00	0.15	0.00	0.00	0.15	0.00	0.00
217.34	217.36	24/1/104-106	upper Tt	1.55	0.00	0.69	11.51	13.75	0.34	0.00	0.34	0.00	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0.00
217.72	217.74	24/1/142-144	upper Tt	0.64	0.00	0.48	10.79	11.92	0.16	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
218.08	218.10	24/2/28-30	upper Tt	0.75	0.00	0.45	12.74	13.94	0.30	0.00	0.30	0.00	0.00	0.00	0.30	0.00	0.00	0.30	0.00	0.00
218.52	218.54	24/2/72-74	upper Tt	0.46	0.00	0.53	4.12	5.11	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.00	0.00	0.53	0.00	0.00
218.87	218.89	24/2/107-109	upper Tt	0.69	0.00	0.80	10.86	12.34	0.34	0.00	0.34	0.00	0.00	0.00	0.46	0.00	0.00	0.46	0.00	0.00
219.31	219.33	24/3/1-3	upper Tt	0.65	0.00	1.53	8.39	10.57	0.11	0.00	0.11	0.11	0.00	0.11	0.22	0.00	0.00	0.22	0.00	0.00
219.72	219.74	24/3/42-44	upper Tt	1.31	0.00	1.97	14.55	17.82	0.79	0.00	0.79	0.00	0.00	0.00	0.92	0.00	0.00	0.92	0.00	0.00
220.12	220.14	24/3/82-84	upper Tt	1.67	0.00	1.43	10.62	13.72	0.48	0.00	0.48	0.00	0.00	0.00	0.24	0.00	0.00	0.24	0.00	0.00
220.46	220.48	24/3/116-118	upper Tt	0.43	0.00	0.22	5.27	5.91	2.04	0.00	2.04	0.00	0.00	0.00	1.29	0.22	0.00	1.51	0.00	0.00
220.87	220.89	24/4/7-9	upper Tt	2.49	0.00	0.78	11.04	14.31	2.02	0.00	2.02	0.00	0.00	0.00	0.93	0.00	0.00	0.93	0.00	0.00
221.27	221.29	24/4/47-49	upper Tt	2.43	0.00	0.85	11.75	15.03	2.33	0.00	2.33	0.00	0.00	0.00	0.42	0.00	0.00	0.42	0.00	0.00
221.66	221.68	24/4/86-88	upper Tt	1.22	0.00	0.61	7.29	9.11	1.22	0.00	1.22	0.00	0.00	0.00	0.97	0.00	0.00	0.97	0.00	0.00
222.13	222.15	24/4/133-135	upper Tt	1.60	0.00	0.98	8.00	10.58	0.86	0.00	0.86	0.00	0.00	0.00	0.86	0.12	0.00	0.98	0.00	0.00
222.45	222.47	24/5/15-17	upper Tt	0.53	0.00	0.53	5.51	6.57	1.17	0.00	1.17	0.00	0.00	0.00	0.53	0.00	0.42	0.95	0.00	0.00
222.93	222.95	24/5/63-65	upper Tt	0.79	0.00	1.45	6.44	8.67	0.92	0.00	0.92	0.00	0.00	0.00	0.13	0.00	0.00	0.13	0.00	0.00
223.33	223.35	24/5/103-105	upper Tt	1.25	0.00	1.57	7.21	10.03	0.47	0.00	0.47	0.00	0.00	0.00	0.31	0.16	0.00	0.47	0.00	0.00
223.72	223.74	24/5/142-144	upper Tt	1.82	0.00	0.70	8.26	10.78	0.84	0.00	0.84	0.00	0.00	0.00	0.84	0.00	0.00	0.84	0.00	0.00
224.07	224.09	24/6/27-29	upper Tt	1.57	0.00	0.52	4.17	6.26	1.91	0.00	1.91	0.00	0.00	0.00	0.52	0.00	0.00	0.52	0.00	0.00
224.47	224.49	24/6/67-69	upper Tt	1.46	0.19	0.49	6.50	8.64	0.49	0.10	0.58	0.00	0.00	0.00	0.97	0.00	0.00	0.97	0.00	0.00
224.87	224.89	24/6/107-109	upper Tt	1.03	0.00	1.45	5.58	8.06	0.41	0.00	0.41	0.00	0.00	0.00	1.24	0.00	0.00	1.24	0.00	0.00
225.36	225.38	24CC/9-11	upper Tt	0.83	0.00	1.67	4.51	7.01	1.34	0.00	1.34	0.00	0.00	0.00	0.83	0.00	0.00	0.83	0.00	0.00
226.13	226.15	25/1/23-25	upper Tt	1.53	0.00	2.15	8.74	12.42	0.77	0.00	0.77	0.00	0.00	0.00	0.15	0.00	0.00	0.15	0.00	0.00
226.53	226.55	25/1/63-65	upper Tt	1.46	0.00	0.57	4.38	6.41	1.62	0.00	1.62	0.00	0.00	0.00	0.65	0.08	0.00	0.73	0.00	0.00
226.93	226.95	25/1/103-105	upper Tt	2.28	0.00	1.93	10.00	14.21	0.00	0.00	0.00	0.00	0.00	0.00	0.88	0.00	0.00	0.88	0.00	0.00
227.34	227.36	25/1/144-146	upper Tt	1.42	0.00	1.74	7.89	11.04	0.00	0.00	0.00	0.00	0.00	0.00	1.10	0.00	0.00	1.10	0.00	0.00
227.72	227.74	25/2/-32-34	upper Tt	2.26	0.00	1.50	7.52	11.28	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.38	0.00	0.00
228.12	228.14	25/2/72-74	upper Tt	2.22	0.00	3.21	11.60	17.04	0.49	0.00	0.49	0.00	0.00	0.00	0.12	0.00	0.49	0.62	0.00	0.00
228.52	228.54	25/2/112-114	upper Tt	2.36	0.00	1.23	7.99	11.58	1.33	0.00	1.33	0.00	0.00	0.00	0.82	0.00	0.00	0.82	0.00	0.00
228.90	228.92	25/3/0-2	upper Tt	2.52	0.00	1.36	7.17	11.05	0.58	0.19	0.78	0.00	0.00	0.00	0.78	0.00	0.00	0.78	0.00	0.00
229.33	229.35	25/3/43-45	upper Tt	0.82	0.00	2.36	12.01	15.19	0.71	0.00	0.71	0.00	0.00	0.00	0.35	0.12	0.00	0.47	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	NZ Stage	*Globigerina bulloides*	*Globigerina eamesi*	*Globigerina falconensis*	*Globigerina* sp.	***Gg. bulloides* gp**	*Globigerina cf. angustiumbilicata*	*Globigerina quinqueloba*	***Gg. quinqueloba* gp**	*Globigerinella aequilateralis*	*Globigerinella aequilateralis?*	***Globigerinella***	*Globigerinita glutinata*	*Globigerinita uvula*	*Globigerinita uvula?*	***Globigerinita***	*Globigerinoides obliquus*	*Globigerinoides obliquus?*
229.85	229.87	25/3/95-97	upper Tt	1.10	0.00	1.65	12.35	15.09	0.41	0.00	0.41	0.00	0.00	0.00	0.69	0.00	0.14	0.82	0.00	0.00
230.27	230.29	25/3/137-139	upper Tt	1.83	0.00	3.49	7.16	12.48	0.55	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.73	0.73	0.00	0.00
230.47	230.49	25/4/7-9	upper Tt	1.51	0.00	1.95	6.38	9.84	1.24	0.00	1.24	0.00	0.00	0.00	0.27	0.09	0.00	0.35	0.00	0.00
230.93	230.95	25/4/53-55	upper Tt	1.45	0.00	3.27	10.53	15.25	0.00	0.00	0.00	0.00	0.00	0.00	0.91	0.00	0.00	0.91	0.00	0.00
231.33	231.35	25/4/93-95	upper Tt	1.59	0.00	3.80	9.07	14.46	1.23	0.00	1.23	0.00	0.12	0.12	0.37	0.37	0.00	0.74	0.00	0.00
231.73	231.75	25/4/133-135	upper Tt	3.48	0.00	1.45	8.27	13.21	0.44	0.00	0.44	0.00	0.15	0.15	1.31	0.15	0.00	1.45	0.00	0.00
232.06	232.08	25/5/16-18	upper Tt	1.62	0.00	4.68	10.34	16.64	1.13	0.00	1.13	0.00	0.00	0.00	0.65	0.16	0.00	0.81	0.00	0.00
232.52	232.54	25/5/62-64	upper Tt	1.90	0.00	1.00	6.80	9.70	0.89	0.00	0.89	0.00	0.00	0.00	0.45	0.22	0.00	0.67	0.00	0.00
232.92	232.94	25/5/102-104	upper Tt	1.66	0.00	2.69	7.87	12.22	1.24	0.00	1.24	0.00	0.00	0.00	0.21	0.00	0.21	0.41	0.00	0.00
233.27	233.29	25/5137-139	upper Tt	1.77	0.00	4.78	9.73	16.28	1.59	0.00	1.59	0.00	0.00	0.00	0.35	0.18	0.00	0.53	0.00	0.18
233.67	233.69	25/6/27-29	upper Tt	1.07	0.00	3.49	5.09	9.65	1.34	0.00	1.34	0.00	0.00	0.00	0.80	0.13	0.00	0.94	0.00	0.00
234.15	234.17	25/6/75-77	upper Tt	3.41	0.00	4.01	8.88	16.30	1.82	0.00	1.82	0.00	0.00	0.00	1.22	0.12	0.00	1.34	0.00	0.00
234.52	234.54	25/6/112-114	upper Tt	2.99	0.00	5.99	9.95	18.93	0.96	0.00	0.96	0.00	0.00	0.00	1.07	0.00	0.00	1.07	0.00	0.11
234.91	234.93	25/7/1-3	upper Tt	2.71	0.00	3.85	7.26	13.82	0.85	0.00	0.85	0.00	0.00	0.00	0.71	0.28	0.00	1.00	0.00	0.00
235.26	235.28	25CC/10-22	upper Tt	1.95	0.00	4.72	8.47	15.15	1.14	0.00	1.14	0.00	0.00	0.00	0.98	0.16	0.00	1.14	0.00	0.00
235.73	235.75	26/1/23-25	upper Tt	5.56	0.00	1.16	10.19	16.90	0.69	0.23	0.93	0.00	0.23	0.23	1.16	0.23	0.00	1.39	0.00	0.00
236.08	236.10	26/1/58-60	upper Tt	3.38	0.00	2.25	6.11	11.74	0.16	0.00	0.16	0.00	0.00	0.00	0.80	0.32	0.00	1.13	0.00	0.00
236.52	236.54	26/1/102-104	upper Tt	2.20	0.00	4.84	5.28	12.32	1.03	0.00	1.03	0.00	0.15	0.15	0.73	0.00	0.00	0.73	0.00	0.00
236.92	236.94	26/1/142-144	upper Tt	1.69	0.00	1.21	9.18	12.08	1.45	0.00	1.45	0.00	0.00	0.00	0.48	0.24	0.00	0.72	0.00	0.00
237.32	237.34	26/2/32-34	upper Tt	1.70	0.00	0.00	7.53	9.23	0.43	0.00	0.43	0.00	0.00	0.00	0.57	0.28	0.00	0.85	0.00	0.00
237.93	237.95	26/2/93-95	upper Tt	3.69	0.00	1.23	11.27	16.19	0.61	0.00	0.61	0.00	0.00	0.00	0.82	0.61	0.00	1.43	0.00	0.00
238.33	238.35	26/2/133-135	upper Tt	1.32	0.00	1.69	15.25	18.27	3.20	0.00	3.20	0.00	0.00	0.00	0.75	0.00	0.00	0.75	0.00	0.00
238.51	238.53	26/3/1-3	upper Tt	3.95	0.00	0.70	9.88	14.53	0.70	0.00	0.70	0.00	0.12	0.12	0.70	0.12	0.00	0.81	0.00	0.00
238.93	238.95	26/3/43-45	upper Tt	3.45	0.00	1.44	8.06	12.95	0.72	0.00	0.72	0.00	0.00	0.00	0.72	0.43	0.00	1.15	0.00	0.00
239.32	239.34	26/3/82-84	upper Tt	1.77	0.00	0.41	11.85	14.03	0.41	0.00	0.41	0.00	0.00	0.00	0.54	0.14	0.00	0.68	0.00	0.00
239.67	239.69	26/3/117-119	upper Tt	2.61	0.00	1.57	7.14	11.32	0.00	0.00	0.00	0.00	0.00	0.00	1.05	0.17	0.00	1.22	0.00	0.00
240.07	240.09	26/4/7-9	upper Tt	3.69	0.00	2.46	7.85	14.00	0.46	0.00	0.46	0.00	0.31	0.31	0.62	0.15	0.00	0.77	0.00	0.00
240.52	240.54	26/4/52-54	upper Tt	3.76	0.00	0.77	8.98	13.51	0.10	0.00	0.10	0.00	0.00	0.00	0.39	0.00	0.00	0.39	0.00	0.00
240.92	240.94	26/4/92-94	upper Tt	0.88	0.00	4.39	10.20	15.46	0.33	0.00	0.33	0.00	0.11	0.11	0.33	0.11	0.00	0.44	0.00	0.00
241.32	241.34	26/4/132-134	upper Tt	1.97	0.00	4.40	10.62	17.00	0.91	0.00	0.91	0.00	0.00	0.00	1.52	0.30	0.00	1.82	0.00	0.00
241.65	241.67	26/5/15-17	upper Tt	3.12	0.00	1.19	11.72	16.02	0.15	0.00	0.15	0.00	0.00	0.00	1.04	0.30	0.00	1.34	0.00	0.00
242.13	242.15	26/5/63-65	upper Tt	2.17	0.00	1.09	8.70	11.96	0.43	0.00	0.43	0.00	0.00	0.00	2.17	0.22	0.00	2.39	0.00	0.00
242.52	242.54	26/5/102-104	upper Tt	1.09	0.00	1.27	10.34	12.70	0.54	0.00	0.54	0.00	0.00	0.00	2.72	0.00	0.00	2.72	0.00	0.36
242.92	242.94	26/5/142-144	upper Tt	3.14	0.00	2.84	11.06	17.04	0.45	0.00	0.45	0.00	0.00	0.00	1.20	0.15	0.00	1.35	0.00	0.00
243.26	243.28	26/6/26-28	upper Tt	2.31	0.00	2.12	23.08	27.50	0.38	0.00	0.38	0.00	0.00	0.00	0.38	0.00	0.00	0.38	0.00	0.00
243.63	243.65	26/6/63-65	upper Tt	2.05	0.00	3.20	8.90	14.16	1.37	0.00	1.37	0.00	0.00	0.00	0.00	0.23	0.00	0.23	0.00	0.00
243.86	243.88	26CC/13-15	upper Tt	2.03	0.00	2.03	8.10	12.15	1.10	0.00	1.10	0.00	0.00	0.00	0.92	0.00	0.18	1.10	0.00	0.00
245.11	245.13	27/1/1-3	upper Tt	3.08	0.00	1.85	8.92	13.85	0.31	0.00	0.31	0.00	0.00	0.00	0.15	0.00	0.00	0.15	0.00	0.00
245.53	245.55	27/1/43-45	upper Tt	0.56	0.00	2.11	10.55	13.22	0.42	0.00	0.42	0.00	0.00	0.00	0.28	0.00	0.00	0.28	0.00	0.00
245.91	245.93	27/1/81-83	upper Tt	3.61	0.00	1.91	13.16	18.68	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.64	0.00	0.00
246.27	246.29	27/1/117-119	upper Tt	2.03	0.00	2.32	8.68	13.02	0.14	0.00	0.14	0.00	0.00	0.00	0.14	0.00	0.00	0.14	0.00	0.00
246.52	246.54	27/1/142-144	upper Tt	1.56	0.00	2.19	10.01	13.76	1.04	0.00	1.04	0.00	0.00	0.00	0.52	0.00	0.10	0.63	0.00	0.00
246.87	246.89	27/2/27-29	upper Tt	2.42	0.00	1.21	9.69	13.32	0.48	0.00	0.48	0.00	0.00	0.00	0.36	0.00	0.00	0.36	0.00	0.00
247.33	247.35	27/2/73-76	upper Tt	1.67	0.00	2.23	10.04	13.94	1.12	0.00	1.12	0.00	0.00	0.00	0.56	0.00	0.00	0.56	0.00	0.00
247.67	247.69	27/2/107-109	upper Tt	1.33	0.00	0.85	7.50	9.67	1.33	0.00	1.33	0.12	0.24	0.36	0.48	0.00	0.00	0.48	0.00	0.00
248.11	248.13	27/3/1-3	upper Tt	1.87	0.00	2.25	8.80	12.92	1.87	0.00	1.87	0.00	0.00	0.00	0.75	0.00	0.00	0.75	0.00	0.00
248.47	248.49	27/3/37-39	upper Tt	1.60	0.00	0.85	7.45	9.89	1.49	0.00	1.49	0.00	0.00	0.00	0.43	0.00	0.00	0.43	0.00	0.00
248.93	248.95	27/3/83-85	upper Tt	2.17	0.00	2.17	9.16	13.49	1.69	0.00	1.69	0.00	0.00	0.00	0.48	0.00	0.00	0.48	0.00	0.00
249.27	249.27	27/3/117-119	upper Tt	0.95	0.00	1.36	10.60	12.91	1.36	0.00	1.36	0.00	0.00	0.00	0.27	0.00	0.00	0.27	0.00	0.00
249.67	249.69	27/4/7-9	upper Tt	2.13	0.00	1.91	13.24	17.28	2.02	0.00	2.02	0.00	0.00	0.00	0.56	0.00	0.00	0.56	0.00	0.00
250.12	250.14	27/4/52-54	upper Tt	1.55	0.00	1.83	9.15	12.54	1.41	0.00	1.41	0.00	0.00	0.00	0.56	0.00	0.00	0.56	0.00	0.00
250.46	250.48	27/4/86-88	upper Tt	0.59	0.00	0.20	10.28	11.07	0.40	0.00	0.40	0.00	0.00	0.00	0.79	0.00	0.00	0.79	0.00	0.00
250.92	250.94	27/4/132-134	upper Tt	1.18	0.00	0.88	11.63	13.70	0.29	0.00	0.29	0.00	0.00	0.00	0.59	0.15	0.00	0.74	0.00	0.00
251.33	251.36	27/5/23-26	upper Tt	0.79	0.00	1.74	12.32	14.85	0.47	0.00	0.47	0.00	0.00	0.00	0.79	0.00	0.00	0.79	0.00	0.00
251.67	251.69	27/5/57-59	upper Tt	2.00	0.00	1.09	12.20	15.30	0.36	0.00	0.36	0.00	0.00	0.00	0.18	0.00	0.00	0.18	0.00	0.00
252.13	252.15	27/5/103-105	upper Tt	1.16	0.00	1.89	8.73	11.79	0.73	0.00	0.73	0.00	0.00	0.00	0.58	0.00	0.00	0.58	0.00	0.00
252.53	252.55	27/5/143-145	upper Tt	0.49	0.00	3.62	6.41	10.53	0.00	0.00	0.00	0.00	0.00	0.00	0.66	0.00	0.00	0.66	0.00	0.00
252.92	252.94	27/6/32-34	upper Tt	0.83	0.00	2.66	9.65	13.14	0.33	0.00	0.33	0.00	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0.00
253.33	253.35	27/6/73-75	upper Tt	3.37	0.00	5.06	14.04	22.47	0.00	0.00	0.00	0.00	0.00	0.00	0.84	0.00	0.00	0.84	0.00	0.00
253.67	253.69	27/6/107-109	upper Tt	2.47	0.00	1.64	11.92	16.03	0.55	0.00	0.55	0.00	0.00	0.00	0.68	0.00	0.00	0.68	0.00	0.00
254.10	254.12	27/7/0-2	upper Tt	1.11	0.00	1.75	13.33	16.19	0.32	0.00	0.32	0.00	0.00	0.00	1.59	0.00	0.00	1.59	0.00	0.00
254.49	254.51	27CC/10-12	lower Tt	0.97	0.00	2.29	12.32	15.58	0.00	0.00	0.00	0.00	0.00	0.00	1.57	0.00	0.00	1.57	0.00	0.00
254.93	254.95	28/1/23-25	lower Tt	1.38	0.00	2.31	13.23	16.92	0.31	0.00	0.31	0.00	0.00	0.00	2.31	0.31	0.00	2.62	0.00	0.00
255.28	255.30	28/1/58-60	lower Tt	0.61	0.00	4.70	12.73	18.03	0.30	0.00	0.30	0.00	0.00	0.00	0.45	0.00	0.00	0.45	0.00	0.00
255.73	255.75	28/1/103-105	lower Tt	0.75	0.00	3.20	15.82	19.77	0.56	0.00	0.56	0.00	0.00	0.00	0.75	0.00	0.00	0.75	0.00	0.00
256.11	256.13	28/1/141-143	lower Tt	0.93	0.00	3.72	11.86	16.51	0.00	0.00	0.00	0.00	0.00	0.00	2.09	0.00	0.00	2.09	0.00	0.00
256.53	256.55	28/2/33-35	lower Tt	0.87	0.00	2.43	8.32	11.61	0.35	0.00	0.35	0.00	0.00	0.00	2.60	0.00	0.00	2.60	0.00	0.00
257.03	257.05	28/2/83-85	lower Tt	1.30	0.00	1.96	8.70	11.96	0.43	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
257.33	257.35	28/2/113-115	lower Tt	1.39	0.00	1.39	11.11	13.89	0.00	0.00	0.00	0.00	0.00	0.00	1.85	0.00	0.00	1.85	0.00	0.00
257.71	257.73	28/3/1-3	lower Tt	0.83	0.00	1.67	8.75	11.25	0.00	0.00	0.00	0.00	0.00	0.00	1.46	0.00	0.00	1.46	0.00	0.00
258.12	258.14	28/3/42-44	lower Tt	0.67	0.00	3.85	9.05	13.57	0.17	0.00	0.17	0.00	0.00	0.00	1.68	0.00	0.00	1.68	0.00	0.00
258.54	258.56	28/3/84-86	lower Tt	1.57	0.00	0.00	10.47	12.04	0.26	0.00	0.26	0.00	0.00	0.00	3.66	0.00	0.00	3.66	0.00	0.00
259.07	259.09	28/3/137-139	lower Tt	0.51	0.00	2.05	9.21	11.76	0.00	0.00	0.00	0.00	0.00	0.00	3.07	0.00	0.00	3.07	0.00	0.00
259.53	259.55	28/4/33-35	lower Tt	1.31	0.00	2.12	8.81	12.23	0.33	0.00	0.33	0.00	0.00	0.00	1.96	0.00	0.00	1.96	0.00	0.00
259.86	259.88	28/4/66-68	lower Tt	1.28	0.00	3.07	11.25	15.60	0.13	0.00	0.13	0.00	0.00	0.00	1.53	0.00	0.00	1.53	0.00	0.00
260.28	260.30	28/4/108-110	lower Tt	1.56	0.00	4.20	13.22	18.97	0.31	0.00	0.31	0.00	0.00	0.00	1.24	0.00	0.00	1.24	0.00	0.00
260.54	260.56	28/4/134-136	lower Tt	1.62	0.00	0.44	13.70	15.76	0.00	0.00	0.00	0.00	0.15	0.15	1.03	0.00	0.00	1.03	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	NZ Stage	*Globigerina bulloides*	*Globigerina earnesi*	*Globigerina falconensis*	*Globigerina* sp.	**Gg. bulloides gp**	*Globigerina cf. angustiumbilicata*	*Globigerina quinqueloba*	**Gg. quinqueloba gp**	*Globigerinella aequilateralis*	*Globigerinella aequilateralis?*	**Globigerinella**	*Globigerinita glutinata*	*Globigerinita uvula*	*Globigerinita uvula?*	**Globigerinita**	*Globigerinoides obliquus*	*Globigerinoides obliquus?*
260.86	260.88	28/5/16-18	lower Tt	2.57	0.00	3.85	9.42	15.85	0.00	0.00	0.00	0.00	0.00	0.00	1.93	0.00	0.00	1.93	0.00	0.21
261.31	261.33	28/5/61-63	lower Tt	1.68	0.00	1.37	14.33	17.38	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.00	0.00	0.61	0.00	0.00
261.72	261.74	28/5/102-104	lower Tt	1.69	0.00	3.51	9.75	14.95	0.00	0.00	0.00	0.00	0.00	0.00	1.17	0.00	0.00	1.17	0.00	0.00
262.11	262.13	28/5/141-143	lower Tt	0.77	0.00	1.34	9.40	11.52	0.00	0.00	0.00	0.00	0.00	0.00	0.77	0.00	0.19	0.96	0.00	0.00
262.45	262.47	28CC/8-10	lower Tt	1.28	0.00	1.28	7.56	10.12	0.00	0.00	0.00	0.00	0.00	0.00	1.38	0.11	0.00	1.49	0.00	0.00
264.30	264.32	29/1/0-2	lower Tt	2.32	0.00	1.55	9.02	12.89	0.00	0.00	0.00	0.00	0.00	0.00	1.03	0.00	0.00	1.03	0.00	0.00
264.64	264.66	29/1/34-36	lower Tt	0.77	0.00	1.24	8.04	10.05	0.00	0.00	0.00	0.00	0.00	0.00	1.85	0.00	0.00	1.85	0.00	0.00
264.88	264.90	29/1/58-60	lower Tt	0.96	0.00	3.21	7.37	11.54	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.32	0.00	0.00
265.26	265.28	29/1/96-98	lower Tt	1.48	0.00	5.10	9.21	15.79	0.16	0.00	0.16	0.00	0.00	0.00	1.48	0.00	0.00	1.48	0.00	0.00
265.72	265.74	29/1/142-144	lower Tt	1.36	0.00	2.53	15.37	19.26	0.97	0.00	0.97	0.00	0.00	0.00	0.97	0.00	0.00	0.97	0.00	0.00
266.12	266.14	29/2/32-34	lower Tt	1.30	0.00	4.98	16.23	22.51	1.30	0.00	1.30	0.00	0.00	0.00	2.16	0.00	0.00	2.16	0.00	0.00
266.44	266.46	29/2/64-66	lower Tt	1.12	0.00	0.45	12.75	14.32	0.22	0.00	0.22	0.00	0.00	0.00	1.12	0.00	0.00	1.12	0.00	0.00
266.87	266.89	29/2/107-109	lower Tt	0.99	0.00	2.96	9.11	13.05	0.00	0.00	0.00	0.00	0.00	0.00	1.23	0.00	0.00	1.23	0.00	0.00
267.31	267.33	29/3/1-3	lower Tt	0.51	0.00	3.06	13.52	17.09	0.26	0.00	0.26	0.00	0.00	0.00	1.28	0.00	0.00	1.28	0.00	0.00
267.53	267.55	29/3/23-25	lower Tt	0.88	0.00	1.23	8.99	11.11	0.71	0.00	0.71	0.00	0.00	0.00	0.71	0.00	0.18	0.88	0.00	0.00
267.72	267.74	29/3/42-44	lower Tt	0.99	0.00	2.98	11.91	15.89	0.14	0.00	0.14	0.00	0.00	0.00	1.13	0.00	0.00	1.13	0.00	0.00
267.87	267.89	29/3/57-59	lower Tt	1.40	0.00	2.98	11.56	15.94	0.53	0.00	0.53	0.00	0.00	0.00	1.40	0.00	0.35	1.75	0.00	0.00
268.14	268.16	29/3/84-86	lower Tt	1.28	0.00	5.30	10.05	16.64	0.73	0.00	0.73	0.00	0.00	0.00	0.91	0.00	0.00	0.91	0.00	0.00
268.34	268.36	29/3/104-106	lower Tt	1.09	0.00	5.99	12.16	19.24	0.91	0.00	0.91	0.00	0.00	0.00	0.36	0.00	0.18	0.54	0.00	0.00
268.47	268.49	29/3/117-119	lower Tt	1.17	0.00	4.14	9.33	14.63	0.85	0.00	0.85	0.00	0.00	0.00	1.06	0.00	0.00	1.06	0.00	0.00
268.68	268.70	29/3/138-140	lower Tt	0.26	0.00	3.12	7.01	10.39	0.78	0.00	0.78	0.00	0.00	0.00	0.52	0.00	0.00	0.52	0.00	0.00
268.86	268.88	29/4/6-8	lower Tt	0.87	0.00	3.50	6.12	10.50	0.87	0.00	0.87	0.00	0.00	0.00	1.75	0.00	0.58	2.33	0.00	0.00
269.28	269.30	29/4/48-50	lower Tt	1.70	0.00	5.40	9.66	16.76	0.28	0.00	0.28	0.00	0.00	0.00	1.14	0.00	0.00	1.14	0.00	0.00
269.52	269.54	29/4/72-74	lower Tt	1.69	0.00	6.02	6.75	14.46	0.24	0.00	0.24	0.00	0.00	0.00	0.72	0.00	0.00	0.72	0.00	0.00
269.75	269.77	29/4/95-97	lower Tt	1.65	0.00	5.13	9.16	15.93	0.18	0.00	0.18	0.00	0.00	0.00	0.92	0.00	0.00	0.92	0.00	0.00
269.87	269.89	29/4/107-109	lower Tt	2.06	0.00	4.94	12.35	19.34	0.21	0.00	0.21	0.00	0.00	0.00	0.62	0.00	0.00	0.62	0.00	0.00
270.15	270.17	29/4/135-137	lower Tt	1.02	0.00	4.40	6.94	12.35	0.17	0.00	0.17	0.00	0.00	0.00	1.18	0.00	0.00	1.18	0.00	0.00
270.31	270.33	29/5/1-3	lower Tt	0.73	0.00	6.11	5.39	12.23	0.00	0.00	0.00	0.00	0.00	0.00	1.60	0.00	0.15	1.75	0.00	0.00
270.45	270.47	29/5/15-17	lower Tt	1.13	0.00	2.03	6.98	10.14	0.00	0.00	0.00	0.00	0.00	0.00	1.13	0.00	0.00	1.13	0.00	0.00
270.72	270.74	29/5/42-44	lower Tt	1.13	0.00	1.81	6.77	9.71	0.00	0.00	0.00	0.00	0.00	0.00	1.81	0.00	0.00	1.81	0.00	0.00
270.91	270.93	29/5/61-63	lower Tt	0.90	0.00	2.87	12.19	15.95	0.00	0.00	0.00	0.00	0.00	0.00	1.08	0.00	0.00	1.08	0.00	0.00
271.15	271.17	29/5/85-87	lower Tt	1.84	0.00	3.50	8.10	13.44	0.00	0.00	0.00	0.00	0.00	0.00	1.66	0.00	0.00	1.66	0.00	0.00
271.34	271.36	29/5/104-106	lower Tt	2.00	0.00	3.20	11.60	16.80	0.00	0.00	0.00	0.00	0.00	0.00	2.20	0.00	0.00	2.20	0.00	0.00
271.48	271.50	29/5/118-120	lower Tt	2.56	0.00	1.38	20.87	24.80	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.39	0.00	0.00
271.72	271.74	29/5/142-144	lower Tt	3.38	0.00	2.86	11.69	17.92	0.26	0.00	0.26	0.00	0.00	0.00	0.26	0.00	0.00	0.26	0.00	0.00
271.94	271.96	29/6/14-16	lower Tt	2.59	0.00	1.85	13.49	17.93	0.00	0.00	0.00	0.00	0.00	0.00	0.92	0.00	0.00	0.92	0.00	0.00
272.19	272.21	29CC/17-19	lower Tt	2.55	0.00	3.50	11.45	17.50	0.00	0.00	0.00	0.00	0.00	0.00	1.17	0.11	0.00	1.27	0.00	0.00
273.91	273.93	30/1/1-A7303	lower Tt	0.99	0.00	2.81	9.90	13.70	0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.00	0.00	0.99	0.00	0.00
274.04	274.06	30/1/14-16	lower Tt	2.47	0.00	6.95	13.68	23.09	0.00	0.00	0.00	0.00	0.00	0.00	1.12	0.00	0.00	1.12	0.00	0.00
274.32	274.34	30/1/42-44	lower Tt	3.47	0.00	7.64	11.28	22.40	0.00	0.00	0.00	0.00	0.00	0.00	1.04	0.00	0.00	1.04	0.00	0.00
274.48	274.50	30/1/58-60	lower Tt	1.63	0.00	6.12	7.14	14.90	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.00	0.00	0.61	0.00	0.00
274.72	274.74	30/1/82-84	lower Tt	2.22	0.00	5.13	7.07	14.42	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.42	0.00	0.00
274.93	274.95	30/1/103-105	lower Tt	6.00	0.00	4.70	12.16	22.85	0.00	0.00	0.00	0.00	0.16	0.16	2.11	0.00	0.16	2.27	0.00	0.00
275.12	275.14	30/1/122-124	lower Tt	1.47	0.00	6.83	12.85	21.15	0.00	0.00	0.00	0.00	0.00	0.00	1.34	0.00	0.00	1.34	0.00	0.00
275.31	275.33	30/1/141-143	lower Tt	2.43	0.00	2.57	9.73	14.73	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00	0.14	0.54	0.00	0.00
275.45	275.47	30/2/5-7	lower Tt	1.08	0.00	6.68	11.73	19.49	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00	0.54	0.00	0.00
275.93	275.95	30/2/53-55	lower Tt	0.98	0.00	1.31	6.56	8.85	0.00	0.00	0.00	0.00	0.00	0.00	1.15	0.00	0.00	1.15	0.00	0.00
276.52	276.54	30/2/112-114	lower Tt	1.24	0.00	2.67	8.10	12.01	0.00	0.00	0.00	0.00	0.00	0.00	1.05	0.00	0.19	1.24	0.00	0.00
276.91	276.93	30/3/1-3	lower Tt	1.87	0.00	1.53	8.01	11.41	0.17	0.00	0.17	0.00	0.00	0.00	0.51	0.00	0.00	0.51	0.00	0.00
277.33	277.35	30/3/43-45	lower Tt	1.68	0.00	7.34	14.37	23.39	0.00	0.00	0.00	0.00	0.00	0.00	0.92	0.15	0.00	1.07	0.00	0.00
277.74	277.76	30/3/84-86	lower Tt	1.25	0.00	6.56	15.16	22.97	0.00	0.00	0.00	0.00	0.00	0.00	2.19	0.00	0.00	2.19	0.00	0.00
278.07	278.09	30/3/117-119	lower Tt	0.93	0.00	3.44	10.32	14.68	0.26	0.00	0.26	0.00	0.00	0.00	0.13	0.00	0.00	0.13	0.00	0.00
278.49	278.51	30/4/9-11	lower Tt	1.56	0.00	3.57	8.03	13.15	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	0.67	0.00	0.00
278.88	278.90	30/4/48-50	lower Tt	0.81	0.00	5.70	10.10	16.61	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00	0.16	0.81	0.00	0.00
279.33	279.35	30/4/93-95	lower Tt	0.19	0.00	5.99	8.24	14.42	0.19	0.00	0.19	0.00	0.00	0.00	1.12	0.00	0.00	1.12	0.00	0.00
279.75	279.77	30/4/135-137	lower Tt	0.52	0.00	4.49	8.64	13.64	0.00	0.00	0.00	0.00	0.00	0.00	1.38	0.00	0.00	1.38	0.00	0.00
280.05	280.07	30/5/15-17	lower Tt	0.37	0.00	3.69	6.63	10.69	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.25	0.00	0.00
280.25	280.27	30/5/35-37	lower Tt	1.59	0.00	3.07	9.53	14.19	0.00	0.00	0.00	0.00	0.11	0.11	1.38	0.00	0.00	1.38	0.00	0.00
280.92	280.94	30/5/102-104	lower Tt	0.89	0.00	5.54	8.39	14.82	0.00	0.00	0.00	0.00	0.00	0.00	1.43	0.36	0.00	1.79	0.00	0.00
283.51	283.53	31/1/1-3	lower Tt	0.73	0.00	2.78	8.20	11.71	0.00	0.00	0.00	0.00	0.00	0.00	1.90	0.00	0.00	1.90	0.00	0.00
283.94	283.96	31/1/44-46	lower Tt	0.45	0.00	4.34	8.53	13.32	0.00	0.00	0.00	0.00	0.00	0.00	0.90	0.30	0.00	1.20	0.00	0.00
284.33	284.35	31/1/83-85	lower Tt	0.61	0.00	1.38	6.60	8.59	0.00	0.00	0.00	0.00	0.00	0.00	2.45	0.31	0.00	2.76	0.00	0.00
284.55	284.57	31/1/105-107	lower Tt	0.59	0.00	2.84	6.27	9.70	0.00	0.00	0.00	0.00	0.00	0.00	2.25	0.00	0.00	2.25	0.00	0.00
284.88	284.90	31/1/138-140	lower Tt	1.62	0.00	0.40	7.13	9.15	0.00	0.00	0.00	0.00	0.00	0.00	1.35	0.00	0.00	1.35	0.00	0.00
285.29	285.31	31/2/29-31	lower Tt	1.56	0.00	2.34	6.41	10.31	0.00	0.00	0.00	0.00	0.00	0.00	1.41	0.00	0.00	1.41	0.00	0.00
285.73	285.75	31/2/73-75	lower Tt	0.85	0.00	5.08	10.83	16.75	0.00	0.00	0.00	0.00	0.00	0.00	1.18	0.00	0.00	1.18	0.00	0.00
286.10	286.12	31/2/110-112	lower Tt	0.71	0.00	4.57	8.71	14.00	0.00	0.00	0.00	0.00	0.14	0.14	1.14	0.14	0.00	1.29	0.00	0.00
286.51	286.53	31/3/1-3	lower Tt	0.74	0.00	5.10	8.07	13.91	0.00	0.00	0.00	0.00	0.11	0.11	0.74	0.00	0.00	0.74	0.00	0.00
286.88	286.90	31/3/38-40	lower Tt	0.72	0.00	5.73	8.96	15.41	0.00	0.00	0.00	0.00	0.00	0.00	1.25	0.00	0.00	1.25	0.00	0.00
287.32	287.34	31/3/82-84	lower Tt	0.18	0.00	2.30	6.01	8.48	0.00	0.00	0.00	0.00	0.00	0.00	1.06	0.00	0.00	1.06	0.00	0.00
287.67	287.69	31/3/117-119	lower Tt	0.36	0.00	2.26	8.68	11.30	0.00	0.00	0.00	0.00	0.12	0.12	1.55	0.00	0.00	1.55	0.00	0.00
288.08	288.10	31/4/8-10	lower Tt	0.52	0.00	3.67	6.50	10.69	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.42	0.00	0.00
288.55	288.57	31/4/55-57	lower Tt	0.62	0.00	2.38	5.89	8.88	0.00	0.00	0.00	0.00	0.00	0.00	0.72	0.00	0.00	0.72	0.00	0.00
288.89	288.91	31/4/89-91	lower Tt	0.81	0.00	3.50	10.51	14.82	0.00	0.00	0.00	0.00	0.00	0.00	0.81	0.00	0.00	0.81	0.00	0.00
289.34	289.36	31/4/134-136	lower Tt	1.79	0.00	2.51	10.77	15.07	0.00	0.00	0.00	0.00	0.00	0.00	1.44	0.00	0.12	1.56	0.00	0.00
289.73	289.75	31/5/23-25	lower Tt	0.75	0.00	4.63	17.01	22.39	0.00	0.00	0.00	0.00	0.15	0.15	0.75	0.00	0.00	0.75	0.00	0.00
290.12	290.14	31/5/62-64	lower Tt	0.81	0.00	4.86	9.08	14.75	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.65	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	NZ Stage	*Globigerina bulloides*	*Globigerina eamesi*	*Globigerina falconensis*	*Globigerina* sp.	***Gg. bulloides* gp**	*Globigerina cf. angustiumbilicata*	*Globigerina quinqueloba*	***Gg. quinqueloba* gp**	*Globigerinella aequilateralis*	*Globigerinella aequilateralis?*	***Globigerinella***	*Globigerinita glutinata*	*Globigerinita uvula*	*Globigerinita uvula?*	***Globigerinita***	*Globigerinoides obliquus*	*Globigerinoides obliquus?*
290.51	290.53	31/5/101-103	lower Tt	0.99	0.00	5.44	7.17	13.60	0.00	0.00	0.00	0.00	0.00	0.00	1.11	0.00	0.00	1.11	0.00	0.00
290.74	290.76	31CC/0-2	lower Tt	1.02	0.00	1.40	11.69	14.10	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.25	0.00	0.76	0.00	0.00
293.11	293.13	32/1/1-3	lower Tt	1.30	0.00	5.19	7.47	13.96	0.00	0.00	0.00	0.00	0.00	0.00	0.97	0.00	0.00	0.97	0.00	0.00
293.33	293.35	32/1/23-25	lower Tt	1.62	0.00	4.55	17.47	23.64	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.15	0.00	0.88	0.00	0.00
293.71	293.73	32/1/61-63	lower Tt	3.32	0.00	0.50	12.77	16.58	0.00	0.00	0.00	0.00	0.00	0.00	1.33	0.00	0.00	1.33	0.00	0.00
294.12	294.14	32/1/102-104	lower Tt	1.23	0.00	3.85	9.81	14.89	0.00	0.00	0.00	0.00	0.00	0.00	1.23	0.18	0.00	1.40	0.00	0.00
294.51	294.53	32/1/141-143	lower Tt	0.95	0.00	3.49	5.72	10.17	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.00	0.71	0.00	0.00
294.90	294.92	32/2/30-32	lower Tt	2.83	0.00	5.04	15.25	23.12	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.12	0.00	0.86	0.00	0.00
295.33	295.35	32/2/73-75	lower Tt	2.71	0.00	2.58	14.65	19.95	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.95	0.00	0.00
295.73	295.75	32/2/113-115	lower Tt	1.87	0.00	1.36	12.10	15.33	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.00	0.00	1.02	0.00	0.00
295.93	295.95	32/2/133-135	lower Tt	1.60	0.00	2.81	10.02	14.43	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.00	0.80	0.00	0.00
296.50	296.52	32/3/40-42	lower Tt	1.43	0.00	5.25	7.17	13.85	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.64	0.00	0.00
296.93	296.95	32/3/83-85	lower Tt	2.02	0.00	2.87	17.88	22.77	0.00	0.00	0.00	0.00	0.00	0.00	1.18	0.00	0.00	1.18	0.00	0.00
297.33	297.35	32/3/123-125	lower Tt	5.14	0.00	2.00	17.14	24.29	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.29	0.00	0.00
297.70	297.72	32/4/10-12	lower Tt	4.10	0.00	2.55	16.55	23.20	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.00	0.71	0.00	0.00
298.08	298.10	32/4/48-50	lower Tt	1.14	0.00	3.10	14.03	18.27	0.00	0.00	0.00	0.00	0.00	0.00	1.63	0.00	0.00	1.63	0.00	0.00
298.52	298.54	32/4/92-94	lower Tt	1.03	0.00	8.90	5.99	15.92	0.00	0.00	0.00	0.00	0.17	0.17	0.86	0.00	0.00	0.86	0.00	0.00
298.93	298.95	32/4/133-135	lower Tt	4.03	0.00	5.00	13.87	22.90	0.00	0.00	0.00	0.16	0.00	0.16	0.97	0.00	0.00	0.97	0.00	0.00
299.38	299.40	32/5/28-30	lower Tt	1.82	0.00	3.64	13.71	19.16	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.42	0.00	0.00
299.67	299.69	32CC/2-4	lower Tt	0.84	0.00	5.12	7.21	13.17	0.00	0.00	0.00	0.00	0.00	0.00	1.25	0.00	0.00	1.25	0.00	0.00
302.71	302.73	33/1/1-3	lower Tt	0.16	0.00	4.71	8.28	13.15	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.65	0.00	0.00
302.97	302.99	33/1/27-29	lower Tt	1.25	0.00	3.41	11.65	16.31	0.00	0.00	0.00	0.00	0.00	0.00	2.33	0.18	0.00	2.51	0.00	0.00
303.29	303.31	33/1/59-61	lower Tt	1.76	0.00	1.76	12.50	16.03	0.00	0.00	0.00	0.00	0.00	0.00	2.24	0.00	0.00	2.24	0.00	0.00
303.77	303.79	33/1/107-109	lower Tt	1.16	0.00	1.66	12.65	15.47	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.50	0.00	0.00
304.13	304.15	33/1/143-145	lower Tt	1.75	0.00	3.70	16.57	22.03	0.00	0.00	0.00	0.00	0.00	0.00	1.56	0.00	0.00	1.56	0.00	0.00
304.29	304.31	33/2/9-11	lower Tt	1.60	0.00	3.91	10.66	16.16	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.18	0.89	0.00	0.00
304.47	304.49	33/2/27-29	lower Tt	1.45	0.00	4.26	10.59	16.30	0.00	0.00	0.00	0.00	0.10	0.10	1.14	0.00	0.00	1.14	0.00	0.00
304.66	304.68	33/2/46-48	lower Tt	2.83	0.00	4.25	19.82	26.90	0.00	0.00	0.00	0.00	0.00	0.00	1.95	0.00	0.53	2.48	0.00	0.00
305.02	305.04	33/2/82-84	lower Tt	1.30	0.00	2.76	13.29	17.34	0.00	0.00	0.00	0.00	0.00	0.00	1.13	0.49	0.00	1.62	0.00	0.00
305.15	305.17	33/2/95-97	lower Tt	1.51	0.00	1.51	12.28	15.30	0.00	0.00	0.00	0.00	0.00	0.00	2.37	0.00	0.00	2.37	0.00	0.00
305.34	305.36	33/2/114-116	lower Tt	1.24	0.00	2.70	13.69	17.63	0.00	0.00	0.00	0.00	0.00	0.00	0.62	0.00	0.00	0.62	0.00	0.00
305.55	305.57	33/2/135-137	lower Tt	0.89	0.00	2.32	9.45	12.66	0.00	0.00	0.00	0.00	0.00	0.00	1.78	0.00	0.18	1.96	0.00	0.00
305.71	305.73	33/3/1-3	lower Tt	2.50	0.00	5.63	12.71	20.83	0.21	0.00	0.21	0.00	0.00	0.00	1.25	0.00	0.00	1.25	0.00	0.00
305.93	305.95	33/3/23-25	lower Tt	1.35	0.00	1.35	5.61	8.30	0.00	0.00	0.00	0.00	0.00	0.00	1.12	0.00	0.00	1.12	0.00	0.00
306.11	306.13	33/3/41-43	lower Tt	1.38	0.00	4.35	10.47	16.21	0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.20	0.00	1.19	0.00	0.00
306.27	306.29	33/3/57-59	lower Tt	0.86	0.00	3.45	9.20	13.51	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.14	0.57	0.00	0.00
306.54	306.56	33/3/84-86	lower Tt	0.76	0.00	1.07	4.57	6.39	0.00	0.00	0.00	0.00	0.00	0.00	1.22	0.00	0.15	1.37	0.00	0.00
306.75	306.77	33/3/105-107	lower Tt	0.98	0.00	3.70	8.05	12.73	0.00	0.00	0.00	0.00	0.00	0.00	1.31	0.00	0.22	1.52	0.00	0.00
306.86	306.88	33/3/116-118	lower Tt	1.09	0.00	5.02	13.32	19.43	0.00	0.00	0.00	0.00	0.00	0.00	1.09	0.00	0.00	1.09	0.00	0.00
307.08	307.10	33/3/138-140	lower Tt	0.41	0.00	2.46	7.17	10.04	0.00	0.00	0.00	0.00	0.00	0.00	1.64	0.00	0.00	1.64	0.00	0.00
307.30	307.32	33/4/10-12	lower Tt	2.58	0.00	4.90	13.14	20.62	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.52	0.00	0.00
307.49	307.51	33/4/29-31	lower Tt	1.19	0.00	1.49	3.57	6.25	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.00	0.30	1.19	0.00	0.00
307.70	307.72	33/4/50-52	lower Tt	0.75	0.00	3.01	6.77	10.53	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
307.93	307.95	33/4/73-75	lower Tt	0.78	0.00	6.81	14.98	22.57	0.00	0.00	0.00	0.00	0.00	0.00	2.14	0.00	0.00	2.14	0.00	0.00
308.14	308.16	33/4/94-96	lower Tt	1.78	0.00	3.88	13.59	19.26	0.00	0.00	0.00	0.00	0.00	0.00	0.81	0.00	0.00	0.81	0.00	0.00
308.30	308.32	33/4/110-112	lower Tt	1.80	0.00	3.38	15.09	20.27	0.00	0.00	0.00	0.00	0.23	0.23	1.58	0.23	0.00	1.80	0.00	0.00
308.53	308.55	33/4/133-135	lower Tt	0.52	0.00	2.95	7.11	10.57	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.52	0.00	0.00
308.71	308.73	33/5/1-3	lower Tt	1.53	0.00	2.44	8.09	12.06	0.00	0.00	0.00	0.00	0.15	0.15	0.00	0.31	0.00	0.31	0.00	0.00
308.99	309.01	33/5/29-31	lower Tt	1.92	0.00	2.77	10.66	15.35	0.00	0.00	0.00	0.00	0.00	0.00	1.28	0.00	0.00	1.28	0.00	0.00
309.11	309.13	33/5/41-43	lower Tt	1.02	0.00	3.07	11.04	15.13	0.00	0.00	0.00	0.00	0.00	0.00	1.84	0.20	0.00	2.04	0.00	0.00
309.28	309.30	33/5/58-60	lower Tt	0.92	0.00	4.29	10.87	16.08	0.00	0.00	0.00	0.00	0.00	0.00	1.38	0.00	0.00	1.38	0.00	0.00
309.54	309.56	33/5/84-86	lower Tt	0.00	0.00	3.57	6.89	10.46	0.00	0.00	0.00	0.00	0.00	0.00	1.11	0.12	0.00	1.23	0.00	0.00
309.74	309.76	33/5/104-106	lower Tt	0.93	0.00	3.18	8.49	12.60	0.00	0.00	0.00	0.00	0.00	0.00	1.19	0.13	0.00	1.33	0.00	0.00
312.31	312.33	34/1/1-3	lower Tt	0.72	0.00	3.58	6.99	11.29	0.00	0.00	0.00	0.00	0.00	0.00	1.43	0.00	0.00	1.43	0.00	0.00
312.54	312.56	34/1/24-26	lower Tt	0.79	0.00	2.17	11.26	14.23	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.20	0.00	0.00
312.67	312.69	34/1/37-39	lower Tt	0.42	0.00	3.59	10.55	14.56	0.00	0.00	0.00	0.00	0.00	0.00	1.27	0.00	0.00	1.27	0.00	0.00
312.87	312.89	34/1/57-59	lower Tt	0.91	0.00	2.50	8.41	11.82	0.00	0.00	0.00	0.00	0.00	0.00	2.05	0.00	0.00	2.05	0.00	0.00
313.07	313.09	34/1/77-79	lower Tt	1.29	0.00	5.15	14.59	21.03	0.00	0.00	0.00	0.00	0.00	0.00	2.36	0.21	0.00	2.58	0.00	0.00
313.31	313.33	34/1/101-103	lower Tt	0.61	0.00	3.88	8.16	12.65	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.00	0.00	1.02	0.00	0.00
313.53	313.55	34/1/123-125	lower Tt	1.53	0.00	1.02	9.85	12.39	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.34	0.00	0.85	0.00	0.00
313.71	313.73	34/1/141-143	lower Tt	2.67	0.00	2.51	8.63	13.81	0.00	0.00	0.00	0.00	0.00	0.00	1.57	0.31	0.00	1.88	0.00	0.00
313.90	313.92	34/2/10-12	lower Tt	1.19	0.00	1.59	10.34	13.12	0.00	0.00	0.00	0.00	0.00	0.00	1.99	0.20	0.00	2.19	0.00	0.00
314.09	314.11	34/2/29-31	lower Tt	1.59	0.00	2.12	6.10	9.81	0.27	0.00	0.27	0.00	0.00	0.00	1.33	0.27	0.00	1.59	0.00	0.00
314.29	314.31	34/2/49-51	lower Tt	0.75	0.00	2.24	4.23	7.21	0.00	0.00	0.00	0.00	0.25	0.25	0.25	0.00	0.00	0.25	0.00	0.00
314.45	314.47	34/2/65-67	lower Tt	0.74	0.00	1.33	5.16	7.23	0.29	0.00	0.29	0.00	0.00	0.00	0.15	0.88	0.00	1.03	0.00	0.00
314.69	314.71	34/2/89-91	lower Tt	0.40	0.00	3.72	7.58	11.70	0.53	0.00	0.53	0.00	0.00	0.00	0.53	0.00	0.00	0.53	0.00	0.00
314.90	314.92	34/2/110-112	lower Tt	1.88	0.00	2.71	7.10	11.69	0.00	0.00	0.00	0.00	0.00	0.00	0.84	0.00	0.00	0.84	0.00	0.00
315.13	315.15	34/2/133-135	lower Tt	0.29	0.00	3.59	5.60	9.47	0.72	0.00	0.72	0.00	0.00	0.00	1.58	0.00	0.00	1.58	0.00	0.00
315.30	315.32	34/3/0-2	lower Tt	1.96	0.00	3.35	9.22	14.53	0.28	0.00	0.28	0.00	0.00	0.00	1.96	0.00	0.00	1.96	0.00	0.00
315.52	315.54	34/3/22-24	lower Tt	1.87	0.00	2.29	11.64	15.80	1.66	0.00	1.66	0.00	0.00	0.00	2.29	0.00	0.00	2.29	0.00	0.00
315.71	315.73	34/3/41-43	lower Tt	2.81	0.00	4.32	10.58	17.71	0.65	0.00	0.65	0.00	0.00	0.00	1.73	0.43	0.00	2.16	0.00	0.00
316.06	316.08	34/3/76-78	lower Tt	2.44	0.00	2.16	9.48	14.08	1.72	0.00	1.72	0.00	0.00	0.00	1.01	0.00	0.00	1.01	0.00	0.00
316.27	316.29	34/3/97-99	lower Tt	0.72	0.00	1.23	4.42	6.37	1.03	0.00	1.03	0.00	0.00	0.00	0.51	0.00	0.31	0.82	0.00	0.00
316.48	316.50	34/3/118-120	lower Tt	0.38	0.00	2.84	8.70	11.91	0.57	0.00	0.57	0.00	0.00	0.00	1.13	0.19	0.00	1.32	0.00	0.00
316.67	316.69	34/3/137-139	upper Sw	1.36	0.00	2.26	13.12	16.74	2.94	0.00	2.94	0.00	0.00	0.00	0.90	0.00	0.00	0.90	0.00	0.00
317.10	317.12	34/4/30-32	upper Sw	0.56	0.00	3.72	9.87	14.15	1.86	0.00	1.86	0.00	0.00	0.00	2.05	0.00	0.00	2.05	0.00	0.00
317.50	317.52	34/4/70-72	upper Sw	0.72	0.00	2.65	9.16	12.53	0.00	0.00	0.00	0.00	0.00	0.00	2.41	0.00	0.00	2.41	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	NZ Stage	*Globigerina bulloides*	*Globigerina eamesi*	*Globigerina falconensis*	*Globigerina* sp.	***Gg. bulloides* gp**	*Globigerina cf. angustiumbilicata*	*Globigerina quinqueloba*	***Gg. quinqueloba* gp**	*Globigerinella aequilateralis*	*Globigerinella aequilateralis?*	***Globigerinella***	*Globigerinita glutinata*	*Globigerinita uvula*	*Globigerinita uvula?*	***Globigerinita***	*Globigerinoides obliquus*	*Globigerinoides obliquus?*
317.90	317.92	34/4/110-112	upper Sw	0.00	0.00	1.98	2.72	4.70	0.25	0.00	0.25	0.00	0.00	0.00	2.97	0.00	0.00	2.97	0.00	0.00
318.35	318.37	34/5/5-7	upper Sw	0.41	0.00	1.02	3.48	4.91	0.20	0.00	0.20	0.00	0.00	0.00	1.43	0.00	0.00	1.43	0.00	0.00
318.60	318.62	34/5/30-32	upper Sw	0.49	0.00	2.79	5.35	8.63	1.22	0.00	1.22	0.00	0.00	0.00	0.49	0.00	0.00	0.49	0.00	0.00
321.91	321.93	35/1/1-3	upper Sw	0.16	0.00	7.09	7.73	14.98	0.32	0.00	0.32	0.00	0.00	0.00	0.97	0.00	0.00	0.97	0.00	0.00
322.33	322.35	35/1/43-45	upper Sw	0.31	0.00	6.66	11.48	18.44	0.72	0.00	0.72	0.00	0.00	0.00	0.92	0.00	0.00	0.92	0.00	0.00
322.72	322.74	35/1/82-84	upper Sw	2.40	0.00	2.20	9.60	14.20	0.20	0.00	0.20	0.00	0.00	0.00	1.60	0.00	0.00	1.60	0.00	0.00
323.09	323.11	35/1/119-121	upper Sw	0.57	0.00	1.71	4.37	6.65	0.57	0.00	0.57	0.00	0.00	0.00	2.28	0.00	0.00	2.28	0.00	0.00
323.48	323.50	35/2/8-10	upper Sw	0.27	0.00	0.00	3.50	3.77	2.43	0.00	2.43	0.00	0.00	0.00	1.89	0.27	0.00	2.16	0.00	0.00
323.91	323.93	35/2/51-53	upper Sw	0.22	0.00	0.75	1.83	2.80	1.29	0.00	1.29	0.00	0.00	0.00	0.86	0.00	0.00	0.86	0.00	0.00
324.50	324.52	35/2/110-112	upper Sw	0.47	0.00	1.87	4.92	7.26	0.23	0.00	0.23	0.00	0.00	0.00	0.70	0.00	0.00	0.70	0.00	0.00
324.91	324.93	35/3/1-3	upper Sw	0.59	0.00	1.18	2.95	4.72	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.00	0.00	0.59	0.00	0.00
325.33	325.35	35/3/43-45	upper Sw	1.14	0.00	2.61	3.26	7.01	0.00	0.00	0.00	0.00	0.00	0.00	2.61	0.00	0.00	2.61	0.00	0.00
325.71	325.73	35/3/81-83	upper Sw	0.67	0.00	0.40	4.56	5.63	0.00	0.00	0.00	0.00	0.00	0.00	1.21	0.00	0.00	1.21	0.00	0.00
325.94	325.96	35/3/104-106	upper Sw	0.27	0.00	0.82	2.73	3.82	0.00	0.00	0.00	0.00	0.00	0.00	2.46	0.14	0.00	2.59	0.00	0.00
326.28	326.30	35/3/138-140	upper Sw	1.15	0.00	8.29	14.98	24.42	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	3.00	0.00	0.00
326.70	326.72	35/4/30-32	upper Sw	1.07	0.00	1.79	5.54	8.39	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00	0.54	0.00	0.00
327.09	327.11	35/4/69-71	upper Sw	0.77	0.00	5.02	7.34	13.13	0.00	0.00	0.00	0.00	0.00	0.00	1.54	0.00	0.00	1.54	0.00	0.00
327.50	327.52	35/4/110-112	upper Sw	2.86	0.00	1.50	6.92	11.28	1.05	0.00	1.05	0.00	0.00	0.00	0.90	0.00	0.00	0.90	0.00	0.00
327.91	327.93	35/5/1-3	upper Sw	0.84	0.00	9.09	15.15	25.08	0.67	0.00	0.67	0.00	0.00	0.00	0.51	0.00	0.00	0.51	0.00	0.00
328.27	328.29	35/5/37-39	upper Sw	0.56	0.00	2.25	5.76	8.57	0.00	0.00	0.00	0.00	0.00	0.00	0.84	0.70	0.00	1.54	0.00	0.00
328.72	328.74	35/5/82-84	upper Sw	0.32	0.00	2.06	2.92	5.30	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.11	0.00	0.32	0.00	0.00
331.69	331.71	36/1/19-21	upper Sw	0.44	0.00	1.91	5.01	7.36	0.15	0.00	0.15	0.00	0.00	0.00	0.59	0.00	0.00	0.59	0.00	0.00
332.11	332.13	36/1/61-63	upper Sw	0.57	0.00	4.93	8.54	14.04	0.38	0.00	0.38	0.00	0.00	0.00	0.57	0.00	0.00	0.57	0.00	0.00
332.68	332.70	36/1/118-120	upper Sw	1.94	0.00	2.58	10.75	15.27	0.22	0.00	0.22	0.00	0.00	0.00	0.22	0.00	0.00	0.22	0.00	0.00
332.98	333.00	36/1/148-150	upper Sw	1.10	0.00	3.52	9.25	13.88	0.22	0.00	0.22	0.00	0.00	0.00	0.88	0.22	0.00	1.10	0.00	0.00
333.40	333.42	36/2/40-42	upper Sw	1.60	0.00	5.15	10.30	17.05	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.00	0.00	0.53	0.00	0.00
334.00	334.02	36/2/100-102	upper Sw	1.37	0.00	4.50	12.72	18.59	0.39	0.00	0.39	0.00	0.00	0.00	0.98	0.00	0.00	0.98	0.00	0.00
334.36	334.38	36/2/136-138	upper Sw	1.61	0.00	3.22	4.37	9.20	0.23	0.00	0.23	0.00	0.00	0.00	0.92	0.00	0.00	0.92	0.00	0.00
334.87	334.89	36/3/37-39	upper Sw	1.44	0.00	3.69	6.74	11.88	0.00	0.00	0.00	0.00	0.00	0.00	0.96	0.00	0.00	0.96	0.00	0.00
335.47	335.49	36/3/97-99	upper Sw	4.55	0.00	5.28	15.30	25.14	0.00	0.00	0.00	0.00	0.18	0.18	0.91	0.00	0.00	0.91	0.00	0.00
335.88	335.90	36/3/138-140	upper Sw	2.37	0.00	2.20	7.78	12.35	0.17	0.00	0.17	0.00	0.00	0.00	1.02	0.00	0.00	1.02	0.00	0.00
336.20	336.22	36/4/20-22	upper Sw	3.99	0.00	6.98	19.10	30.07	0.17	0.00	0.17	0.00	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0.00
336.60	336.62	36/4/60-62	upper Sw	0.90	0.00	4.65	16.04	21.59	0.15	0.00	0.15	0.00	0.00	0.00	1.20	0.30	0.00	1.50	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Globigerinoides q. immaturus*	*Globigerinoides quadrilobatus* s.s.	*Globigerinoides quadrilobatus* s.s.?	*Globigerinoides q. trilobus*	*Globigerinoides sacculifer*	***Globigerinoides***	*Globigerinopsis obesa*	*Globigerinopsis obesa?*	*Globigerinopsis sp. ?*	***Globigerinopsis***	*Globoconella conomiozea* s.l.	*Globoconella conomiozea* s.s.	*Globoconella explicationis*	*Globoconella sp. indet.*	*Globoconella miotumida*	*Globoconella mons*	*Globoconella mons?*	*Globoconella pliozea*	*Globoconella pliozea?*
120.30	120.33	14/1/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.00	0.00	0.00	0.00	0.00	0.25	1.52	1.02
120.51	120.54	14/1/21-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.82	0.00	0.00	0.00	0.00	0.20	0.00	0.41	1.02
120.69	120.72	14/1/39-42	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.23	0.00	0.23	2.04	0.00	0.00	0.00	0.00	0.00	0.00	2.49	0.91
120.90	120.93	14/1/60-63	0.00	0.00	0.00	0.00	0.00	2.38	0.00	0.00	0.65	0.65	2.38	0.00	0.00	0.00	0.00	0.22	0.00	6.26	0.43
121.11	121.14	14/1/81-84	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00	1.39	1.39	3.94	0.00	0.00	0.00	0.00	0.00	0.00	5.10	0.93
121.26	121.29	14/1/96-99	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.43	0.43	0.86	2.58	0.00	0.00	0.00	0.00	0.21	0.00	7.30	0.64
121.49	121.52	14/1/119-122	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.87	1.45	2.31	2.89	0.00	0.00	0.00	0.00	0.00	0.58	3.18	0.00
121.69	121.72	14/1/139-142	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.19	0.37	1.67	0.00	0.00	0.00	0.00	0.00	0.00	1.67	0.00
121.90	121.93	14/2/10-13	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.20	0.40	3.24	0.00	0.00	0.00	0.00	0.00	0.20	3.24	0.00
122.09	122.12	14/2/29-32	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	1.34	0.00	0.00	0.00	0.00	0.00	0.00	1.12	0.00
122.26	122.29	14/2/46-49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.69	1.62	0.00	0.00	0.00	0.00	0.00	0.00	1.85	0.00
122.51	122.55	14/2/71-75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.70	0.93	0.00	0.00	0.00	0.00	0.00	0.00	1.40	0.70
122.71	122.74	14/2/91-94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.71	0.99	1.97	0.00	0.00	0.00	0.00	0.00	0.14	0.56	0.28
122.92	122.95	14/2/112-115	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.18	0.00	0.18	0.72	0.00	0.00	0.00	0.00	0.00	0.00	1.08	0.18
123.10	123.13	14/2/130-133	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00	1.61	2.58
123.30	123.33	14/3/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.44	1.56	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00
123.53	123.56	14/3/23-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.32	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.96
123.69	123.72	14/3/39-42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.41	1.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.22
123.88	123.91	14/3/58-61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	1.22	1.47	1.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.71
124.11	124.14	14/3/81-84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.79	0.99	2.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.76
124.30	124.33	14/3/100-103	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.30	2.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.84
124.50	124.53	14/3/120-123	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.87	0.87	1.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.83
124.68	124.71	14/3/138-141	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.42	1.26	0.00	0.00	0.00	0.00	0.00	0.42	0.00	1.68
124.90	124.93	14/4/10-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	1.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.09
125.10	125.13	14/4/30-33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.35	1.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.43
125.30	125.33	14/4/50-53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.91	0.91	1.37	0.00	0.00	0.00	0.00	0.00	2.13	0.00	2.74
125.48	125.51	14/4/68-71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.15	0.30	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.29
125.71	125.74	14/4/91-94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.71	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.66
125.91	125.94	14/4/111-114	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.11	0.11	0.00	0.00	0.00	0.11	0.00	0.00	0.00	1.01
126.10	126.13	14/4/130-133	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.88	1.10	0.66	0.00	0.00	0.00	0.44	0.00	0.00	0.00	1.32
126.30	126.33	14/5/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.78	0.00	0.00	0.00	1.29
126.56	126.59	14/5/26-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.97	0.97	0.00	0.00	0.00	0.00	0.19	0.19	0.00	0.19	0.00
126.70	126.73	14/5/40-43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.26	0.26	0.00	0.00	0.00	0.00	0.52	0.78	0.00	0.00
126.90	126.93	14/5/60-63	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.55	0.55	0.37	0.00
127.12	127.15	14/5/82-85	0.00	0.00	0.00	0.00	0.00	0.63	0.00	0.31	0.00	0.31	0.78	0.00	0.00	0.00	0.31	0.16	0.00	0.16	0.00
127.30	127.33	14/5/100-103	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.18	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00
127.51	127.54	14/5/121-124	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00
127.70	127.73	14/5/140-143	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.16	0.49	0.00	0.00	0.00	0.00	0.16	0.16	0.65	0.00
127.90	127.93	14/6/10-13	0.00	0.00	0.00	0.00	0.00	0.30	0.45	0.00	0.30	0.75	0.45	0.00	0.00	0.00	0.00	0.00	0.15	2.54	0.00
128.29	128.32	14/6/49-52	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.18	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.18
128.72	128.75	14/6/92-95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63	0.63	0.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
129.10	129.13	14/6/130-133	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.45	0.67	2.45	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00
129.50	129.53	14/7/20-23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.27	2.05	0.00	0.00	0.00	0.14	0.00	0.41	0.82	0.00
129.90	129.93	15/1/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.26	1.29	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.77
130.29	130.32	15/1/39-42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.37	0.74	1.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
130.69	130.72	15/1/79-82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.16	0.94	0.00	0.00	0.00	0.16	0.31	0.00	0.00	0.00
131.10	131.13	15/1/120-123	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.18	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
131.51	131.54	15/2/11-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
131.91	131.93	15/2/51-53	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.16	0.49	1.64	0.00	0.00	0.00	0.00	0.82	0.00	0.00	0.00
132.33	132.36	15/2/93-96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.52	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00
132.74	132.76	15/2/134-136	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.23	1.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
133.07	133.10	15/3/17-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.58	3.09	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00
133.46	133.49	15/3/56-59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.13	0.80	0.00	0.00	0.00	0.13	0.00	0.27	0.00	0.00
133.89	133.92	15/3/99-102	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
134.30	134.33	15/3/140-143	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00
134.70	134.73	15/4/30-33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.18	3.62	0.00	0.00	0.00	0.18	0.18	0.00	0.00	0.00
135.10	135.13	15/4/70-73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.23	6.35	0.00	0.00	0.00	2.49	0.00	0.23	0.00	0.00
135.30	135.33	15/4/90-93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.90	0.00	0.35	0.00	0.35	0.70	0.35	0.00	0.00
135.50	135.53	15/4/110-113	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
135.70	135.73	15/4/130-133	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.44	0.00	0.00	0.00	0.32	0.00	0.16	0.00	0.00
135.90	135.93	15/5/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.52	5.19	0.00	0.00	0.00	0.87	0.00	0.00	0.00	0.00
136.06	136.09	15/5/16-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.26	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00
136.32	136.35	15/5/42-45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.49	1.49	7.08	0.00	0.00	0.00	0.93	0.00	0.00	0.00	0.00
136.51	136.53	15/5/61-63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.61	0.00	0.00	0.00	0.28	0.28	0.00	0.00	0.00
136.92	136.95	15/5/102-105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.20	3.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
137.13	137.16	15/5/123-126	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.83	0.00	0.00	0.00	0.44	0.65	0.00	0.00	0.00
137.52	137.55	15/6/12-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.61	0.00	0.00	0.00	2.56	0.17	0.00	0.00	0.00
137.91	137.94	15/6/51-54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.63	0.00	0.00	0.00	0.75	0.19	0.00	0.00	0.00
138.27	138.30	15/6/87-90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.41	6.15	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00
138.66	138.69	15/6/126-129	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	5.98	0.00	0.00	0.00	1.05	0.00	0.00	0.00	0.00
139.07	139.10	15/7/17-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.75	0.00	0.00	0.00	1.55	0.00	0.00	0.00	0.00
139.50	139.53	16/1/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	1.90	0.48	0.00	0.00	0.00
139.93	139.96	16/1/43-46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.82	0.00	0.00	0.00	2.02	0.16	0.00	0.00	0.00
140.34	140.37	16/1/84-87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.37	0.00	0.00	0.00	1.97	0.00	0.00	0.00	0.00
140.73	140.76	16/1/123-126	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.52	4.48	0.00	0.00	0.00	1.38	0.34	0.00	0.00	0.00
141.13	141.15	16/2/13-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.02	0.00	0.00	0.00	1.88	0.00	0.00	0.00	0.00
141.54	141.57	16/2/54-57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.41	7.61	0.00	0.00	0.00	3.70	0.41	0.00	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Globigerinoides q. immaturus*	*Globigerinoides quadrilobatus* s.s.	*Globigerinoides quadrilobatus* s.s.?	*Globigerinoides q. trilobus*	*Globigerinoides sacculifer*	***Globigerinoides***	*Globigerinopsis obesa*	*Globigerinopsis obesa?*	*Globigerinopsis sp. ?*	***Globigerinopsis***	*Globoconella conomiozea* s.l.	*Globoconella conomiozea* s.s.	*Globoconella explicationis*	*Globoconella sp. indet.*	*Globoconella miotumida*	*Globoconella mons*	*Globoconella mons?*	*Globoconella pliozea*	*Globoconella pliozea?*
141.92	141.95	16/2/92-95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.64	0.96	6.71	0.00	0.00	0.00	0.96	0.00	0.00	0.00	0.00
142.32	142.35	16/2/132-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.20	4.64	0.00	0.00	0.00	2.42	0.40	0.00	0.00	0.00
142.75	142.78	16/3/25-28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.19	0.37	6.12	0.00	0.00	0.00	0.74	0.37	0.00	0.00	0.00
143.15	143.18	16/3/65-68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.51	0.85	4.06	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00
143.53	143.56	16/3/103-106	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.27	5.89	0.00	0.14	0.00	1.51	0.27	0.00	0.00	0.00
143.84	143.87	16/3/134-137	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.54	0.00	4.49	0.00	0.00	12.39	0.00	0.00	0.00	0.00
144.26	144.29	16/4/26-29	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	2.95	3.15	0.00	4.72	0.00	0.00	17.32	0.20	0.00	0.00	0.00
144.67	144.70	16/4/67-70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	1.08	1.44	0.00	3.61	0.00	0.00	28.88	0.00	0.00	0.00	0.00
145.13	145.16	16/4/113-116	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.67	0.00	4.19	0.00	0.00	14.41	0.17	0.00	0.00	0.00
145.50	145.53	16/5/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.92	0.00	0.00	17.27	0.16	0.00	0.00	0.00
145.93	145.96	16/5/43-46	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.85	1.49	0.00	6.17	0.21	0.00	21.06	0.00	0.00	0.00	0.00
146.36	146.38	16/5/86-88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.35	1.35	0.00	3.66	0.00	0.00	17.92	0.00	0.00	0.00	0.00
146.71	146.74	16/5/121-124	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	1.58	1.78	0.00	2.17	0.00	0.00	11.66	0.00	0.00	0.00	0.00
147.06	147.09	16/6/6-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.73	1.21	0.00	3.39	0.00	0.00	20.10	0.00	0.00	0.00	0.00
147.47	147.50	16/6/47-50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.60	0.00	3.30	0.00	0.00	22.07	0.00	0.00	0.00	0.00
147.93	147.96	16/6/93-96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.38	0.00	4.78	0.00	0.00	14.15	0.00	0.00	0.00	0.00
148.33	148.36	16/6/133-136	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.13	0.00	2.42	0.00	0.00	8.55	0.00	0.00	0.00	0.00
148.67	148.69	16/7/17-19	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.17	0.00	2.20	0.00	0.00	10.51	0.00	0.00	0.00	0.00
149.10	149.13	17/1/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.00	3.52	0.00	0.00	20.44	0.00	0.00	0.00	0.00
149.52	149.55	17/1/42-45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.04	0.00	0.00	17.51	0.00	0.00	0.00	0.00
150.11	150.14	17/1/101-104	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.89	0.00	0.00	16.81	0.00	0.00	0.00	0.00
150.51	150.54	17/1/141-144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.22	0.00	6.29	0.00	0.00	14.32	0.00	0.00	0.00	0.00
150.87	150.90	17/2/27-30	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.17	0.33	0.00	6.14	0.00	0.00	17.25	0.00	0.00	0.00	0.00
151.07	151.10	17/2/47-50	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.19	0.19	0.00	3.81	0.00	0.00	15.24	0.00	0.00	0.00	0.00
151.52	151.55	17/2/92-95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.94	0.00	0.00	15.76	0.00	0.00	0.00	0.00
151.96	151.98	17/2/136-138	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.43	0.00	5.81	0.00	0.00	16.77	0.00	0.00	0.00	0.00
152.10	152.13	17/3/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.32	0.00	5.92	0.00	0.00	13.76	0.00	0.00	0.00	0.00
152.25	152.28	17/3/15-18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.51	0.00	5.57	0.00	0.00	14.02	0.00	0.00	0.00	0.00
152.47	152.50	17/3/37-40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.22	0.00	4.56	0.22	0.00	12.36	0.00	0.00	0.00	0.00
152.75	152.77	17/3/65-67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.35	0.00	7.22	0.00	0.00	14.96	0.00	0.00	0.00	0.00
152.91	152.94	17/3/81-84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.22	0.00	0.00	17.27	0.00	0.00	0.00	0.00
153.12	153.15	17/3/102-105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40	0.00	4.21	0.00	0.00	20.04	0.00	0.00	0.00	0.00
153.26	153.29	17/3/116-119	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.31	0.31	0.00	3.60	0.00	0.00	18.31	0.00	0.00	0.00	0.00
153.45	153.48	17/3/135-138	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.15	0.00	2.37	0.00	0.00	17.51	0.00	0.00	0.00	0.00
153.66	153.69	17/4/6-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.24	0.48	0.00	2.39	0.00	0.00	15.55	0.00	0.00	0.00	0.00
153.97	153.99	17/4/37-39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.48	0.00	1.91	0.00	0.00	14.01	0.00	0.00	0.00	0.00
154.13	154.16	17/4/53-56	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.63	0.95	0.00	3.32	0.00	0.00	15.03	0.00	0.00	0.00	0.00
154.32	154.35	17/4/72-75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.40	0.67	0.00	3.23	0.00	0.00	14.80	0.00	0.00	0.00	0.00
154.54	154.57	17/4/94-97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.11	0.00	2.50	0.00	0.00	11.72	0.00	0.00	0.00	0.00
154.77	154.79	17/4/117-119	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	2.77	0.00	0.00	15.82	0.00	0.00	0.00	0.00
154.95	154.98	17/4/135-138	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.13	0.00	3.19	0.00	0.00	13.56	0.00	0.00	0.00	0.00
155.10	155.13	17/5/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40	0.00	2.02	0.00	0.00	13.88	0.00	0.00	0.00	0.00
155.24	155.27	17/5/14-17	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	1.23	0.00	0.00	13.18	0.00	0.00	0.00	0.00
155.48	155.50	17/5/38-40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.24	0.00	2.67	0.00	0.00	18.42	0.00	0.00	0.00	0.00
155.67	155.70	17/5/57-60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.48	0.00	2.42	0.00	0.00	22.22	0.00	0.00	0.00	0.00
155.94	155.97	17/5/84-87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.51	0.00	1.54	0.00	0.00	13.72	0.00	0.00	0.00	0.00
156.13	156.16	17/5/103-106	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.11	0.00	0.00	18.23	0.00	0.00	0.00	0.00
156.27	156.30	17/5/117-120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.63	0.78	0.00	2.97	0.16	0.00	15.31	0.00	0.00	0.00	0.00
156.47	156.50	17/5/137-140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.16	0.00	3.76	0.00	0.00	16.37	0.00	0.00	0.00	0.00
156.71	156.74	17/6/11-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.71	0.18	0.00	18.59	0.00	0.00	0.00	0.00
156.95	156.98	17/6/35-38	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	2.95	0.00	0.00	11.62	0.00	0.00	0.00	0.00
157.12	157.15	17/6/52-55	0.00	0.00	0.00	0.00	0.00	0.71	0.14	0.00	0.14	0.29	0.00	2.86	0.00	0.00	13.00	0.00	0.00	0.00	0.00
157.37	157.39	17/6/77-79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.81	0.81	0.00	2.83	0.00	0.00	19.60	0.00	0.00	0.00	0.00
157.52	157.55	17/6/92-95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.21	0.00	5.19	0.00	0.00	23.86	0.00	0.00	0.00	0.00
157.76	157.79	17/6/116-119	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.67	0.15	0.00	16.59	0.00	0.00	0.00	0.00
157.93	157.96	17/6/133-136	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.00	9.20	0.00	0.00	0.00	0.00
158.10	158.13	17/7/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.09	0.00	0.00	10.58	0.00	0.00	0.00	0.00
158.27	158.30	17/7/17-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.00	2.72	0.00	0.00	15.90	0.00	0.00	0.00	0.00
158.52	158.55	17CC/6-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.41	0.00	0.00	14.36	0.00	0.00	0.00	0.00
158.70	158.73	18/1/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.15	0.00	0.00	13.49	0.00	0.00	0.00	0.00
158.95	158.98	18/1/25-28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.45	0.00	0.00	22.90	0.00	0.00	0.00	0.00
159.13	159.16	18/1/43-46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.21	0.00	2.54	0.00	0.00	19.66	0.00	0.00	0.00	0.00
159.35	159.38	18/1/65-68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.17	0.00	0.00	18.62	0.00	0.00	0.00	0.00
159.49	159.52	18/1/79-82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.38	0.00	0.00	16.72	0.00	0.00	0.00	0.00
159.72	159.75	18/1/102-105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.15	0.00	3.37	0.00	0.00	14.35	0.00	0.00	0.00	0.00
159.86	159.89	18/1/116-119	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.16	0.00	0.00	17.72	0.00	0.00	0.00	0.00
160.11	160.14	18/1/141-144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.22	0.00	0.00	18.25	0.00	0.00	0.00	0.00
160.33	160.36	18/2/13-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.24	0.00	1.22	0.00	0.00	11.49	0.00	0.00	0.00	0.00
160.73	160.76	18/2/53-56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.19	0.00	1.93	0.00	0.00	14.84	0.00	0.00	0.00	0.00
161.16	161.19	18/2/96-99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.28	0.00	2.53	0.00	0.00	18.85	0.00	0.00	0.00	0.00
161.53	161.56	18/2/133-136	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.13	0.00	2.30	0.00	0.00	14.41	0.00	0.00	0.00	0.00
161.84	161.87	18/3/14-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.67	0.00	3.69	0.00	0.00	16.58	0.00	0.00	0.00	0.00
162.26	162.29	18/3/56-59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.34	0.00	2.06	0.00	0.00	18.90	0.00	0.00	0.00	0.00
162.87	162.90	18/3/117-120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.93	1.93	0.00	4.05	0.00	0.00	24.08	0.00	0.00	0.00	0.00
163.33	163.36	18/4/13-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.67	0.00	2.69	0.00	0.00	22.87	0.00	0.00	0.00	0.00
163.56	163.59	18/4/36-39	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.22	0.22	0.00	3.88	0.00	0.00	15.10	0.00	0.00	0.00	0.00
163.93	163.96	18/4/73-76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.47	0.93	0.00	2.80	0.00	0.23	21.68	0.00	0.00	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Globigerinoides q. immaturus*	*Globigerinoides quadrilobatus s.s.*	*Globigerinoides quadrilobatus s.s.?*	*Globigerinoides q. trilobus*	*Globigerinoides sacculifer*	***Globigerinoides***	*Globigerinopsis obesa*	*Globigerinopsis obesa?*	*Globigerinopsis sp. ?*	***Globigerinopsis***	*Globoconella conomiozea s.l.*	*Globoconella conomiozea s.s.*	*Globoconella explicationis*	*Globoconella sp. indet.*	*Globoconella miotumida*	*Globoconella mons*	*Globoconella mons?*	*Globoconella pliozea*	*Globoconella pliozea?*
164.31	164.33	18/4/111-113	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.66	0.66	0.00	6.58	0.00	0.00	23.46	0.00	0.00	0.00	0.00
164.70	164.73	18/5/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.34	0.00	4.64	0.00	0.00	22.16	0.00	0.00	0.00	0.00
165.13	165.16	18/5/43-46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.51	0.00	3.03	0.00	0.00	13.51	0.00	0.00	0.00	0.00
165.50	165.53	18/5/80-83	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	3.65	0.00	0.00	18.26	0.00	0.00	0.00	0.00
165.95	165.97	18/5/125-127	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.95	0.00	2.86	0.00	0.00	15.58	0.00	0.00	0.00	0.00
166.26	166.29	18/6/6-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.71	0.00	2.66	0.00	0.00	14.89	0.00	0.00	0.00	0.00
166.66	166.69	18/6/46-49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.34	1.34	0.00	2.52	0.00	0.00	14.60	0.00	0.00	0.00	0.00
167.06	167.09	18/6/86-89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.85	0.00	1.27	0.00	0.00	12.71	0.00	0.00	0.00	0.00
167.44	167.47	18/6/124-127	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.55	0.00	0.00	0.00	0.00	15.32	0.00	0.00	0.00	0.00
168.30	168.33	19/1/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.08	1.08	0.00	0.00	0.00	0.00	17.09	0.00	0.00	0.00	0.00
168.71	168.74	19/1/41-44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.64	0.00	0.00	0.00	0.00	16.20	0.00	0.00	0.00	0.00
169.13	169.15	19/1/83-85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32	1.32	0.00	0.00	0.00	0.00	13.65	0.00	0.00	0.00	0.00
169.51	169.54	19/1/121-124	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.29	0.00	0.00	0.00	0.00	11.46	0.00	0.00	0.00	0.00
169.85	169.88	19/2/5-8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.19	1.19	0.00	0.00	0.00	0.00	15.99	0.00	0.00	0.00	0.00
170.32	170.35	19/2/52-55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	23.59	0.00	0.00	0.00	0.00
170.73	170.76	19/2/93-96	0.00	0.00	0.00	0.00	0.15	0.15	0.00	0.00	0.15	0.15	0.00	0.00	0.00	0.00	18.51	0.00	0.00	0.00	0.00
171.15	171.18	19/2/135-138	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.33	0.49	0.00	0.00	0.00	0.00	24.02	0.00	0.00	0.00	0.00
171.57	171.59	19/3/27-29	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.45	0.15	0.75	0.00	0.00	0.00	0.00	15.64	0.00	0.00	0.00	0.00
171.92	171.94	19/3/62-64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.83	0.00	0.00	0.00	0.00
172.32	172.35	19/3/102-105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	1.08	1.39	0.00	0.00	0.15	0.00	17.77	0.00	0.00	0.00	0.00
172.66	172.68	19/3/136-138	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02	1.53	2.55	0.00	0.00	0.00	0.00	24.23	0.00	0.00	0.00	0.00
173.07	173.09	19/4/27-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.17	0.00	0.00	0.00	0.00
173.52	173.54	19/4/72-74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.12	3.12	0.00	0.00	0.00	0.00	31.15	0.00	0.00	0.00	0.00
173.93	173.95	19/4/113-115	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00	1.22	1.62	0.00	0.00	0.20	0.00	26.17	0.00	0.00	0.00	0.00
174.30	174.33	19/5/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.97	2.97	0.00	0.00	0.21	0.00	27.39	0.00	0.00	0.00	0.00
174.72	174.75	19/5/42-45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.79	0.79	0.00	0.00	0.00	0.00	26.04	0.00	0.00	0.00	0.00
175.26	175.28	19/5/96-99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.41	0.00	0.00	0.00	0.00	20.62	0.00	0.00	0.00	0.00
175.71	175.74	19/5/141-144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.26	0.00	0.00	0.00	0.00	20.73	0.00	0.00	0.00	0.00
176.06	176.09	19/6/26-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.39	1.39	0.00	0.00	0.23	0.00	20.65	0.00	0.00	0.00	0.00
176.47	176.49	19/6/67-69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.57	0.00	0.00	0.00	0.00	10.88	0.00	0.00	0.00	0.00
176.92	176.94	19/6/112-114	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.07	1.07	0.00	0.00	0.00	0.00	18.77	0.00	0.00	0.00	0.00
177.30	177.33	19/7/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.48	0.00	0.00	0.00	0.00	19.23	0.00	0.00	0.00	0.00
177.52	177.55	19/7/22-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.30	0.00	0.00	0.00	0.00	11.66	0.00	0.00	0.00	0.00
177.90	177.93	20/1/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.46	0.00	0.00	0.00	0.00	22.45	0.00	0.00	0.00	0.00
178.27	178.30	20/1/37-40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.99	0.00	0.00	0.00	0.00	19.44	0.00	0.00	0.00	0.00
178.68	178.70	20/1/78-80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63	0.63	0.00	0.00	0.00	0.00	34.10	0.00	0.00	0.00	0.00
179.08	179.10	20/1/118-120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.21	0.00	0.00	0.00	0.00	26.97	0.00	0.00	0.00	0.00
179.45	179.47	20/2/5-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.29	0.58	0.00	0.00	0.00	0.00	24.42	0.00	0.00	0.00	0.00
179.86	179.88	20/2/46-48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.67	0.00	0.00	0.17	0.00	19.03	0.00	0.00	0.00	0.00
180.33	180.35	20/2/93-95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.60	0.00	0.00	0.00	0.00	25.25	0.00	0.00	0.00	0.00
180.73	180.75	20/2/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.22	0.00	0.00	0.22	0.00	24.24	0.00	0.00	0.00	0.00
181.14	181.16	20/3/24-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.28	0.00	0.00	0.28	0.00	30.31	0.00	0.00	0.00	0.00
181.57	181.59	20/3/67-69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.22	0.00	0.00	0.00	0.00	16.55	0.00	0.00	0.00	0.00
181.86	181.88	20/3/96-98	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.92	1.10	0.00	0.00	0.18	0.00	22.43	0.00	0.00	0.00	0.00
182.23	182.25	20/3/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.72	0.72	0.00	0.00	0.00	0.00	27.51	0.00	0.00	0.00	0.00
182.68	182.70	20/4/28-30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.27	0.00	0.00	0.27	0.00	22.16	0.00	0.00	0.00	0.00
183.08	183.10	20/4/68-70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.85	0.00	0.00	0.00	0.00
183.45	183.47	20/4/105-107	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.96	0.00	0.00	0.00	0.00
183.91	183.93	20/5/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.18	0.00	0.00	0.00	0.00	18.33	0.00	0.00	0.00	0.00
184.32	184.34	20/5/42-44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.18	0.00	0.00	0.00	0.00	12.84	0.00	0.00	0.00	0.00
184.72	184.74	20/5/82-84	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.20	0.40	0.00	0.00	0.20	0.00	21.00	0.00	0.00	0.00	0.00
185.07	185.09	20/5/117-119	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.32	0.49	0.00	0.00	0.16	0.00	20.94	0.00	0.00	0.00	0.00
185.47	185.49	20/6/7-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.11	0.00	0.00	0.00	0.00
185.92	185.94	20/6/52-54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.94	0.00	0.00	0.00	0.00
186.32	186.34	20/6/92-94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.36	0.00	0.00	0.00	0.00	15.08	0.00	0.00	0.00	0.00
186.72	186.74	20/6/132-134	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.34	0.00	0.00	0.34	0.00	15.48	0.00	0.00	0.00	0.00
187.07	187.09	20/7/17-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.42	0.00	0.00	0.00	0.00	10.13	0.00	0.00	0.00	0.00
187.51	187.53	21/1/1-3	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.26	0.26	0.00	0.00	0.00	0.00	9.91	0.00	0.00	0.00	0.00
187.93	187.95	21/1/43-45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.12	0.00	0.00	0.00	0.00	4.85	0.00	0.00	0.00	0.00
188.32	188.34	21/182-84	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.41	0.61	0.00	0.00	0.00	0.00	11.27	0.00	0.00	0.00	0.00
188.67	188.69	21/1/117-119	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.32	0.49	0.00	0.00	0.00	0.00	11.51	0.00	0.00	0.00	0.00
189.08	189.10	21/2/8-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.44	0.00	0.00	0.00	0.00
189.46	189.48	21/2/46-48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	14.55	0.00	0.00	0.00	0.00
189.93	189.96	21/2/93-96	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.16	0.47	0.00	0.00	0.00	0.00	10.45	0.00	0.00	0.00	0.00
190.42	190.44	21/2/142-144	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0.00	0.00	0.00	10.00	0.00	0.00	0.00	0.00
190.66	190.68	21/3/16-18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.35	0.00	0.00	0.00	0.00	12.02	0.00	0.00	0.00	0.00
191.12	191.14	21/3/62-64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.70	0.00	0.00	0.00	0.00	9.28	0.00	0.00	0.00	0.00
191.52	191.54	21/3/102-104	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.94	0.00	0.00	0.00	0.00
191.86	191.89	21/3/136-139	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.09	1.09	0.00	0.00	0.00	0.00	17.29	0.00	0.00	0.00	0.00
192.36	192.38	21/4/36-38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40	0.00	0.00	0.00	0.00	7.42	0.00	0.00	0.00	0.00
192.73	192.75	21/4/73-75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.00	9.09	0.00	0.00	0.00	0.00
193.12	193.14	21/4/112-114	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.35	0.00	0.00	0.00	0.00	11.27	0.00	0.00	0.00	0.00
193.50	193.52	21/5/0-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	15.05	0.00	0.00	0.00	0.00
193.92	193.94	21/5/42-44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.79	0.79	0.00	0.00	0.00	0.00	13.97	0.00	0.00	0.00	0.00
194.34	194.26	21/5/84-86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.22	0.00	0.00	0.00	0.00	14.67	0.00	0.00	0.00	0.00
194.72	194.74	21/5/122-124	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.11	0.00	0.00	0.00	0.00	10.63	0.00	0.00	0.00	0.00
195.07	195.09	21/6/7-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.00	0.00	0.00	0.00	5.54	0.00	0.00	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Globigerinoides q. immaturus*	*Globigerinoides quadrilobatus* s.s.	*Globigerinoides quadrilobatus* s.s.?	*Globigerinoides q. trilobus*	*Globigerinoides sacculifer*	***Globigerinoides***	*Globigerinopsis obesa*	*Globigerinopsis obesa?*	*Globigerinopsis sp. ?*	***Globigerinopsis***	*Globoconella conomiozea* s.l.	*Globoconella conomiozea* s.s.	*Globoconella explicationis*	*Globoconella sp. indet.*	*Globoconella miotumida*	*Globoconella mons*	*Globoconella mons?*	*Globoconella pliozea*	*Globoconella pliozea?*
195.49	195.51	21/6/49-51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	10.93	0.00	0.00	0.00	0.00
195.87	195.89	21/6/87-89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.14	0.00	0.00	0.00	0.00
196.34	196.36	21/6/134-136	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.19	0.00	0.00	0.00	0.00	16.01	0.00	0.00	0.00	0.00
196.72	196.74	21/7/22-24	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.54	0.72	0.00	0.00	0.00	0.00	7.54	0.00	0.00	0.00	0.00
197.11	197.13	22/1/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.31	0.00	0.00	0.00	0.00
197.48	197.50	22/1/38-40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.85	0.00	0.00	0.00	0.00
197.94	197.96	22/1/84-86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.00	0.00	0.00	0.00	8.25	0.00	0.00	0.00	0.00
198.32	198.34	22/1/122-124	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.85	0.00	0.00	0.00	0.00
198.73	198.75	22/2/13-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.19	0.00	0.00	0.00	0.00	16.09	0.00	0.00	0.00	0.00
199.14	199.16	22/2/54-56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.46	0.00	0.00	0.00	0.00	10.38	0.00	0.00	0.00	0.00
199.53	199.55	22/2/93-95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.87	0.00	0.00	0.00	0.00
199.93	199.95	22/2/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.59	0.00	0.00	0.00	0.00	2.56	0.00	0.00	0.00	0.00
200.25	200.27	22/3/15-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.16	0.00	0.00	0.00	0.00
200.66	200.68	22/3/56-58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.16	0.00	0.00	0.00	0.00
201.05	201.07	22/3/95-97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.30	0.00	0.00	0.00	0.00	8.37	0.00	0.00	0.00	0.00
201.42	201.44	22/3/132-134	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.80	0.80	0.00	0.00	0.00	0.00	16.25	0.00	0.00	0.00	0.00
201.93	201.95	22/4/33-35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.51	0.00	0.00	0.00	0.00
202.52	202.55	22/4/92-95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.73	0.00	0.00	0.00	0.00
202.93	202.95	22/4/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40	0.00	0.00	0.00	0.00	12.83	0.00	0.00	0.00	0.00
203.17	203.20	22CC/7-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.70	0.00	0.00	0.00	0.00
206.71	206.73	23/1/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.09	0.00	0.00	0.00	0.00	6.43	0.00	0.00	0.00	0.00
207.13	207.15	23/1/43-45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.86	0.00	0.00	0.00	0.00
207.48	207.50	23/1/78-80	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.33	0.50	0.00	0.00	0.00	0.00	12.54	0.00	0.00	0.00	0.00
207.88	207.90	23/1/118-120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.26	0.00	0.00	0.00	0.00	7.46	0.00	0.00	0.00	0.00
208.26	208.28	23/2/6-8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.70	0.00	0.00	0.00	0.00
208.52	208.54	23/2/32-34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.22	0.00	0.00	0.00	0.00
209.06	209.08	23/2/86-88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.26	0.00	0.00	0.00	0.00	8.04	0.00	0.00	0.00	0.00
209.54	209.56	23/2/134-136	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.14	0.00	0.00	0.00	0.00	6.73	0.00	0.00	0.00	0.00
209.85	209.87	23/3/15-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.00	0.00	0.42	0.00	9.42	0.00	0.00	0.00	0.00
210.33	210.35	23/3/63-65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.99	0.00	0.00	0.00	0.00
210.53	210.55	23/3/83-85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.27	0.00	0.00	0.00	0.00
210.87	210.89	23/3/117-119	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.12	0.00	0.00	0.00	0.00	9.67	0.00	0.00	0.00	0.00
211.27	211.29	23/4/7-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.31	0.00	0.00	0.15	0.00	13.29	0.00	0.00	0.00	0.00
211.72	211.74	23/4/52-54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.66	0.00	0.00	0.00	0.00
212.13	212.15	23/4/93-95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	10.76	0.00	0.00	0.00	0.00
212.32	212.34	23/4/112-114	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.10	0.00	0.00	0.00	0.00	12.96	0.00	0.00	0.00	0.00
212.71	212.73	23/5/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.59	0.00	0.00	0.00	0.00
213.12	213.14	23/5/42-44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.00	0.00	0.00	0.00	5.33	0.00	0.00	0.00	0.00
213.72	213.74	23/5/102-104	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.26	0.00	0.00	0.00	0.00
214.12	214.14	23/5/142-144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.31	0.00	0.00	0.00	0.00	5.13	0.00	0.00	0.00	0.00
214.51	214.53	23/6/31-33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.50	0.00	0.00	0.00	0.00
215.05	215.07	23/6/85-87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.19	0.00	0.00	0.00	0.00	20.42	0.00	0.00	0.00	0.00
215.53	215.55	23/6/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.79	0.00	0.00	0.00	0.00
215.93	215.95	23/7/23-25	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.16	0.00	0.00	0.00	0.00	11.64	0.00	0.00	0.00	0.00
216.31	216.33	24/1/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	11.65	0.00	0.00	0.00	0.00
216.57	216.59	24/1/27-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.28	0.00	0.00	0.07	0.00	12.66	0.00	0.00	0.00	0.00
216.94	216.96	24/1/64-66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.15	0.00	0.00	0.00	0.00	16.54	0.00	0.00	0.00	0.00
217.34	217.36	24/1/104-106	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.46	0.00	0.00	0.00	0.00
217.72	217.74	24/1/142-144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.32	0.00	0.00	0.00	0.00	17.07	0.00	0.00	0.00	0.00
218.08	218.10	24/2/28-30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.04	0.00	0.00	0.00	0.00
218.52	218.54	24/2/72-74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.23	0.00	0.00	0.00	0.00
218.87	218.89	24/2/107-109	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.11	0.00	0.00	0.00	0.00	14.63	0.00	0.00	0.00	0.00
219.31	219.33	24/3/1-3	0.00	0.00	0.11	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.84	0.00	0.00	0.00	0.00
219.72	219.74	24/3/42-44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.65	0.00	0.00	0.00	0.00
220.12	220.14	24/3/82-84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.12	0.00	0.00	0.00	0.00	10.62	0.00	0.00	0.00	0.00
220.46	220.48	24/3/116-118	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.02	0.00	0.00	0.00	0.00
220.87	220.89	24/4/7-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.47	0.62	0.00	0.00	0.00	0.00	5.91	0.00	0.00	0.00	0.00
221.27	221.29	24/4/47-49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.21	0.00	0.00	0.00	0.00	3.70	0.00	0.00	0.00	0.00
221.66	221.68	24/4/86-88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.73	0.00	0.00	0.00	0.00	8.14	0.00	0.00	0.00	0.00
222.13	222.15	24/4/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.00	0.00	0.00	0.00	6.64	0.00	0.00	0.00	0.00
222.45	222.47	24/5/15-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.34	0.00	0.00	0.00	0.00
222.93	222.95	24/5/63-65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.23	0.00	0.00	0.00	0.00
223.33	223.35	24/5/103-105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.87	0.00	0.00	0.00	0.00
223.72	223.74	24/5/142-144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.28	0.00	0.00	0.00	0.00	7.98	0.00	0.00	0.00	0.00
224.07	224.09	24/6/27-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.35	0.52	0.00	0.00	0.00	0.00	9.74	0.00	0.00	0.00	0.00
224.47	224.49	24/6/67-69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.00	0.00	0.10	0.00	8.16	0.00	0.00	0.00	0.00
224.87	224.89	24/6/107-109	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.41	0.00	0.00	0.00	0.00	9.30	0.00	0.00	0.00	0.00
225.36	225.38	24CC/9-11	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.33	0.50	0.00	0.00	0.00	0.00	9.68	0.00	0.00	0.00	0.00
226.13	226.15	25/1/23-25	0.00	0.00	0.15	0.00	0.00	0.15	0.00	0.31	0.00	0.31	0.00	0.00	0.00	0.00	8.13	0.00	0.00	0.00	0.00
226.53	226.55	25/1/63-65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.16	0.00	0.00	0.32	0.00	13.14	0.00	0.00	0.00	0.00
226.93	226.95	25/1/103-105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.18	0.00	0.00	0.00	0.00	9.30	0.00	0.00	0.00	0.00
227.34	227.36	25/1/144-146	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.16	0.00	0.00	0.00	0.00	6.15	0.00	0.00	0.00	0.00
227.72	227.74	25/2/-32-34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.90	0.00	0.00	0.00	0.00
228.12	228.14	25/2/72-74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.78	0.00	0.00	0.00	0.00
228.52	228.54	25/2/112-114	0.00	0.31	0.00	0.00	0.00	0.31	0.00	0.00	0.10	0.10	0.00	0.00	0.00	0.00	5.02	0.00	0.00	0.00	0.00
228.90	228.92	25/3/0-2	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.19	0.39	0.00	0.00	0.00	0.00	6.98	0.00	0.00	0.00	0.00
229.33	229.35	25/3/43-45	0.00	0.12	0.00	0.00	0.00	0.12	0.24	0.00	0.00	0.24	0.00	0.00	0.00	0.00	7.42	0.00	0.00	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Globigerinoides q. immaturus*	*Globigerinoides quadrilobatus* s.s.	*Globigerinoides quadrilobatus* s.s.?	*Globigerinoides q. trilobus*	*Globigerinoides sacculifer*	***Globigerinoides***	*Globigerinopsis obesa*	*Globigerinopsis obesa?*	*Globigerinopsis sp. ?*	***Globigerinopsis***	*Globoconella conomiozea* s.l.	*Globoconella conomiozea* s.s.	*Globoconella explicationis*	*Globoconella sp. indet.*	*Globoconella miotumida*	*Globoconella mons*	*Globoconella mons?*	*Globoconella pliozea*	*Globoconella pliozea?*
229.85	229.87	25/3/95-97	0.00	0.14	0.00	0.00	0.00	0.14	0.00	0.00	0.14	0.14	0.00	0.00	0.00	0.00	8.50	0.00	0.00	0.00	0.00
230.27	230.29	25/3/137-139	0.00	0.00	0.18	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.06	0.00	0.00	0.00	0.00
230.47	230.49	25/4/7-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.18	0.00	0.00	0.00	0.00	5.23	0.00	0.00	0.00	0.00
230.93	230.95	25/4/53-55	0.00	0.18	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.81	0.00	0.00	0.00	0.00
231.33	231.35	25/4/93-95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.25	0.00	0.00	0.00	0.00	3.31	0.00	0.00	0.00	0.00
231.73	231.75	25/4/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.64	0.00	0.00	0.00	0.00
232.06	232.08	25/5/16-18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.72	0.00	0.00	0.00	0.00
232.52	232.54	25/5/62-64	0.00	0.33	0.00	0.00	0.00	0.33	0.00	0.00	0.22	0.22	0.00	0.00	0.00	0.00	8.36	0.00	0.00	0.00	0.00
232.92	232.94	25/5/102-104	0.00	0.83	0.00	0.00	0.00	0.83	0.00	0.00	1.04	1.04	0.00	0.00	0.00	0.00	9.73	0.00	0.00	0.00	0.00
233.27	233.29	25/5137-139	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.35	0.35	0.00	0.00	0.00	0.00	4.25	0.00	0.00	0.00	0.00
233.67	233.69	25/6/27-29	0.00	0.00	0.13	0.00	0.00	0.13	0.00	0.13	0.13	0.27	0.00	0.00	0.00	0.00	5.63	0.00	0.00	0.00	0.00
234.15	234.17	25/6/75-77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.12	0.00	0.00	0.00	0.00	6.81	0.00	0.00	0.00	0.00
234.52	234.54	25/6/112-114	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.75	0.75	0.00	0.00	0.00	0.00	6.52	0.00	0.00	0.00	0.00
234.91	234.93	25/7/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.43	0.00	0.00	0.00	0.00	6.55	0.00	0.00	0.00	0.00
235.26	235.28	25CC/10-22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.49	0.00	0.00	0.00	0.00	4.89	0.00	0.00	0.00	0.00
235.73	235.75	26/1/23-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	1.16	1.39	0.00	0.00	0.00	0.00	7.64	0.00	0.00	0.00	0.00
236.08	236.10	26/1/58-60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.96	0.96	0.00	0.00	0.00	0.00	10.93	0.00	0.00	0.00	0.00
236.52	236.54	26/1/102-104	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.29	0.00	0.00	0.00	0.00	13.78	0.00	0.00	0.00	0.00
236.92	236.94	26/1/142-144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.53	0.00	0.00	0.00	0.00
237.32	237.34	26/2/32-34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.28	1.28	0.00	0.00	0.00	0.00	13.92	0.00	0.00	0.00	0.00
237.93	237.95	26/2/93-95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.61	0.00	0.00	0.00	0.00	15.98	0.00	0.00	0.00	0.00
238.33	238.35	26/2/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32	1.32	0.00	0.00	0.00	0.00	7.34	0.00	0.00	0.00	0.00
238.51	238.53	26/3/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.12	0.00	0.00	0.00	0.00	4.65	0.00	0.00	0.00	0.00
238.93	238.95	26/3/43-45	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	1.15	1.44	0.00	0.00	0.00	0.00	3.02	0.00	0.00	0.00	0.00
239.32	239.34	26/3/82-84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.68	0.00	0.00	0.00	0.00	6.95	0.00	0.00	0.00	0.00
239.67	239.69	26/3/117-119	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.70	0.00	0.00	0.00	0.00	5.23	0.00	0.00	0.00	0.00
240.07	240.09	26/4/7-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.54	0.00	0.00	0.00	0.00
240.52	240.54	26/4/52-54	0.00	0.00	0.10	0.00	0.00	0.10	0.00	0.00	0.39	0.39	0.00	0.00	0.00	0.00	5.31	0.00	0.00	0.00	0.00
240.92	240.94	26/4/92-94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.55	0.00	0.00	0.00	0.00	5.59	0.00	0.00	0.00	0.00
241.32	241.34	26/4/132-134	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.61	0.91	0.00	0.00	0.15	0.00	8.65	0.00	0.00	0.00	0.00
241.65	241.67	26/5/15-17	0.00	0.00	0.15	0.00	0.00	0.15	0.15	0.00	0.30	0.45	0.00	0.00	0.00	0.00	8.01	0.00	0.00	0.00	0.00
242.13	242.15	26/5/63-65	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.22	0.43	0.00	0.00	0.00	0.00	12.61	0.00	0.00	0.00	0.00
242.52	242.54	26/5/102-104	0.00	1.09	0.00	1.09	0.00	2.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.69	0.00	0.00	0.00	0.00
242.92	242.94	26/5/142-144	0.00	0.45	0.00	0.15	0.00	0.60	0.30	0.00	1.20	1.49	0.00	0.00	0.00	0.00	14.35	0.00	0.00	0.00	0.00
243.26	243.28	26/6/26-28	0.00	0.19	0.00	0.00	0.00	0.19	0.00	0.00	0.19	0.19	0.00	0.00	0.00	0.00	10.58	0.00	0.00	0.00	0.00
243.63	243.65	26/6/63-65	0.00	4.11	0.00	0.23	0.00	4.34	0.00	0.23	1.14	1.37	0.00	0.00	0.00	0.00	8.68	0.00	0.00	0.00	0.00
243.86	243.88	26CC/13-15	0.00	1.10	0.00	0.37	0.00	1.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.29	0.00	0.00	0.00	0.00
245.11	245.13	27/1/1-3	0.00	1.54	0.00	0.31	0.00	1.85	0.15	0.00	0.46	0.62	0.00	0.00	0.00	0.00	9.38	0.00	0.00	0.00	0.00
245.53	245.55	27/1/43-45	0.00	0.14	0.00	0.28	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.36	0.00	0.00	0.00	0.00
245.91	245.93	27/1/81-83	3.40	0.85	0.00	0.00	0.00	4.25	0.00	0.00	0.42	0.42	0.00	0.00	0.00	0.00	6.37	0.00	0.00	0.00	0.00
246.27	246.29	27/1/117-119	1.45	1.30	0.00	0.00	0.00	2.75	0.00	0.00	0.29	0.29	0.00	0.00	0.00	0.00	6.22	0.00	0.00	0.00	0.00
246.52	246.54	27/1/142-144	0.94	0.94	0.00	0.00	0.00	1.88	0.00	0.00	0.73	0.73	0.00	0.00	0.00	0.00	6.88	0.00	0.00	0.00	0.00
246.87	246.89	27/2/27-29	0.97	1.21	0.00	0.00	0.00	2.18	0.00	0.00	0.12	0.12	0.00	0.00	0.00	0.00	6.42	0.00	0.00	0.00	0.00
247.33	247.35	27/2/73-76	0.93	0.19	0.00	0.00	0.00	1.12	0.00	0.00	0.56	0.56	0.00	0.00	0.00	0.00	7.43	0.00	0.00	0.00	0.00
247.67	247.69	27/2/107-109	0.24	0.73	0.00	0.00	0.00	0.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.32	0.00	0.00	0.00	0.00
248.11	248.13	27/3/1-3	0.19	0.19	0.00	0.00	0.00	0.37	0.00	0.00	0.19	0.19	0.00	0.00	0.00	0.00	5.81	0.00	0.00	0.00	0.00
248.47	248.49	27/3/37-39	0.00	0.11	0.00	0.00	0.00	0.11	0.11	0.00	0.00	0.11	0.00	0.00	0.00	0.00	5.96	0.00	0.00	0.00	0.00
248.93	248.95	27/3/83-85	0.00	0.24	0.00	0.00	0.00	0.24	0.00	0.00	0.24	0.24	0.00	0.00	0.00	0.00	5.30	0.00	0.00	0.00	0.00
249.27	249.27	27/3/117-119	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.53	0.00	0.00	0.00	0.00
249.67	249.69	27/4/7-9	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.22	0.34	0.00	0.00	0.00	0.00	3.82	0.00	0.00	0.00	0.00
250.12	250.14	27/4/52-54	0.00	0.14	0.14	0.00	0.00	0.28	0.00	0.00	0.28	0.28	0.00	0.00	0.00	0.00	8.73	0.00	0.00	0.00	0.00
250.46	250.48	27/4/86-88	0.00	0.00	0.00	0.20	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.89	0.00	0.00	0.00	0.00
250.92	250.94	27/4/132-134	0.00	0.29	0.00	0.00	0.00	0.29	0.00	0.00	0.15	0.15	0.00	0.00	0.00	0.00	9.72	0.00	0.00	0.00	0.00
251.33	251.36	27/5/23-26	0.00	0.16	0.00	0.00	0.00	0.16	0.16	0.00	0.63	0.79	0.00	0.00	0.00	0.00	6.48	0.00	0.00	0.00	0.00
251.67	251.69	27/5/57-59	0.00	0.18	0.00	0.00	0.00	0.18	0.18	0.00	0.00	0.18	0.00	0.00	0.00	0.00	6.38	0.00	0.00	0.00	0.00
252.13	252.15	27/5/103-105	0.15	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.28	0.00	0.00	0.00	0.00
252.53	252.55	27/5/143-145	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.49	0.00	0.00	0.00	0.00	9.54	0.00	0.00	0.00	0.00
252.92	252.94	27/6/32-34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.83	0.83	0.00	0.00	0.00	0.00	10.48	0.00	0.00	0.00	0.00
253.33	253.35	27/6/73-75	0.28	0.00	0.00	0.00	0.00	0.28	0.28	0.00	0.28	0.56	0.00	0.00	0.00	0.00	12.92	0.00	0.00	0.00	0.00
253.67	253.69	27/6/107-109	0.00	0.27	0.00	0.00	0.00	0.27	0.00	0.00	0.55	0.55	0.00	0.00	0.00	0.00	12.19	0.00	0.00	0.00	0.00
254.10	254.12	27/7/0-2	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.32	0.48	0.00	0.00	0.00	0.00	10.48	0.00	0.00	0.00	0.00
254.49	254.51	27CC/10-12	0.00	0.00	0.00	0.12	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.25	0.00	0.00	0.00	0.00
254.93	254.95	28/1/23-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.15	0.00	0.00	0.00	0.00	8.31	0.00	0.00	0.00	0.00
255.28	255.30	28/1/58-60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.15	0.00	0.00	0.00	0.00	10.00	0.00	0.00	0.00	0.00
255.73	255.75	28/1/103-105	0.19	0.19	0.00	0.00	0.00	0.38	0.00	0.00	0.38	0.38	0.00	0.00	0.00	0.00	17.89	0.00	0.00	0.00	0.00
256.11	256.13	28/1/141-143	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.93	0.93	0.00	0.00	0.00	0.00	12.56	0.00	0.00	0.00	0.00
256.53	256.55	28/2/33-35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.84	0.00	0.00	0.00	0.00
257.03	257.05	28/2/83-85	0.22	0.00	0.00	0.00	0.00	0.22	0.00	0.22	0.43	0.65	0.00	0.00	0.00	0.00	13.26	0.00	0.00	0.00	0.00
257.33	257.35	28/2/113-115	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.34	0.00	0.00	0.00	0.00
257.71	257.73	28/3/1-3	0.00	0.21	0.00	0.00	0.00	0.21	0.00	0.00	0.83	0.83	0.00	0.00	0.00	0.00	9.17	0.00	0.00	0.00	0.00
258.12	258.14	28/3/42-44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.34	0.00	0.00	0.00	0.00	8.71	0.00	0.00	0.00	0.00
258.54	258.56	28/3/84-86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.09	0.00	0.00	0.00	0.00
259.07	259.09	28/3/137-139	0.26	0.26	0.00	0.00	0.00	0.51	0.00	0.00	0.26	0.26	0.00	0.00	0.00	0.00	11.00	0.00	0.00	0.00	0.00
259.53	259.55	28/4/33-35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.49	0.00	0.00	0.00	0.00	14.03	0.00	0.00	0.00	0.00
259.86	259.88	28/4/66-68	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.64	0.90	0.00	0.00	0.00	0.00	9.46	0.00	0.00	0.00	0.00
260.28	260.30	28/4/108-110	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.31	0.00	0.00	0.00	0.00	9.80	0.00	0.00	0.00	0.00
260.54	260.56	28/4/134-136	0.00	0.00	0.15	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.51	0.00	0.00	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Globigerinoides q. immaturus*	*Globigerinoides quadrilobatus* s.s.	*Globigerinoides quadrilobatus* s.s.?	*Globigerinoides q. trilobus*	*Globigerinoides sacculifer*	***Globigerinoides***	*Globigerinopsis obesa*	*Globigerinopsis obesa?*	*Globigerinopsis sp.?*	***Globigerinopsis***	*Globoconella conomiozea* s.l.	*Globoconella conomiozea* s.s.	*Globoconella explicationis*	*Globoconella sp. indet.*	*Globoconella miotumida*	*Globoconella mons*	*Globoconella mons?*	*Globoconella pliozea*	*Globoconella pliozea?*
260.86	260.88	28/5/16-18	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.71	0.00	0.00	0.00	0.00
261.31	261.33	28/5/61-63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.30	0.00	0.00	0.00	0.00	7.62	0.00	0.00	0.00	0.00
261.72	261.74	28/5/102-104	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.52	0.00	0.00	0.00	0.00	8.58	0.00	0.00	0.00	0.00
262.11	262.13	28/5/141-143	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.19	0.00	0.00	0.00	0.00	5.76	0.00	0.00	0.00	0.00
262.45	262.47	28CC/8-10	0.00	0.11	0.00	0.00	0.00	0.11	0.00	0.00	0.11	0.11	0.00	0.00	0.00	0.00	6.82	0.00	0.00	0.00	0.00
264.30	264.32	29/1/0-2	0.00	0.52	0.00	0.00	0.00	0.52	0.00	0.00	0.26	0.26	0.00	0.00	0.00	0.00	7.73	0.00	0.00	0.00	0.00
264.64	264.66	29/1/34-36	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.31	0.46	0.00	0.00	0.00	0.00	12.36	0.00	0.00	0.00	0.00
264.88	264.90	29/1/58-60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.32	0.00	0.00	0.00	0.00	11.38	0.00	0.00	0.00	0.00
265.26	265.28	29/1/96-98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.00	0.00	0.00	0.00	11.84	0.00	0.00	0.00	0.00
265.72	265.74	29/1/142-144	0.00	0.19	0.00	0.00	0.00	0.19	0.00	0.00	0.39	0.39	0.00	0.00	0.00	0.00	16.34	0.00	0.00	0.00	0.00
266.12	266.14	29/2/32-34	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.22	0.00	0.00	0.00	0.00	17.10	0.00	0.00	0.00	0.00
266.44	266.46	29/2/64-66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.67	0.00	0.00	0.00	0.00	12.08	0.00	0.00	0.00	0.00
266.87	266.89	29/2/107-109	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.49	0.00	0.00	0.00	0.00	16.01	0.00	0.00	0.00	0.00
267.31	267.33	29/3/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.51	0.00	0.00	0.00	0.00	21.94	0.00	0.00	0.00	0.00
267.53	267.55	29/3/23-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.18	0.00	0.00	0.00	0.00	12.52	0.00	0.00	0.00	0.00
267.72	267.74	29/3/42-44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.94	0.00	0.00	0.00	0.00
267.87	267.89	29/3/57-59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.63	0.00	0.00	0.00	0.00
268.14	268.16	29/3/84-86	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.37	0.00	0.00	0.00	0.00	8.96	0.00	0.00	0.00	0.00
268.34	268.36	29/3/104-106	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00	17.79	0.00	0.00	0.00	0.00
268.47	268.49	29/3/117-119	0.00	0.11	0.00	0.00	0.00	0.11	0.00	0.00	0.32	0.32	0.00	0.00	0.00	0.00	13.15	0.00	0.00	0.00	0.00
268.68	268.70	29/3/138-140	0.00	1.04	0.00	0.00	0.00	1.04	0.26	0.00	1.04	1.30	0.00	0.00	0.00	0.00	16.88	0.00	0.00	0.00	0.00
268.86	268.88	29/4/6-8	0.00	3.79	0.00	0.00	0.00	3.79	0.29	0.00	0.29	0.58	0.00	0.00	0.00	0.00	14.29	0.00	0.00	0.00	0.00
269.28	269.30	29/4/48-50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.57	0.00	0.00	0.00	0.00	12.78	0.00	0.00	0.00	0.00
269.52	269.54	29/4/72-74	0.00	0.24	0.00	0.00	0.00	0.24	0.00	0.00	0.48	0.48	0.00	0.00	0.00	0.00	10.12	0.00	0.00	0.00	0.00
269.75	269.77	29/4/95-97	0.00	0.73	0.00	0.18	0.00	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.13	0.00	0.00	0.00	0.00
269.87	269.89	29/4/107-109	0.00	0.62	0.21	0.00	0.00	0.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.11	0.00	0.00	0.00	0.00
270.15	270.17	29/4/135-137	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.34	0.00	0.00	0.00	0.00	14.38	0.00	0.00	0.00	0.00
270.31	270.33	29/5/1-3	0.00	0.15	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.10	0.00	0.00	0.00	0.00
270.45	270.47	29/5/15-17	0.00	0.00	0.00	0.45	0.00	0.45	0.23	0.00	0.23	0.45	0.00	0.00	0.00	0.00	13.29	0.00	0.00	0.00	0.00
270.72	270.74	29/5/42-44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.90	0.90	0.00	0.00	0.00	0.00	16.70	0.00	0.00	0.00	0.00
270.91	270.93	29/5/61-63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.36	0.00	0.00	0.00	0.00	14.52	0.00	0.00	0.00	0.00
271.15	271.17	29/5/85-87	0.00	1.29	0.00	0.00	0.00	1.29	0.00	0.00	0.18	0.18	0.00	0.00	0.00	0.00	18.05	0.00	0.00	0.00	0.00
271.34	271.36	29/5/104-106	0.00	0.80	0.00	0.00	0.00	0.80	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	18.00	0.00	0.00	0.00	0.00
271.48	271.50	29/5/118-120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.88	0.00	0.00	0.00	0.00
271.72	271.74	29/5/142-144	0.00	0.26	0.00	0.00	0.00	0.26	0.00	0.00	0.26	0.26	0.00	0.00	0.00	0.00	10.65	0.00	0.00	0.00	0.00
271.94	271.96	29/6/14-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.37	0.00	0.00	0.00	0.00	11.83	0.00	0.00	0.00	0.00
272.19	272.21	29CC/17-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.11	0.00	0.00	0.00	0.00	8.06	0.00	0.00	0.00	0.00
273.91	273.93	30/1/1-A7303	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.21	0.00	0.00	0.00	0.00
274.04	274.06	30/1/14-16	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.45	1.12	0.00	0.00	0.00	0.00	16.37	0.00	0.00	0.00	0.00
274.32	274.34	30/1/42-44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.52	0.00	0.00	0.00	0.00	18.23	0.00	0.00	0.00	0.00
274.48	274.50	30/1/58-60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.61	0.00	0.00	0.00	0.00	15.51	0.00	0.00	0.00	0.00
274.72	274.74	30/1/82-84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.42	0.00	0.00	0.00	0.00	12.21	0.00	0.00	0.00	0.00
274.93	274.95	30/1/103-105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.32	0.00	0.00	0.00	0.00	12.64	0.00	0.00	0.00	0.00
275.12	275.14	30/1/122-124	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.13	0.00	0.00	0.00	0.00	9.91	0.00	0.00	0.00	0.00
275.31	275.33	30/1/141-143	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.81	0.81	0.00	0.00	0.00	0.00	9.73	0.00	0.00	0.00	0.00
275.45	275.47	30/2/5-7	0.00	0.18	0.00	0.00	0.00	0.18	0.00	0.00	0.36	0.36	0.00	0.00	0.00	0.00	9.57	0.00	0.00	0.00	0.00
275.93	275.95	30/2/53-55	0.16	0.49	0.00	0.00	0.00	0.66	0.33	0.00	0.49	0.82	0.00	0.00	0.00	0.00	9.67	0.00	0.00	0.00	0.00
276.52	276.54	30/2/112-114	0.00	0.00	0.19	0.00	0.00	0.19	0.19	0.10	0.38	0.67	0.00	0.00	0.00	0.00	5.82	0.00	0.00	0.00	0.00
276.91	276.93	30/3/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.00	0.34	0.85	0.00	0.00	0.00	0.00	8.35	0.00	0.00	0.00	0.00
277.33	277.35	30/3/43-45	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.46	0.61	0.00	0.00	0.00	0.00	8.87	0.00	0.00	0.00	0.00
277.74	277.76	30/3/84-86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.31	0.00	0.00	0.00	0.00	8.91	0.00	0.00	0.00	0.00
278.07	278.09	30/3/117-119	0.13	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.40	0.40	0.00	0.00	0.00	0.00	8.60	0.00	0.00	0.00	0.00
278.49	278.51	30/4/9-11	0.00	0.00	0.33	0.00	0.00	0.33	0.00	0.00	0.22	0.22	0.00	0.00	0.00	0.00	7.36	0.00	0.00	0.00	0.00
278.88	278.90	30/4/48-50	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.33	0.49	0.00	0.00	0.00	0.00	9.93	0.00	0.00	0.00	0.00
279.33	279.35	30/4/93-95	0.00	0.19	0.00	0.00	0.00	0.19	0.19	0.00	0.37	0.56	0.00	0.00	0.00	0.00	6.93	0.00	0.00	0.00	0.00
279.75	279.77	30/4/135-137	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.17	0.35	0.00	0.00	0.00	0.00	6.04	0.00	0.00	0.00	0.00
280.05	280.07	30/5/15-17	0.00	0.12	0.00	0.00	0.00	0.12	0.12	0.00	0.12	0.25	0.00	0.00	0.00	0.00	7.00	0.00	0.00	0.00	0.00
280.25	280.27	30/5/35-37	0.00	0.42	0.00	0.00	0.00	0.42	0.00	0.00	0.32	0.32	0.00	0.00	0.11	0.00	4.66	0.00	0.00	0.00	0.00
280.92	280.94	30/5/102-104	0.00	3.04	0.00	0.71	0.00	3.75	0.54	0.00	0.00	0.54	0.00	0.00	0.00	0.00	7.50	0.00	0.00	0.00	0.00
283.51	283.53	31/1/1-3	0.00	0.00	0.15	0.00	0.00	0.15	0.00	0.00	0.44	0.44	0.00	0.00	0.00	0.00	10.40	0.00	0.00	0.00	0.00
283.94	283.96	31/1/44-46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.15	0.00	0.00	0.00	0.00	9.28	0.00	0.00	0.00	0.00
284.33	284.35	31/1/83-85	0.00	0.15	0.00	0.00	0.00	0.15	0.00	0.00	0.46	0.46	0.00	0.00	0.00	0.00	8.59	0.00	0.00	0.00	0.00
284.55	284.57	31/1/105-107	0.00	0.59	0.00	0.00	0.00	0.59	0.00	0.00	0.47	0.47	0.00	0.00	0.00	0.00	9.82	0.00	0.00	0.00	0.00
284.88	284.90	31/1/138-140	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.27	0.40	0.00	0.00	0.00	0.00	4.98	0.00	0.00	0.00	0.00
285.29	285.31	31/2/29-31	0.00	0.78	0.00	0.00	0.00	0.78	0.16	0.00	0.31	0.47	0.00	0.00	0.00	0.00	5.47	0.00	0.00	0.00	0.00
285.73	285.75	31/2/73-75	0.00	0.17	0.00	0.00	0.00	0.17	0.17	0.00	0.17	0.34	0.00	0.00	0.00	0.00	11.51	0.00	0.00	0.00	0.00
286.10	286.12	31/2/110-112	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.43	0.00	0.00	0.00	0.00	9.71	0.00	0.00	0.00	0.00
286.51	286.53	31/3/1-3	0.00	0.96	0.21	0.00	0.00	1.17	0.00	0.00	0.11	0.11	0.00	0.00	0.00	0.00	8.39	0.00	0.00	0.00	0.00
286.88	286.90	31/3/38-40	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.36	0.54	0.00	0.00	0.00	0.00	7.17	0.00	0.00	0.00	0.00
287.32	287.34	31/3/82-84	0.00	0.53	0.00	0.00	0.00	0.53	0.18	0.00	0.18	0.35	0.00	0.00	0.00	0.00	9.36	0.00	0.00	0.00	0.00
287.67	287.69	31/3/117-119	0.36	1.90	0.00	0.00	0.00	2.26	0.00	0.00	0.12	0.12	0.00	0.00	0.00	0.00	7.02	0.00	0.00	0.00	0.00
288.08	288.10	31/4/8-10	0.31	0.73	0.00	0.00	0.00	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.49	0.00	0.00	0.00	0.00
288.55	288.57	31/4/55-57	0.00	1.24	0.00	0.00	0.00	1.24	0.21	0.00	0.31	0.52	0.00	0.00	0.00	0.00	6.51	0.00	0.00	0.00	0.00
288.89	288.91	31/4/89-91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.42	0.00	0.00	0.00	0.00
289.34	289.36	31/4/134-136	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.24	0.36	0.00	0.00	0.00	0.00	4.78	0.00	0.00	0.00	0.00
289.73	289.75	31/5/23-25	0.00	0.00	0.15	0.00	0.00	0.15	0.00	0.00	0.30	0.30	0.00	0.00	0.00	0.00	8.51	0.00	0.00	0.00	0.00
290.12	290.14	31/5/62-64	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.32	0.49	0.00	0.00	0.00	0.00	7.78	0.00	0.00	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Globigerinoides q. immaturus*	*Globigerinoides quadrilobatus* s.s.	*Globigerinoides quadrilobatus* s.s.?	*Globigerinoides q. trilobus*	*Globigerinoides sacculifer*	***Globigerinoides***	*Globigerinopsis obesa*	*Globigerinopsis obesa?*	*Globigerinopsis sp. ?*	***Globigerinopsis***	*Globoconella conomiozea* s.l.	*Globoconella conomiozea* s.s.	*Globoconella explicationis*	*Globoconella* sp. indet.	*Globoconella miotumida*	*Globoconella mons*	*Globoconella mons?*	*Globoconella pliozea*	*Globoconella pliozea?*
290.51	290.53	31/5/101-103	0.00	0.62	0.25	0.00	0.00	0.87	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	7.54	0.00	0.00	0.00	0.00
290.74	290.76	31CC/0-2	0.00	0.13	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.91	0.00	0.00	0.00	0.00
293.11	293.13	32/1/1-3	0.00	1.14	0.00	0.00	0.00	1.14	0.00	0.00	0.32	0.32	0.00	0.00	0.00	0.00	10.06	0.00	0.00	0.00	0.00
293.33	293.35	32/1/23-25	0.00	0.00	0.00	0.15	0.00	0.15	0.00	0.00	0.29	0.29	0.00	0.00	0.00	0.00	9.25	0.00	0.00	0.00	0.00
293.71	293.73	32/1/61-63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	4.31	0.00	0.00	0.00	0.00
294.12	294.14	32/1/102-104	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.35	0.00	0.00	0.18	0.00	9.46	0.00	0.00	0.00	0.00
294.51	294.53	32/1/141-143	0.00	0.00	0.48	0.00	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	3.34	0.00	0.00	0.00	0.00
294.90	294.92	32/2/30-32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.12	0.00	0.00	0.12	0.00	9.35	0.00	0.00	0.00	0.00
295.33	295.35	32/2/73-75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.00	0.00	0.00	0.00	9.23	0.00	0.00	0.00	0.00
295.73	295.75	32/2/113-115	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.34	0.00	0.00	0.00	0.00	8.69	0.00	0.00	0.00	0.00
295.93	295.95	32/2/133-135	0.00	0.00	0.00	0.20	0.00	0.20	0.00	0.00	0.60	0.60	0.00	0.00	0.00	0.00	13.23	0.00	0.00	0.00	0.00
296.50	296.52	32/3/40-42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.32	0.00	0.00	0.00	0.00	12.42	0.00	0.00	0.00	0.00
296.93	296.95	32/3/83-85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	17.20	0.00	0.00	0.00	0.00
297.33	297.35	32/3/123-125	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.14	0.00	0.00	0.00	0.00
297.70	297.72	32/4/10-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.50	0.00	0.00	0.00	0.00
298.08	298.10	32/4/48-50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.16	0.00	0.00	0.00	0.00	10.28	0.00	0.00	0.00	0.00
298.52	298.54	32/4/92-94	0.00	0.17	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.34	0.00	0.00	0.00	0.00
298.93	298.95	32/4/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.58	0.00	0.00	0.00	0.00
299.38	299.40	32/5/28-30	0.00	2.24	0.00	0.00	0.00	2.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.81	0.00	0.00	0.00	0.00
299.67	299.69	32CC/2-4	0.00	1.25	0.00	0.00	0.00	1.25	0.00	0.00	0.21	0.21	0.00	0.00	0.10	0.00	7.73	0.00	0.00	0.00	0.00
302.71	302.73	33/1/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.16	0.00	0.00	0.00	0.00	10.39	0.00	0.00	0.00	0.00
302.97	302.99	33/1/27-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00	13.08	0.00	0.00	0.00	0.00
303.29	303.31	33/1/59-61	0.00	0.16	0.00	0.00	0.00	0.16	0.00	0.00	0.48	0.48	0.00	0.00	0.16	0.00	16.51	0.00	0.00	0.00	0.00
303.77	303.79	33/1/107-109	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.00	0.00	0.00	0.00	16.31	0.00	0.00	0.00	0.00
304.13	304.15	33/1/143-145	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.81	0.00	0.00	0.00	0.00
304.29	304.31	33/2/9-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.36	0.00	0.00	0.00	0.00	16.52	0.00	0.00	0.00	0.00
304.47	304.49	33/2/27-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.00	0.00	0.00	0.00	12.46	0.00	0.00	0.00	0.00
304.66	304.68	33/2/46-48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.97	0.00	0.00	0.00	0.00
305.02	305.04	33/2/82-84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.16	0.00	0.00	0.16	0.00	14.59	0.00	0.00	0.00	0.00
305.15	305.17	33/2/95-97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.72	0.00	0.00	0.00	0.00
305.34	305.36	33/2/114-116	0.00	0.21	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.56	0.00	0.00	0.00	0.00
305.55	305.57	33/2/135-137	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.18	0.00	0.00	0.00	0.00	18.36	0.00	0.00	0.00	0.00
305.71	305.73	33/3/1-3	0.00	0.42	0.00	0.00	0.00	0.42	0.00	0.00	0.21	0.21	0.00	0.00	0.21	0.00	20.42	0.00	0.00	0.00	0.00
305.93	305.95	33/3/23-25	0.00	0.22	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.40	0.00	0.00	0.00	0.00
306.11	306.13	33/3/41-43	0.00	1.38	0.00	0.00	0.00	1.38	0.00	0.00	0.40	0.40	0.00	0.00	0.00	0.00	9.29	0.00	0.00	0.00	0.00
306.27	306.29	33/3/57-59	0.00	0.14	0.00	0.14	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.19	0.00	0.00	0.00	0.00
306.54	306.56	33/3/84-86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.85	0.00	0.00	0.00	0.00
306.75	306.77	33/3/105-107	0.00	0.11	0.00	0.00	0.00	0.11	0.00	0.00	0.22	0.22	0.00	0.00	0.00	0.00	15.78	0.00	0.00	0.00	0.00
306.86	306.88	33/3/116-118	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.62	0.00	0.00	0.00	0.00
307.08	307.10	33/3/138-140	0.00	0.00	0.20	0.00	0.00	0.20	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	19.26	0.00	0.00	0.00	0.00
307.30	307.32	33/4/10-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.44	0.00	0.00	0.00	0.00
307.49	307.51	33/4/29-31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.30	0.00	0.00	0.00	0.00	29.17	0.00	0.00	0.00	0.00
307.70	307.72	33/4/50-52	0.00	0.25	0.00	0.00	0.00	0.25	0.00	0.00	0.25	0.25	0.00	0.00	0.00	0.00	28.82	0.00	0.00	0.00	0.00
307.93	307.95	33/4/73-75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.19	0.00	0.00	0.00	0.00	16.93	0.00	0.00	0.00	0.00
308.14	308.16	33/4/94-96	0.00	0.16	0.00	0.00	0.00	0.16	0.00	0.00	0.16	0.16	0.00	0.00	0.00	0.00	9.87	0.00	0.00	0.00	0.00
308.30	308.32	33/4/110-112	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.45	0.00	0.00	0.00	0.00	8.33	0.00	0.00	0.00	0.00
308.53	308.55	33/4/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.50	0.00	0.00	0.00	0.00
308.71	308.73	33/5/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.15	0.00	0.00	0.00	0.00	14.35	0.00	0.00	0.00	0.00
308.99	309.01	33/5/29-31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.21	0.00	0.00	0.00	0.00	15.35	0.00	0.00	0.00	0.00
309.11	309.13	33/5/41-43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	12.07	0.00	0.00	0.00	0.00
309.28	309.30	33/5/58-60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.75	0.00	0.00	0.00	0.00
309.54	309.56	33/5/84-86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.90	0.00	0.00	0.00	0.00
309.74	309.76	33/5/104-106	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.59	0.00	0.00	0.00	0.00
312.31	312.33	34/1/1-3	0.00	0.18	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.62	0.00	0.00	0.00	0.00
312.54	312.56	34/1/24-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.79	0.79	0.00	0.00	0.00	0.00	14.62	0.00	0.00	0.00	0.00
312.67	312.69	34/1/37-39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.49	0.00	0.00	0.00	0.00
312.87	312.89	34/1/57-59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.91	0.00	0.00	0.00	0.00
313.07	313.09	34/1/77-79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.89	0.00	0.00	0.00	0.00
313.31	313.33	34/1/101-103	0.00	0.00	0.00	0.20	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.22	0.00	0.00	0.00	0.00
313.53	313.55	34/1/123-125	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.51	0.00	0.00	0.00	0.00	12.56	0.00	0.00	0.00	0.00
313.71	313.73	34/1/141-143	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.16	0.00	0.00	0.00	0.00	8.95	0.00	0.00	0.00	0.00
313.90	313.92	34/2/10-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	15.11	0.00	0.00	0.00	0.00
314.09	314.11	34/2/29-31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.53	0.00	0.00	0.00	0.00	19.89	0.00	0.00	0.00	0.00
314.29	314.31	34/2/49-51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	17.16	0.00	0.00	0.00	0.00
314.45	314.47	34/2/65-67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.29	0.00	0.00	0.00	0.00	9.29	0.00	0.00	0.00	0.00
314.69	314.71	34/2/89-91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.18	0.00	0.00	0.00	0.00
314.90	314.92	34/2/110-112	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.21	0.00	0.00	0.00	0.00	6.68	0.00	0.00	0.00	0.00
315.13	315.15	34/2/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.61	0.00	0.00	0.00	0.00
315.30	315.32	34/3/0-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.76	0.00	0.00	0.00	0.00
315.52	315.54	34/3/22-24	0.00	0.21	0.00	0.00	0.00	0.21	0.00	0.00	0.42	0.42	0.00	0.00	0.00	0.00	12.89	0.00	0.00	0.00	0.00
315.71	315.73	34/3/41-43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.22	0.00	0.00	0.00	0.00	8.42	0.00	0.00	0.00	0.00
316.06	316.08	34/3/76-78	0.00	0.00	0.00	0.14	0.00	0.14	0.00	0.00	0.29	0.29	0.00	0.00	0.00	0.00	9.05	0.00	0.00	0.00	0.00
316.27	316.29	34/3/97-99	0.00	0.10	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	8.63	0.00	0.00	0.00	0.00
316.48	316.50	34/3/118-120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.99	0.00	0.00	0.00	0.00
316.67	316.69	34/3/137-139	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.23	0.00	0.00	0.00	0.00	12.90	0.00	0.00	0.00	0.00
317.10	317.12	34/4/30-32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.19	0.00	0.00	0.00	0.00	9.87	0.00	0.00	0.00	0.00
317.50	317.52	34/4/70-72	0.00	0.00	0.00	0.24	0.00	0.24	0.24	0.00	0.00	0.24	0.00	0.00	0.00	0.00	25.54	0.00	0.00	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Globigerinoides q. immaturus*	*Globigerinoides quadrilobatus* s.s.	*Globigerinoides quadrilobatus* s.s.?	*Globigerinoides q. trilobus*	*Globigerinoides sacculifer*	***Globigerinoides***	*Globigerinopsis obesa*	*Globigerinopsis obesa?*	*Globigerinopsis sp.?*	***Globigerinopsis***	*Globoconella conomiozea* s.l.	*Globoconella conomiozea* s.s.	*Globoconella explicationis*	*Globoconella sp. indet.*	*Globoconella miotumida*	*Globoconella mons*	*Globoconella mons?*	*Globoconella pliozea*	*Globoconella pliozea?*
317.90	317.92	34/4/110-112	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.25	0.00	0.00	0.00	0.00	17.33	0.00	0.00	0.00	0.00
318.35	318.37	34/5/5-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02	1.02	0.00	0.00	0.00	0.00	14.11	0.00	0.00	0.00	0.00
318.60	318.62	34/5/30-32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.61	0.00	0.00	0.00	0.00	6.44	0.00	0.00	0.00	0.00
321.91	321.93	35/1/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.32	0.00	0.00	0.00	0.00	10.47	0.00	0.00	0.00	0.00
322.33	322.35	35/1/43-45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	6.76	0.00	0.00	0.00	0.00
322.72	322.74	35/1/82-84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	11.60	0.00	0.00	0.00	0.00
323.09	323.11	35/1/119-121	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.19	0.00	0.00	0.00	0.00	11.41	0.00	0.00	0.00	0.00
323.48	323.50	35/2/8-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.27	0.00	0.00	0.00	0.00	11.59	0.00	0.00	0.00	0.00
323.91	323.93	35/2/51-53	0.00	0.00	0.00	0.11	0.00	0.11	0.00	0.00	0.11	0.11	0.00	0.00	0.00	0.00	10.76	0.00	0.00	0.00	0.00
324.50	324.52	35/2/110-112	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.90	0.00	0.00	0.00	0.00
324.91	324.93	35/3/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.29	0.00	0.00	0.29	0.00	12.09	0.00	0.00	0.00	0.00
325.33	325.35	35/3/43-45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.16	0.00	0.00	0.00	0.00	12.07	0.00	0.00	0.00	0.00
325.71	325.73	35/3/81-83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40	0.00	0.00	0.00	0.00	6.57	0.00	0.00	0.00	0.00
325.94	325.96	35/3/104-106	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.96	0.00	0.00	0.00	0.00
326.28	326.30	35/3/138-140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.23	0.00	0.00	0.00	0.00	13.82	0.00	0.00	0.00	0.00
326.70	326.72	35/4/30-32	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.18	0.36	0.00	0.00	0.00	0.00	12.14	0.00	0.00	0.00	0.00
327.09	327.11	35/4/69-71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.16	1.16	0.00	0.00	0.00	0.00	17.37	0.00	0.00	0.00	0.00
327.50	327.52	35/4/110-112	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.15	0.00	0.00	0.00	0.00	5.71	0.00	0.00	0.00	0.00
327.91	327.93	35/5/1-3	0.00	0.00	0.00	0.17	0.00	0.17	0.00	0.00	0.17	0.17	0.00	0.00	0.00	0.00	6.90	0.00	0.00	0.00	0.00
328.27	328.29	35/5/37-39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.42	0.00	0.00	0.00	0.00	4.35	0.00	0.00	0.00	0.00
328.72	328.74	35/5/82-84	0.00	0.00	0.00	0.11	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.71	0.00	0.00	0.00	0.00
331.69	331.71	36/1/19-21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.29	0.00	0.00	0.00	0.00	5.15	0.00	0.00	0.00	0.00
332.11	332.13	36/1/61-63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.57	0.00	0.00	0.00	0.00	11.95	0.00	0.00	0.00	0.00
332.68	332.70	36/1/118-120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.43	0.00	0.00	0.22	0.00	12.69	0.00	0.00	0.00	0.00
332.98	333.00	36/1/148-150	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.44	0.00	0.00	0.00	0.00	13.66	0.00	0.00	0.00	0.00
333.40	333.42	36/2/40-42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.89	0.00	0.00	0.00	0.00	5.51	0.00	0.00	0.00	0.00
334.00	334.02	36/2/100-102	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.20	0.00	0.00	0.00	0.00	9.00	0.00	0.00	0.00	0.00
334.36	334.38	36/2/136-138	0.00	0.00	0.23	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.45	0.00	0.00	0.00	0.00
334.87	334.89	36/3/37-39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.80	0.00	0.00	0.00	0.00	3.05	0.00	0.00	0.00	0.00
335.47	335.49	36/3/97-99	0.00	2.37	0.00	0.36	0.00	2.73	0.00	0.00	0.36	0.36	0.00	0.00	0.18	0.00	2.55	0.00	0.00	0.00	0.00
335.88	335.90	36/3/138-140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.00	0.00	0.00	0.00	1.69	0.00	0.00	0.00	0.00
336.20	336.22	36/4/20-22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.49	0.00	0.00	0.00	0.00
336.60	336.62	36/4/60-62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.45	0.00	0.00	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Globoconella puncticulata* s.l.	*Globoconella puncticulata* s.s.	*Globoconella sphericomiozea* s.l.	*Globoconella sphericomiozea* s.s.	**Globoconella**	*Globoquadrina dehiscens*	*Globoquadrina* sp.?	*Globoquadrina venezuelana*?	**Globoquadrina**	*Globorotalia* cf. *lenguaensis*	**Globorotalia**	*Globorotaloides hexagonus*	**Globorotaloides**	*Hirsutella* cf. *ichinosekiensis*	*Hirsutella margaritae*	*Hirsutella scitula*	*Hirsutella panda*	*Hirsutella* sp.	**Hirsutella**
120.30	120.33	14/1/0-3	0.00	25.38	0.00	0.00	29.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.00	0.00	1.02
120.51	120.54	14/1/21-24	0.00	22.90	0.20	0.00	25.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00	0.00	0.41
120.69	120.72	14/1/39-42	0.00	14.74	0.00	0.00	20.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.00	0.00	0.68
120.90	120.93	14/1/60-63	0.00	7.34	0.00	0.00	16.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30	0.00	0.00	1.30
121.11	121.14	14/1/81-84	0.00	9.05	0.00	0.00	19.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.23
121.26	121.29	14/1/96-99	0.00	8.15	0.00	0.00	18.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.86	0.00	0.00	1.07
121.49	121.52	14/1/119-122	0.00	13.87	0.00	0.00	20.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.29
121.69	121.72	14/1/139-142	0.00	17.66	0.00	0.00	21.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.37
121.90	121.93	14/2/10-13	0.00	24.09	0.00	0.00	30.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.40
122.09	122.12	14/2/29-32	0.00	30.43	0.00	0.00	32.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.22	0.89
122.26	122.29	14/2/46-49	0.00	33.80	0.00	0.00	37.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.46	0.00	0.00	0.69
122.51	122.55	14/2/71-75	0.00	19.86	0.00	0.00	22.90	0.00	0.23	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.93	0.00	0.00	0.93
122.71	122.74	14/2/91-94	0.00	21.02	0.00	0.00	23.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.00	0.00	0.99
122.92	122.95	14/2/112-115	0.00	23.65	0.00	0.00	25.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.18
123.10	123.13	14/2/130-133	17.39	0.00	0.00	0.32	22.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.32
123.30	123.33	14/3/0-3	19.33	0.00	0.00	0.00	21.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.89	0.00	0.00	0.89
123.53	123.56	14/3/23-26	17.04	0.00	0.00	0.00	18.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.16	0.00	0.00	0.48
123.69	123.72	14/3/39-42	15.45	0.00	0.00	0.00	17.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.22	0.00	0.00	1.22
123.88	123.91	14/3/58-61	17.36	0.00	0.00	0.00	20.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00	0.73
124.11	124.14	14/3/81-84	14.60	0.00	0.00	0.00	19.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.78	0.00	0.00	1.78
124.30	124.33	14/3/100-103	21.79	0.00	0.00	0.75	27.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.45
124.50	124.53	14/3/120-123	23.75	0.00	0.00	0.00	27.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.44
124.68	124.71	14/3/138-141	20.63	0.00	0.00	0.00	24.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63	0.00	0.00	0.63
124.90	124.93	14/4/10-13	17.24	0.00	0.00	0.00	22.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30	0.00	0.00	1.30
125.10	125.13	14/4/30-33	20.49	0.00	0.00	0.52	24.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.17
125.30	125.33	14/4/50-53	10.50	0.00	0.00	0.30	17.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.15
125.48	125.51	14/4/68-71	9.60	0.00	0.00	0.30	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.00	0.00	0.61
125.71	125.74	14/4/91-94	11.37	0.00	0.00	0.71	13.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.00	0.71
125.91	125.94	14/4/111-114	12.88	0.00	0.00	0.22	14.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.01	0.00	0.00	1.01
126.10	126.13	14/4/130-133	14.79	0.00	0.00	0.22	17.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.88	0.00	0.00	0.88
126.30	126.33	14/5/0-3	16.28	0.00	0.00	1.29	19.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.78	0.00	0.00	0.78
126.56	126.59	14/5/26-29	15.59	0.00	0.00	1.56	17.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.39
126.70	126.73	14/5/40-43	16.71	0.00	0.00	1.83	20.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.09	0.00	0.00	2.09
126.90	126.93	14/5/60-63	11.97	0.00	0.00	0.74	14.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.55
127.12	127.15	14/5/82-85	15.20	0.00	0.00	0.94	17.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.78	0.00	0.00	0.78
127.30	127.33	14/5/100-103	14.62	0.00	0.00	2.71	18.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.36
127.51	127.54	14/5/121-124	11.99	0.00	0.00	1.55	13.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.19
127.70	127.73	14/5/140-143	9.55	0.00	0.00	3.07	14.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.32
127.90	127.93	14/6/10-13	5.54	0.00	0.00	1.05	9.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.45
128.29	128.32	14/6/49-52	9.43	0.00	0.00	2.31	12.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.00	0.71
128.72	128.75	14/6/92-95	16.28	0.00	0.00	3.55	20.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
129.10	129.13	14/6/130-133	15.14	0.00	0.00	2.67	20.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.78	0.00	0.00	1.78
129.50	129.53	14/7/20-23	15.32	0.00	0.00	3.01	21.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.00	0.00	0.68
129.90	129.93	15/1/0-3	10.31	0.00	0.00	2.84	15.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.03	0.00	0.00	1.03
130.29	130.32	15/1/39-42	5.34	0.00	0.00	5.52	12.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.18
130.69	130.72	15/1/79-82	5.94	0.00	0.00	4.22	11.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.00	0.47
131.10	131.13	15/1/120-123	4.26	0.00	0.00	3.73	8.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.00	0.71
131.51	131.54	15/2/11-14	3.77	0.00	0.00	3.77	8.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.51
131.91	131.93	15/2/51-53	10.33	0.00	0.00	4.43	17.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.16
132.33	132.36	15/2/93-96	3.66	0.00	0.00	2.44	6.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.70
132.74	132.76	15/2/134-136	6.14	0.00	0.00	5.00	12.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.45
133.07	133.10	15/3/17-20	9.09	0.00	0.00	5.22	17.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.39
133.46	133.49	15/3/56-59	10.92	0.00	0.00	5.33	17.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.13
133.89	133.92	15/3/99-102	9.67	0.00	0.00	7.82	17.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.62	0.00	0.00	0.62
134.30	134.33	15/3/140-143	11.36	0.00	0.00	8.26	19.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.52
134.70	134.73	15/4/30-33	4.35	0.00	0.00	5.98	14.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
135.10	135.13	15/4/70-73	13.61	0.00	0.00	11.79	34.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
135.30	135.33	15/4/90-93	12.94	0.00	0.00	14.86	34.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.35
135.50	135.53	15/4/110-113	14.99	0.00	0.00	19.24	36.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.22
135.70	135.73	15/4/130-133	12.99	0.00	0.00	9.25	25.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.32	0.00	0.00	0.49
135.90	135.93	15/5/0-3	7.61	0.00	0.00	11.59	25.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.35
136.06	136.09	15/5/16-19	8.91	0.00	0.00	9.57	22.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.22
136.32	136.35	15/5/42-45	4.28	0.00	0.00	12.10	24.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
136.51	136.53	15/5/61-63	4.77	0.00	0.00	9.40	20.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.42
136.92	136.95	15/5/102-105	7.24	0.00	0.00	18.79	29.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.39
137.13	137.16	15/5/123-126	7.63	0.00	0.00	14.60	26.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.96	0.00	0.00	1.96
137.52	137.55	15/6/12-15	5.12	0.00	0.00	18.09	30.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.85
137.91	137.94	15/6/51-54	5.07	0.00	0.00	11.07	22.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.38
138.27	138.30	15/6/87-90	4.51	0.00	0.00	13.11	23.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.20
138.66	138.69	15/6/126-129	3.51	0.00	0.00	13.18	23.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.00	0.00	0.53
139.07	139.10	15/7/17-20	0.93	0.00	0.00	11.34	19.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.93	0.00	0.00	0.93
139.50	139.53	16/1/0-3	1.67	0.00	0.00	13.57	22.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.43	0.00	0.00	1.43
139.93	139.96	16/1/43-46	1.24	0.00	0.00	16.17	24.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.00	0.47
140.34	140.37	16/1/84-87	2.84	0.00	0.00	23.36	32.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	0.22
140.73	140.76	16/1/123-126	2.41	0.00	0.00	11.03	19.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.69
141.13	141.15	16/2/13-16	3.76	0.00	0.00	19.44	30.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.94	0.00	0.00	0.94
141.54	141.57	16/2/54-57	1.03	0.00	0.00	27.16	39.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.23	0.00	0.00	1.23

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Globoconella puncticulata* s.l.	*Globoconella puncticulata* s.s.	*Globoconella sphericomiozea* s.l.	*Globoconella sphericomiozea* s.s.	***Globoconella***	*Globoquadrina dehiscens*	*Globoquadrina* sp.?	*Globoquadrina venezuelana*?	***Globoquadrina***	*Globorotalia* cf. *lenguaensis*	***Globorotalia***	*Globorotaloides hexagonus*	***Globorotaloides***	*Hirsutella* cf. *ichinosekiensis*	*Hirsutella margaritae*	*Hirsutella scitula*	*Hirsutella panda*	*Hirsutella* sp.	***Hirsutella***
141.92	141.95	16/2/92-95	4.47	0.00	0.00	26.52	38.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.24	0.00	0.00	2.24
142.32	142.35	16/2/132-135	2.02	0.00	0.00	21.98	31.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.81	0.00	0.00	1.81
142.75	142.78	16/3/25-28	1.48	0.00	0.00	13.91	22.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.56
143.15	143.18	16/3/65-68	2.03	0.00	0.00	11.00	17.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.85
143.53	143.56	16/3/103-106	0.68	0.00	0.00	14.11	22.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	1.10	0.00	0.00	1.37
143.84	143.87	16/3/134-137	0.18	0.00	0.00	0.00	17.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.36
144.26	144.29	16/4/26-29	0.00	0.00	0.00	0.00	22.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.39
144.67	144.70	16/4/67-70	0.00	0.00	0.00	0.00	32.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.33	0.00	0.36	4.69
145.13	145.16	16/4/113-116	0.17	0.00	0.00	0.00	18.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.34	0.00	0.00	1.34
145.50	145.53	16/5/0-3	0.00	0.00	0.00	0.00	23.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.13	0.00	0.00	3.13
145.93	145.96	16/5/43-46	0.00	0.00	0.00	0.00	27.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.34	0.00	0.00	2.34
146.36	146.38	16/5/86-88	0.00	0.00	0.00	0.00	21.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50	0.00	0.00	2.50
146.71	146.74	16/5/121-124	0.00	0.00	0.00	0.00	13.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.17	0.00	0.00	2.17
147.06	147.09	16/6/6-9	0.00	0.00	0.00	0.00	23.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.60	0.00	0.00	4.60
147.47	147.50	16/6/47-50	0.00	0.00	0.00	0.00	25.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.55	0.00	0.00	2.55
147.93	147.96	16/6/93-96	0.00	0.00	0.00	0.00	18.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.25	0.00	0.00	3.25
148.33	148.36	16/6/133-136	0.00	0.00	0.00	0.00	10.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.17	0.00	0.00	2.17
148.67	148.69	16/7/17-19	0.00	0.00	0.00	0.00	12.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.20	0.00	0.00	2.20
149.10	149.13	17/1/0-3	0.00	0.00	0.00	0.00	23.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.84	0.00	0.00	1.84
149.52	149.55	17/1/42-45	0.00	0.00	0.00	0.00	21.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.02	0.00	0.00	2.02
150.11	150.14	17/1/101-104	0.00	0.00	0.00	0.00	21.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.06	0.00	0.00	1.06
150.51	150.54	17/1/141-144	0.00	0.00	0.00	0.00	20.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.74	0.00	0.00	1.74
150.87	150.90	17/2/27-30	0.00	0.00	0.00	0.00	23.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.32	0.00	0.00	2.32
151.07	151.10	17/2/47-50	0.19	0.00	0.00	0.00	19.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.52	0.00	0.00	1.52
151.52	151.55	17/2/92-95	0.00	0.00	0.00	0.00	17.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.94	0.00	0.00	1.94
151.96	151.98	17/2/136-138	0.22	0.00	0.00	0.00	22.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.29	0.00	0.00	1.29
152.10	152.13	17/3/0-3	0.16	0.00	0.00	0.00	19.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.44	0.00	0.00	1.44
152.25	152.28	17/3/15-18	0.34	0.00	0.00	0.00	19.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.69	0.00	0.00	1.69
152.47	152.50	17/3/37-40	0.22	0.00	0.00	0.00	17.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.52	0.00	0.00	1.52
152.75	152.77	17/3/65-67	0.00	0.00	0.00	0.00	22.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.94	0.00	0.00	1.94
152.91	152.94	17/3/81-84	0.20	0.00	0.00	0.00	23.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.61	0.00	0.00	2.61
153.12	153.15	17/3/102-105	0.40	0.00	0.00	0.00	24.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60	0.00	0.00	1.60
153.26	153.29	17/3/116-119	0.31	0.00	0.00	0.00	22.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.56	0.00	0.00	1.56
153.45	153.48	17/3/135-138	0.30	0.00	0.00	0.00	20.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.08	0.00	0.00	2.08
153.66	153.69	17/4/6-9	0.00	0.00	0.00	0.00	17.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.96	0.00	0.00	0.96
153.97	153.99	17/4/37-39	0.16	0.00	0.00	0.00	16.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.11	0.00	0.00	1.11
154.13	154.16	17/4/53-56	0.00	0.00	0.00	0.00	18.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.00	0.95
154.32	154.35	17/4/72-75	0.00	0.00	0.00	0.00	18.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.88	0.00	0.00	1.88
154.54	154.57	17/4/94-97	0.23	0.00	0.00	0.00	14.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	1.82	0.00	0.00	1.93
154.77	154.79	17/4/117-119	0.16	0.00	0.00	0.00	18.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.63	0.00	0.00	1.63
154.95	154.98	17/4/135-138	0.27	0.00	0.00	0.00	17.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.13	0.00	0.00	2.13
155.10	155.13	17/5/0-3	0.00	0.00	0.00	0.00	15.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.29	0.00	0.00	2.29
155.24	155.27	17/5/14-17	0.00	0.00	0.00	0.00	14.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.70
155.48	155.50	17/5/38-40	0.00	0.00	0.00	0.00	21.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.09	0.00	0.00	1.09
155.67	155.70	17/5/57-60	0.00	0.00	0.00	0.00	24.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.42	0.00	0.00	2.42
155.94	155.97	17/5/84-87	0.13	0.00	0.00	0.00	15.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.08	0.00	0.00	3.08
156.13	156.16	17/5/103-106	0.00	0.00	0.00	0.00	20.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.26	0.00	0.00	3.26
156.27	156.30	17/5/117-120	0.00	0.00	0.00	0.00	18.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.56	0.00	0.00	1.56
156.47	156.50	17/5/137-140	0.00	0.00	0.00	0.00	20.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.13	0.00	0.00	2.13
156.71	156.74	17/6/11-14	0.00	0.00	0.00	0.00	21.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.62	0.00	0.00	1.62
156.95	156.98	17/6/35-38	0.00	0.00	0.00	0.00	14.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.06	0.00	0.00	4.06
157.12	157.15	17/6/52-55	0.00	0.00	0.00	0.00	15.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.14	0.00	0.00	2.14
157.37	157.39	17/6/77-79	0.61	0.00	0.00	0.00	23.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.02	0.00	0.00	2.02
157.52	157.55	17/6/92-95	0.00	0.00	0.00	0.00	29.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.62	0.00	0.00	0.62
157.76	157.79	17/6/116-119	0.00	0.00	0.00	0.00	18.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.22	0.00	0.00	1.22
157.93	157.96	17/6/133-136	0.00	0.00	0.00	0.00	9.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.66	0.00	0.00	1.66
158.10	158.13	17/7/0-3	0.00	0.00	0.00	0.00	11.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.31	0.00	0.00	2.31
158.27	158.30	17/7/17-20	0.00	0.00	0.00	0.00	18.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.63	0.00	0.00	1.63
158.52	158.55	17CC/6-9	0.00	0.00	0.00	0.00	17.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.26	0.00	0.00	1.26
158.70	158.73	18/1/0-3	0.00	0.00	0.00	0.00	15.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.01	0.00	0.00	2.01
158.95	158.98	18/1/25-28	0.00	0.00	0.00	0.00	25.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.10	0.00	0.00	2.10
159.13	159.16	18/1/43-46	0.00	0.00	0.00	0.00	22.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.75	0.00	0.00	2.75
159.35	159.38	18/1/65-68	0.00	0.00	0.00	0.00	21.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.79	0.00	0.00	1.79
159.49	159.52	18/1/79-82	0.00	0.00	0.00	0.00	21.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.04	0.00	0.00	2.04
159.72	159.75	18/1/102-105	0.00	0.00	0.00	0.00	17.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.64	0.00	0.00	2.64
159.86	159.89	18/1/116-119	0.00	0.00	0.00	0.00	21.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.41	0.00	0.00	7.41
160.11	160.14	18/1/141-144	0.00	0.00	0.00	0.00	21.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.20	0.00	0.00	10.20
160.33	160.36	18/2/13-16	0.00	0.00	0.00	0.00	12.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.42	0.00	0.00	3.42
160.73	160.76	18/2/53-56	0.00	0.00	0.00	0.00	16.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.97	0.00	0.00	5.97
161.16	161.19	18/2/96-99	0.00	0.00	0.00	0.00	21.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.63	0.00	0.00	5.63
161.53	161.56	18/2/133-136	0.00	0.00	0.00	0.00	16.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.93	0.00	0.00	2.93
161.84	161.87	18/3/14-17	0.00	0.00	0.00	0.00	20.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.04	0.00	0.00	7.04
162.26	162.29	18/3/56-59	0.00	0.00	0.00	0.00	20.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.81	0.00	0.00	4.81
162.87	162.90	18/3/117-120	0.00	0.00	0.00	0.00	28.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.43	0.00	0.00	4.43
163.33	163.36	18/4/13-16	0.00	0.00	0.00	0.00	25.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.26	0.00	0.00	4.26
163.56	163.59	18/4/36-39	0.00	0.00	0.00	0.00	18.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.83	0.00	0.00	5.83
163.93	163.96	18/4/73-76	0.00	0.00	0.00	0.00	24.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	8.62	0.00	0.00	8.86

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Globoconella puncticulata* s.l.	*Globoconella puncticulata* s.s.	*Globoconella sphericomiozea* s.l.	*Globoconella sphericomiozea* s.s.	***Globoconella***	*Globoquadrina dehiscens*	*Globoquadrina* sp.?	*Globoquadrina venezuelana*?	***Globoquadrina***	*Globorotalia* cf. *lenguaensis*	***Globorotalia***	*Globorotaloides hexagonus*	***Globorotaloides***	*Hirsutella* cf. *ichinosekiensis*	*Hirsutella margaritae*	*Hirsutella scitula*	*Hirsutella panda*	*Hirsutella* sp.	***Hirsutella***
164.31	164.33	18/4/111-113	0.00	0.00	0.00	0.00	30.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.02	0.00	0.00	7.02
164.70	164.73	18/5/0-3	0.00	0.00	0.00	0.00	26.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.78	0.00	0.00	3.78
165.13	165.16	18/5/43-46	0.00	0.00	0.00	0.00	16.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.21	0.00	0.00	8.21
165.50	165.53	18/5/80-83	0.00	0.00	0.00	0.00	21.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.14	0.00	0.00	5.14
165.95	165.97	18/5/125-127	0.00	0.00	0.00	0.00	18.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.61	0.00	0.00	11.61
166.26	166.29	18/6/6-9	0.00	0.00	0.00	0.00	17.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.90	0.00	0.00	3.90
166.66	166.69	18/6/46-49	0.00	0.00	0.00	0.00	17.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.72	0.00	0.00	7.72
167.06	167.09	18/6/86-89	0.00	0.00	0.00	0.00	13.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.19	0.00	0.00	8.19
167.44	167.47	18/6/124-127	0.00	0.00	0.00	0.00	15.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.99	0.00	0.00	7.99
168.30	168.33	19/1/0-3	0.00	0.00	0.00	0.00	17.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.45	0.00	0.00	8.45
168.71	168.74	19/1/41-44	0.00	0.00	0.00	0.00	16.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.76	0.00	0.00	4.76
169.13	169.15	19/1/83-85	0.00	0.00	0.00	0.00	13.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.43	0.00	0.00	5.43
169.51	169.54	19/1/121-124	0.00	0.00	0.00	0.00	11.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.16	0.00	0.00	7.16
169.85	169.88	19/2/5-8	0.00	0.00	0.00	0.00	15.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.48	0.00	0.00	7.48
170.32	170.35	19/2/52-55	0.00	0.00	0.00	0.00	23.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.31	0.00	0.00	7.31
170.73	170.76	19/2/93-96	0.00	0.00	0.00	0.00	18.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.89	0.00	0.00	7.89
171.15	171.18	19/2/135-138	0.00	0.00	0.00	0.00	24.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.19	0.00	0.00	7.19
171.57	171.59	19/3/27-29	0.00	0.00	0.00	0.00	15.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.23	0.00	0.00	10.23
171.92	171.94	19/3/62-64	0.00	0.00	0.00	0.00	21.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.40	0.00	0.00	5.40
172.32	172.35	19/3/102-105	0.00	0.00	0.00	0.00	17.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.64	0.00	0.00	4.64
172.66	172.68	19/3/136-138	0.00	0.00	0.00	0.00	24.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.12	0.00	0.00	6.12
173.07	173.09	19/4/27-29	0.00	0.00	0.00	0.00	20.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.16	0.00	0.00	4.16
173.52	173.54	19/4/72-74	0.00	0.00	0.00	0.00	31.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.05	0.00	0.00	4.05
173.93	173.95	19/4/113-115	0.00	0.00	0.00	0.00	26.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.30	0.00	0.00	7.30
174.30	174.33	19/5/0-3	0.00	0.00	0.00	0.00	27.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.94	0.00	0.00	5.94
174.72	174.75	19/5/42-45	0.00	0.00	0.00	0.00	26.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.55	0.00	0.00	3.55
175.26	175.28	19/5/96-99	0.00	0.00	0.00	0.00	20.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.63	0.00	0.00	7.63
175.71	175.74	19/5/141-144	0.00	0.00	0.00	0.00	20.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.40	0.00	0.00	8.40
176.06	176.09	19/6/26-29	0.00	0.00	0.00	0.00	20.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.55	0.00	0.00	2.55
176.47	176.49	19/6/67-69	0.00	0.00	0.00	0.00	10.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.48	0.00	0.00	2.48
176.92	176.94	19/6/112-114	0.00	0.00	0.00	0.00	18.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.14	0.00	0.00	2.14
177.30	177.33	19/7/0-3	0.00	0.00	0.00	0.00	19.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.88	0.00	0.00	2.88
177.52	177.55	19/7/22-25	0.00	0.00	0.00	0.00	11.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.89	0.00	0.00	3.89
177.90	177.93	20/1/0-3	0.00	0.00	0.00	0.00	22.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.00	0.46
178.27	178.30	20/1/37-40	0.00	0.00	0.00	0.00	19.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.78	0.00	0.00	2.78
178.68	178.70	20/1/78-80	0.00	0.00	0.00	0.00	34.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.05	0.00	0.00	1.05
179.08	179.10	20/1/118-120	0.00	0.00	0.00	0.00	26.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.83	0.00	0.00	0.83
179.45	179.47	20/2/5-7	0.00	0.00	0.00	0.00	24.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30	0.00	0.00	1.30
179.86	179.88	20/2/46-48	0.00	0.00	0.00	0.00	19.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.67	0.00	0.00	2.67
180.33	180.35	20/2/93-95	0.00	0.00	0.00	0.00	25.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.21	0.00	0.00	3.21
180.73	180.75	20/2/133-135	0.00	0.00	0.00	0.00	24.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.60	0.00	0.00	2.60
181.14	181.16	20/3/24-26	0.00	0.00	0.00	0.00	30.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.57
181.57	181.59	20/3/67-69	0.00	0.00	0.00	0.00	16.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.91	0.00	0.00	2.91
181.86	181.88	20/3/96-98	0.00	0.00	0.00	0.00	22.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.76	0.00	0.00	2.76
182.23	182.25	20/3/133-135	0.00	0.00	0.00	0.00	27.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.67	0.00	0.00	1.67
182.68	182.70	20/4/28-30	0.00	0.00	0.00	0.00	22.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.51	0.00	0.00	3.51
183.08	183.10	20/4/68-70	0.00	0.00	0.00	0.00	25.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.44	0.00	0.00	2.44
183.45	183.47	20/4/105-107	0.00	0.00	0.00	0.00	20.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.55	0.00	0.00	1.55
183.91	183.93	20/5/1-3	0.00	0.00	0.00	0.00	18.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.20	0.00	0.00	3.20
184.32	184.34	20/5/42-44	0.00	0.00	0.00	0.00	12.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.06	0.00	0.00	6.06
184.72	184.74	20/5/82-84	0.00	0.00	0.00	0.00	21.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00	5.00
185.07	185.09	20/5/117-119	0.00	0.00	0.00	0.00	21.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.31	0.00	0.00	7.31
185.47	185.49	20/6/7-9	0.00	0.00	0.00	0.00	19.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.78	0.00	0.00	2.78
185.92	185.94	20/6/52-54	0.00	0.00	0.00	0.00	14.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.88	0.00	0.00	11.88
186.32	186.34	20/6/92-94	0.00	0.00	0.00	0.00	15.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.26	0.00	0.00	8.26
186.72	186.74	20/6/132-134	0.00	0.00	0.00	0.00	15.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.18	0.00	0.00	9.18
187.07	187.09	20/7/17-19	0.00	0.00	0.00	0.00	10.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.63	0.00	0.00	5.63
187.51	187.53	21/1/1-3	0.00	0.00	0.00	0.00	9.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.54	0.00	0.00	1.54
187.93	187.95	21/1/43-45	0.00	0.00	0.00	0.00	4.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.88	0.00	0.00	7.88
188.32	188.34	21/182-84	0.00	0.00	0.00	0.00	11.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.15	0.00	0.00	6.15
188.67	188.69	21/1/117-119	0.00	0.00	0.00	0.00	11.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.16	0.00	0.00	6.16
189.08	189.10	21/2/8-10	0.00	0.00	0.00	0.00	12.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.99	0.00	0.00	8.99
189.46	189.48	21/2/46-48	0.00	0.00	0.00	0.00	14.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.48	0.00	0.00	2.48
189.93	189.96	21/2/93-96	0.00	0.00	0.00	0.00	10.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.34	0.00	0.00	2.34
190.42	190.44	21/2/142-144	0.00	0.00	0.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.78	0.00	0.00	6.78
190.66	190.68	21/3/16-18	0.00	0.00	0.00	0.00	12.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.49	0.00	0.00	7.49
191.12	191.14	21/3/62-64	0.00	0.00	0.00	0.00	9.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.85	0.00	0.00	3.85
191.52	191.54	21/3/102-104	0.00	0.00	0.00	0.00	12.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.81	0.00	0.00	1.81
191.86	191.89	21/3/136-139	0.00	0.00	0.00	0.00	17.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.35	0.00	0.00	6.35
192.36	192.38	21/4/36-38	0.00	0.00	0.00	0.00	7.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.95	0.00	0.00	7.95
192.73	192.75	21/4/73-75	0.00	0.00	0.00	0.00	9.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.76	0.00	0.00	13.76
193.12	193.14	21/4/112-114	0.00	0.00	0.00	0.00	11.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.29	0.00	0.00	3.29
193.50	193.52	21/5/0-2	0.00	0.00	0.00	0.00	15.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.63	0.00	0.00	2.63
193.92	193.94	21/5/42-44	0.00	0.00	0.00	0.00	13.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.33	0.00	0.00	3.33
194.34	194.26	21/5/84-86	0.00	0.00	0.00	0.00	14.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.22	0.00	0.00	2.22
194.72	194.74	21/5/122-124	0.00	0.00	0.00	0.00	10.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.34	0.00	0.00	4.34
195.07	195.09	21/6/7-9	0.00	0.00	0.00	0.00	5.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.85	0.00	0.00	4.85

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Globoconella puncticulata* s.l.	*Globoconella puncticulata* s.s.	*Globoconella spheriomiozea* s.l.	*Globoconella spheriomiozea* s.s.	***Globoconella***	*Globoquadrina dehiscens*	*Globoquadrina* sp.?	*Globoquadrina venezuelana?*	***Globoquadrina***	*Globorotalia* cf. *lenguaensis*	***Globorotalia***	*Globorotaloides hexagonus*	***Globorotaloides***	*Hirsutella* cf. *ichinosekiensis*	*Hirsutella margaritae*	*Hirsutella scitula*	*Hirsutella panda*	*Hirsutella* sp.	***Hirsutella***
195.49	195.51	21/6/49-51	0.00	0.00	0.00	0.00	11.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.91	0.00	0.00	3.91
195.87	195.89	21/6/87-89	0.00	0.00	0.00	0.00	7.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.20	0.00	0.00	2.20
196.34	196.36	21/6/134-136	0.00	0.00	0.00	0.00	16.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.91	0.00	0.00	3.91
196.72	196.74	21/7/22-24	0.00	0.00	0.00	0.00	7.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.26	0.00	0.00	1.26
197.11	197.13	22/1/1-3	0.00	0.00	0.00	0.00	16.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.29	0.00	0.00	5.29
197.48	197.50	22/1/38-40	0.00	0.00	0.00	0.00	4.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.82	0.00	0.00	2.82
197.94	197.96	22/1/84-86	0.00	0.00	0.00	0.00	8.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.41	0.00	0.00	3.41
198.32	198.34	22/1/122-124	0.00	0.00	0.00	0.00	11.85	0.00	0.00	0.13	0.13	0.00	0.00	0.00	0.00	0.00	0.00	7.31	0.00	0.00	7.31
198.73	198.75	22/2/13-15	0.00	0.00	0.00	0.00	16.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.64	0.00	0.00	3.64
199.14	199.16	22/2/54-56	0.00	0.00	0.00	0.00	10.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.42	0.00	0.00	2.42
199.53	199.55	22/2/93-95	0.00	0.00	0.00	0.00	9.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.55	0.00	0.00	8.55
199.93	199.95	22/2/133-135	0.00	0.00	0.00	0.00	2.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.96	0.00	0.00	2.96
200.25	200.27	22/3/15-17	0.00	0.00	0.00	0.00	7.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.35	0.00	0.00	4.35
200.66	200.68	22/3/56-58	0.00	0.00	0.00	0.00	16.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.45	0.00	0.00	2.45
201.05	201.07	22/3/95-97	0.00	0.00	0.00	0.00	8.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.68	0.00	0.00	5.68
201.42	201.44	22/3/132-134	0.00	0.00	0.00	0.00	16.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.81	0.00	0.00	3.81
201.93	201.95	22/4/33-35	0.00	0.00	0.00	0.00	10.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.65	0.00	0.00	3.65
202.52	202.55	22/4/92-95	0.00	0.00	0.00	0.00	7.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.08	0.00	0.00	8.08
202.93	202.95	22/4/133-135	0.00	0.00	0.00	0.00	12.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.35	0.00	0.00	6.35
203.17	203.20	22CC/7-10	0.00	0.00	0.00	0.00	6.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.53	0.00	0.00	3.53
206.71	206.73	23/1/1-3	0.00	0.00	0.00	0.00	6.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.58	0.00	0.00	4.58
207.13	207.15	23/1/43-45	0.00	0.00	0.00	0.00	8.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.68	0.00	0.00	3.68
207.48	207.50	23/1/78-80	0.00	0.00	0.00	0.00	12.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.64	0.00	0.00	2.64
207.88	207.90	23/1/118-120	0.00	0.00	0.00	0.00	7.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.21	0.00	0.00	7.21
208.26	208.28	23/2/6-8	0.00	0.00	0.00	0.00	6.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.74	0.00	0.00	3.74
208.52	208.54	23/2/32-34	0.00	0.00	0.00	0.00	6.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.40	0.00	0.00	3.40
209.06	209.08	23/2/86-88	0.00	0.00	0.00	0.00	8.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.23	0.00	0.00	6.23
209.54	209.56	23/2/134-136	0.00	0.00	0.00	0.00	6.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.15	0.00	0.00	4.15
209.85	209.87	23/3/15-17	0.00	0.00	0.00	0.00	9.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.22	0.00	0.00	4.22
210.33	210.35	23/3/63-65	0.00	0.00	0.00	0.00	7.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.01	0.00	0.00	9.01
210.53	210.55	23/3/83-85	0.00	0.00	0.00	0.00	7.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.48	0.00	0.00	7.48
210.87	210.89	23/3/117-119	0.00	0.00	0.00	0.00	9.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.18	0.00	0.00	4.18
211.27	211.29	23/4/7-9	0.00	0.00	0.00	0.00	13.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.72	0.00	0.00	5.72
211.72	211.74	23/4/52-54	0.00	0.00	0.00	0.00	7.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.46	0.00	0.00	3.46
212.13	212.15	23/4/93-95	0.00	0.00	0.00	0.00	10.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.37	0.00	0.00	2.37
212.32	212.34	23/4/112-114	0.00	0.00	0.00	0.00	12.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.51	0.00	0.00	2.51
212.71	212.73	23/5/1-3	0.00	0.00	0.00	0.00	11.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.04	0.00	0.00	1.04
213.12	213.14	23/5/42-44	0.00	0.00	0.00	0.00	5.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.87	0.00	0.00	2.87
213.72	213.74	23/5/102-104	0.00	0.00	0.00	0.00	10.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.65	0.00	0.00	1.65
214.12	214.14	23/5/142-144	0.00	0.00	0.00	0.00	5.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.02	0.00	0.00	2.02
214.51	214.53	23/6/31-33	0.00	0.00	0.00	0.00	11.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.23	0.00	0.00	2.23
215.05	215.07	23/6/85-87	0.00	0.00	0.00	0.00	20.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.93	0.00	0.00	1.93
215.53	215.55	23/6/133-135	0.00	0.00	0.00	0.00	15.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.85	0.00	0.00	1.85
215.93	215.95	23/7/23-25	0.00	0.00	0.00	0.00	11.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.77	0.00	0.00	3.77
216.31	216.33	24/1/1-3	0.00	0.00	0.00	0.00	11.83	0.00	0.18	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	4.84	0.00	0.00	4.84
216.57	216.59	24/1/27-29	0.00	0.00	0.00	0.00	12.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.52	0.00	0.00	3.52
216.94	216.96	24/1/64-66	0.00	0.00	0.00	0.00	16.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.11	0.00	0.00	6.11
217.34	217.36	24/1/104-106	0.00	0.00	0.00	0.00	15.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.78	0.00	0.00	3.78
217.72	217.74	24/1/142-144	0.00	0.00	0.00	0.00	17.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.15	0.00	0.00	5.15
218.08	218.10	24/2/28-30	0.00	0.00	0.00	0.00	16.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.20	0.00	0.00	4.20
218.52	218.54	24/2/72-74	0.00	0.00	0.00	0.00	16.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.96	0.00	0.00	3.96
218.87	218.89	24/2/107-109	0.00	0.00	0.00	0.00	14.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.09	0.00	0.00	3.09
219.31	219.33	24/3/1-3	0.00	0.00	0.00	0.00	7.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.16	0.00	0.00	3.16
219.72	219.74	24/3/42-44	0.00	0.00	0.00	0.00	8.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.28	0.00	0.00	3.28
220.12	220.14	24/3/82-84	0.00	0.00	0.00	0.00	10.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.22	0.00	0.00	3.22
220.46	220.48	24/3/116-118	0.00	0.00	0.00	0.00	6.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.66	0.00	0.00	3.66
220.87	220.89	24/4/7-9	0.00	0.00	0.00	0.00	5.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.62	0.00	0.00	7.62
221.27	221.29	24/4/47-49	0.00	0.00	0.00	0.00	3.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.98	0.00	0.00	6.98
221.66	221.68	24/4/86-88	0.00	0.00	0.00	0.00	8.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.01	0.00	0.00	4.01
222.13	222.15	24/4/133-135	0.00	0.00	0.00	0.00	6.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.41	0.00	0.00	5.41
222.45	222.47	24/5/15-17	0.00	0.00	0.00	0.00	4.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.97	0.00	0.00	2.97
222.93	222.95	24/5/63-65	0.00	0.00	0.00	0.00	7.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.47	0.00	0.00	4.47
223.33	223.35	24/5/103-105	0.00	0.00	0.00	0.00	9.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.41	0.00	0.00	1.41
223.72	223.74	24/5/142-144	0.00	0.00	0.00	0.00	7.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.52	0.00	0.00	2.52
224.07	224.09	24/6/27-29	0.00	0.00	0.00	0.00	9.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.22	0.00	0.00	5.22
224.47	224.49	24/6/67-69	0.00	0.00	0.00	0.00	8.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.15	0.00	0.00	5.15
224.87	224.89	24/6/107-109	0.00	0.00	0.00	0.00	9.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.69	0.00	0.00	2.69
225.36	225.38	24CC/9-11	0.00	0.00	0.00	0.00	9.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.18	0.00	0.00	6.18
226.13	226.15	25/1/23-25	0.00	0.00	0.00	0.00	8.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.22	0.00	0.00	3.22
226.53	226.55	25/1/63-65	0.00	0.00	0.00	0.00	13.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.16	0.00	0.00	3.16
226.93	226.95	25/1/103-105	0.00	0.00	0.00	0.00	9.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.28	0.00	0.00	2.28
227.34	227.36	25/1/144-146	0.00	0.00	0.00	0.00	6.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.52	0.00	0.00	2.52
227.72	227.74	25/2/-32-34	0.00	0.00	0.00	0.00	10.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.63	0.00	0.00	2.63
228.12	228.14	25/2/72-74	0.00	0.00	0.00	0.00	7.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.98	0.00	0.00	1.98
228.52	228.54	25/2/112-114	0.00	0.00	0.00	0.00	5.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.84	0.00	0.00	1.84
228.90	228.92	25/3/0-2	0.00	0.00	0.00	0.00	6.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.16	0.00	0.00	1.16
229.33	229.35	25/3/43-45	0.00	0.00	0.00	0.00	7.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.83	0.00	0.00	2.83

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Globoconella puncticulata* s.l.	*Globoconella puncticulata* s.s.	*Globoconella sphericomiozea* s.l.	*Globoconella sphericomiozea* s.s.	***Globoconella***	*Globoquadrina dehiscens*	*Globoquadrina* sp.?	*Globoquadrina venezuelana*?	***Globoquadrina***	*Globorotalia* cf. *lenguaensis*	***Globorotalia***	*Globorotaloides hexagonus*	***Globorotaloides***	*Hirsutella* cf. *ichinosekiensis*	*Hirsutella margaritae*	*Hirsutella scitula*	*Hirsutella panda*	*Hirsutella* sp.	***Hirsutella***
229.85	229.87	25/3/95-97	0.00	0.00	0.00	0.00	8.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.06	0.00	0.00	2.06
230.27	230.29	25/3/137-139	0.00	0.00	0.00	0.00	6.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.06	0.00	0.00	6.06
230.47	230.49	25/4/7-9	0.00	0.00	0.00	0.00	5.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.49	0.00	0.09	9.57
230.93	230.95	25/4/53-55	0.00	0.00	0.00	0.00	3.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.43	0.00	0.00	11.43
231.33	231.35	25/4/93-95	0.00	0.00	0.00	0.00	3.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.13	0.00	0.00	12.13
231.73	231.75	25/4/133-135	0.00	0.00	0.00	0.00	4.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.42	0.00	0.00	8.42
232.06	232.08	25/5/16-18	0.00	0.00	0.00	0.00	3.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.75	0.00	0.00	7.75
232.52	232.54	25/5/62-64	0.00	0.00	0.00	0.00	8.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.03	0.00	0.11	9.14
232.92	232.94	25/5/102-104	0.00	0.00	0.00	0.00	9.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.11	0.00	0.00	3.11
233.27	233.29	25/5137-139	0.00	0.00	0.00	0.00	4.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.37	0.00	0.00	6.37
233.67	233.69	25/6/27-29	0.00	0.00	0.00	0.00	5.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.36	0.00	0.27	5.63
234.15	234.17	25/6/75-77	0.00	0.00	0.00	0.00	6.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.76	0.00	0.00	8.76
234.52	234.54	25/6/112-114	0.00	0.00	0.00	0.00	6.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.59	0.00	0.00	10.59
234.91	234.93	25/7/1-3	0.00	0.00	0.00	0.00	6.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.70	0.00	0.14	5.84
235.26	235.28	25CC/10-22	0.00	0.00	0.00	0.00	4.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.31	0.00	0.00	8.31
235.73	235.75	26/1/23-25	0.00	0.00	0.00	0.00	7.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.62	0.00	0.00	1.62
236.08	236.10	26/1/58-60	0.00	0.00	0.00	0.00	10.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.13	0.00	0.00	1.13
236.52	236.54	26/1/102-104	0.00	0.00	0.00	0.00	13.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.76	0.00	0.00	1.76
236.92	236.94	26/1/142-144	0.00	0.00	0.00	0.00	20.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.21	0.00	0.00	1.21
237.32	237.34	26/2/32-34	0.00	0.00	0.00	0.00	13.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.13	0.00	0.00	2.13
237.93	237.95	26/2/93-95	0.00	0.00	0.00	0.00	15.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.07	0.00	0.00	3.07
238.33	238.35	26/2/133-135	0.00	0.00	0.00	0.00	7.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.56
238.51	238.53	26/3/1-3	0.00	0.00	0.00	0.00	4.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.02	0.00	0.00	3.02
238.93	238.95	26/3/43-45	0.00	0.00	0.00	0.00	3.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.92	0.00	0.14	9.06
239.32	239.34	26/3/82-84	0.00	0.00	0.00	0.00	6.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	7.77	0.00	0.00	7.90
239.67	239.69	26/3/117-119	0.00	0.00	0.00	0.00	5.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.00	8.01	0.00	0.00	8.71
240.07	240.09	26/4/7-9	0.00	0.00	0.00	0.00	7.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.92	0.00	10.31	0.00	0.00	11.23
240.52	240.54	26/4/52-54	0.00	0.00	0.00	0.00	5.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.54	0.00	0.00	1.54
240.92	240.94	26/4/92-94	0.00	0.00	0.00	0.00	5.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.41	0.00	0.00	2.41
241.32	241.34	26/4/132-134	0.00	0.00	0.00	0.00	8.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.16	0.00	0.00	5.16
241.65	241.67	26/5/15-17	0.00	0.00	0.00	0.00	8.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.08	0.00	0.00	6.08
242.13	242.15	26/5/63-65	0.00	0.00	0.00	0.00	12.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.13	0.00	0.00	4.13
242.52	242.54	26/5/102-104	0.00	0.00	0.00	0.00	18.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.27	0.00	0.00	3.27
242.92	242.94	26/5/142-144	0.00	0.00	0.00	0.00	14.35	0.00	0.15	0.00	0.15	0.00	0.00	0.00	0.00	0.60	0.00	4.48	0.00	0.00	5.08
243.26	243.28	26/6/26-28	0.00	0.00	0.00	0.00	10.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.88	0.00	0.00	2.88
243.63	243.65	26/6/63-65	0.00	0.00	0.00	0.00	8.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.91	0.00	5.02	0.00	0.00	5.94
243.86	243.88	26CC/13-15	0.00	0.00	0.00	0.00	8.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.00	4.79	0.00	0.00	5.16
245.11	245.13	27/1/1-3	0.00	0.00	0.00	0.00	9.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.31	0.00	0.00	2.31
245.53	245.55	27/1/43-45	0.00	0.00	0.00	0.00	4.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.97	0.00	0.00	1.97
245.91	245.93	27/1/81-83	0.00	0.00	0.00	0.00	6.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.27	0.00	0.00	1.27
246.27	246.29	27/1/117-119	0.00	0.00	0.00	0.00	6.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.72	0.00	0.00	0.72
246.52	246.54	27/1/142-144	0.00	0.00	0.00	0.00	6.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.83	0.00	0.00	0.83
246.87	246.89	27/2/27-29	0.00	0.00	0.00	0.00	6.42	0.00	0.12	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	1.21	0.00	0.12	1.33
247.33	247.35	27/2/73-76	0.00	0.00	0.00	0.00	7.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.56
247.67	247.69	27/2/107-109	0.00	0.00	0.00	0.00	5.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.24
248.11	248.13	27/3/1-3	0.00	0.00	0.00	0.00	5.81	0.00	0.19	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	1.50	0.00	0.00	1.50
248.47	248.49	27/3/37-39	0.00	0.00	0.00	0.00	5.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.49	0.00	0.00	1.49
248.93	248.95	27/3/83-85	0.00	0.00	0.00	0.00	5.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.45	0.00	0.00	1.45
249.27	249.27	27/3/117-119	0.00	0.00	0.00	0.00	3.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.77	0.00	0.00	1.77
249.67	249.69	27/4/7-9	0.00	0.00	0.00	0.00	3.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.25	0.00	0.00	3.25
250.12	250.14	27/4/52-54	0.00	0.00	0.00	0.00	8.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	2.25	0.00	0.00	2.39
250.46	250.48	27/4/86-88	0.00	0.00	0.00	0.00	8.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.20
250.92	250.94	27/4/132-134	0.00	0.00	0.00	0.00	9.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.88	0.00	0.00	0.88
251.33	251.36	27/5/23-26	0.00	0.00	0.00	0.00	6.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.42	0.00	0.00	1.42
251.67	251.69	27/5/57-59	0.00	0.00	0.00	0.00	6.38	0.00	0.18	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	1.28	0.00	0.18	1.46
252.13	252.15	27/5/103-105	0.00	0.00	0.00	0.00	7.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.44
252.53	252.55	27/5/143-145	0.00	0.00	0.00	0.00	9.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.47	0.00	0.00	2.47
252.92	252.94	27/6/32-34	0.00	0.00	0.00	0.00	10.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	2.33	0.00	0.00	2.50
253.33	253.35	27/6/73-75	0.00	0.00	0.00	0.00	12.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.81	0.00	0.00	2.81
253.67	253.69	27/6/107-109	0.00	0.00	0.00	0.00	12.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.33	0.00	0.00	2.33
254.10	254.12	27/7/0-2	0.00	0.00	0.00	0.00	10.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.43	0.00	0.00	1.43
254.49	254.51	27CC/10-12	0.00	0.00	0.00	0.00	7.25	0.36	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.12	0.00	3.02	0.00	0.00	3.14
254.93	254.95	28/1/23-25	0.00	0.00	0.00	0.00	8.31	1.54	0.00	0.00	1.54	0.00	0.00	0.00	0.00	0.00	0.00	3.54	0.00	0.00	3.54
255.28	255.30	28/1/58-60	0.00	0.00	0.00	0.00	10.00	0.45	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.91	0.00	2.42	0.00	0.00	3.33
255.73	255.75	28/1/103-105	0.00	0.00	0.00	0.00	17.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.32	0.00	0.00	1.32
256.11	256.13	28/1/141-143	0.00	0.00	0.00	0.00	12.56	0.23	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.00	0.47
256.53	256.55	28/2/33-35	0.00	0.00	0.00	0.00	8.84	0.17	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.35	0.00	1.39	0.00	0.00	1.73
257.03	257.05	28/2/83-85	0.00	0.00	0.00	0.00	13.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.65
257.33	257.35	28/2/113-115	0.00	0.00	0.00	0.00	11.34	1.16	0.00	0.00	1.16	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.00	0.46
257.71	257.73	28/3/1-3	0.00	0.00	0.00	0.00	9.17	1.25	0.00	0.00	1.25	0.21	0.21	0.00	0.00	0.42	0.00	2.92	0.00	0.00	3.33
258.12	258.14	28/3/42-44	0.00	0.00	0.00	0.00	8.71	0.84	0.00	0.00	0.84	0.00	0.00	0.00	0.00	0.67	0.00	1.17	0.00	0.17	2.01
258.54	258.56	28/3/84-86	0.00	0.00	0.00	0.00	13.09	2.62	0.00	0.00	2.62	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.52
259.07	259.09	28/3/137-139	0.00	0.00	0.00	0.00	11.00	1.53	0.00	0.00	1.53	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.00	0.00	1.02
259.53	259.55	28/4/33-35	0.00	0.00	0.00	0.00	14.03	0.65	0.00	0.00	0.65	0.16	0.16	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.33
259.86	259.88	28/4/66-68	0.00	0.00	0.00	0.00	9.46	1.79	0.00	0.00	1.79	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.51
260.28	260.30	28/4/108-110	0.00	0.00	0.00	0.00	9.80	0.78	0.00	0.00	0.78	0.16	0.16	0.00	0.00	0.00	0.00	0.62	0.00	0.00	0.62
260.54	260.56	28/4/134-136	0.00	0.00	0.00	0.00	7.51	1.18	0.00	0.00	1.18	0.00	0.00	0.00	0.00	0.15	0.00	1.33	0.00	0.00	1.47

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Globoconella puncticulata* s.l.	*Globoconella puncticulata* s.s.	*Globoconella sphericomiozea* s.l.	*Globoconella sphericomiozea* s.s.	***Globoconella***	*Globoquadrina dehiscens*	*Globoquadrina* sp.?	*Globoquadrina venezuelana*?	***Globoquadrina***	*Globorotalia* cf. *lenguaensis*	***Globorotalia***	*Globorotaloides hexagonus*	***Globorotaloides***	*Hirsutella* cf. *ichinosekiensis*	*Hirsutella margaritae*	*Hirsutella scitula*	*Hirsutella panda*	*Hirsutella* sp.	***Hirsutella***
260.86	260.88	28/5/16-18	0.00	0.00	0.00	0.00	10.71	1.28	0.00	0.00	1.28	0.00	0.00	0.00	0.00	0.00	0.00	0.86	0.00	0.00	0.86
261.31	261.33	28/5/61-63	0.00	0.00	0.00	0.00	7.62	0.30	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.15	0.00	1.22	0.00	0.00	1.37
261.72	261.74	28/5/102-104	0.00	0.00	0.00	0.00	8.58	1.30	0.00	0.00	1.30	0.00	0.00	0.00	0.00	0.00	0.00	2.73	0.00	0.00	2.73
262.11	262.13	28/5/141-143	0.00	0.00	0.00	0.00	5.76	1.73	0.00	0.00	1.73	0.00	0.00	0.00	0.00	0.00	0.00	2.50	0.00	0.00	2.50
262.45	262.47	28CC/8-10	0.00	0.00	0.00	0.00	6.82	1.70	0.00	0.00	1.70	0.00	0.00	0.00	0.00	0.00	0.00	0.96	0.00	0.00	0.96
264.30	264.32	29/1/0-2	0.00	0.00	0.00	0.00	7.73	1.80	0.00	0.00	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.77	0.00	0.00	0.77
264.64	264.66	29/1/34-36	0.00	0.00	0.00	0.00	12.36	2.01	0.00	0.00	2.01	0.00	0.00	0.00	0.00	0.00	0.00	0.62	0.00	0.00	0.62
264.88	264.90	29/1/58-60	0.00	0.00	0.00	0.00	11.38	2.24	0.00	0.00	2.24	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.00	0.80
265.26	265.28	29/1/96-98	0.00	0.00	0.00	0.00	11.84	0.66	0.00	0.00	0.66	0.00	0.00	0.00	0.00	0.16	0.00	0.16	0.00	0.00	0.33
265.72	265.74	29/1/142-144	0.00	0.00	0.00	0.00	16.34	1.56	0.00	0.00	1.56	0.00	0.00	0.00	0.00	0.19	0.00	0.58	0.00	0.00	0.78
266.12	266.14	29/2/32-34	0.00	0.00	0.00	0.00	17.10	1.73	0.00	0.00	1.73	0.00	0.00	0.00	0.00	0.22	0.00	1.30	0.00	0.00	1.52
266.44	266.46	29/2/64-66	0.00	0.00	0.00	0.00	12.08	2.68	0.00	0.00	2.68	0.00	0.00	0.00	0.00	0.22	0.00	0.67	0.00	0.00	0.89
266.87	266.89	29/2/107-109	0.00	0.00	0.00	0.00	16.01	0.99	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.25	0.00	0.25	0.00	0.00	0.49
267.31	267.33	29/3/1-3	0.00	0.00	0.00	0.00	21.94	1.02	0.00	0.00	1.02	0.00	0.00	0.00	0.00	1.02	0.00	0.26	0.00	0.00	1.28
267.53	267.55	29/3/23-25	0.00	0.00	0.00	0.00	12.52	0.88	0.00	0.00	0.88	0.00	0.00	0.00	0.00	0.53	0.00	0.53	0.00	0.00	1.06
267.72	267.74	29/3/42-44	0.00	0.00	0.00	0.00	8.94	0.57	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.28	0.00	0.43	0.00	0.00	0.71
267.87	267.89	29/3/57-59	0.00	0.00	0.00	0.00	9.63	0.35	0.00	0.00	0.35	0.35	0.35	0.00	0.00	0.53	0.00	0.88	0.00	0.00	1.40
268.14	268.16	29/3/84-86	0.00	0.00	0.00	0.00	8.96	1.28	0.00	0.00	1.28	0.00	0.00	0.00	0.00	0.55	0.00	1.65	0.00	0.00	2.19
268.34	268.36	29/3/104-106	0.00	0.00	0.00	0.00	17.79	1.09	0.00	0.00	1.09	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.18
268.47	268.49	29/3/117-119	0.00	0.00	0.00	0.00	13.15	0.21	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.00	0.00	0.74
268.68	268.70	29/3/138-140	0.00	0.00	0.00	0.00	16.88	0.78	0.00	0.00	0.78	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.52
268.86	268.88	29/4/6-8	0.00	0.00	0.00	0.00	14.29	1.17	0.00	0.00	1.17	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.58
269.28	269.30	29/4/48-50	0.00	0.00	0.00	0.00	12.78	0.00	0.28	0.00	0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.57
269.52	269.54	29/4/72-74	0.00	0.00	0.00	0.00	10.12	0.96	0.00	0.00	0.96	0.00	0.00	0.00	0.00	0.00	0.00	1.20	0.00	0.00	1.20
269.75	269.77	29/4/95-97	0.00	0.00	0.00	0.00	18.13	1.28	0.00	0.00	1.28	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.55
269.87	269.89	29/4/107-109	0.00	0.00	0.00	0.00	18.11	1.44	0.00	0.00	1.44	0.00	0.00	0.00	0.00	0.21	0.00	0.62	0.00	0.00	0.82
270.15	270.17	29/4/135-137	0.00	0.00	0.00	0.00	14.38	0.34	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	1.69	0.00	0.00	1.69
270.31	270.33	29/5/1-3	0.00	0.00	0.00	0.00	13.10	0.29	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.58	0.00	1.46	0.00	0.00	2.04
270.45	270.47	29/5/15-17	0.00	0.00	0.00	0.00	13.29	0.23	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.45	0.00	1.58	0.00	0.00	2.03
270.72	270.74	29/5/42-44	0.00	0.00	0.00	0.00	16.70	0.45	0.00	0.00	0.45	0.00	0.00	0.00	0.00	1.13	0.00	5.42	0.00	0.00	6.55
270.91	270.93	29/5/61-63	0.00	0.00	0.00	0.00	14.52	0.18	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.18	0.00	1.97	0.00	0.00	2.15
271.15	271.17	29/5/85-87	0.00	0.00	0.00	0.00	18.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
271.34	271.36	29/5/104-106	0.00	0.00	0.00	0.00	18.00	0.20	0.00	0.00	0.20	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
271.48	271.50	29/5/118-120	0.00	0.00	0.00	0.00	19.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.79	0.00	0.00	0.98
271.72	271.74	29/5/142-144	0.00	0.00	0.00	0.00	10.65	0.26	0.00	0.00	0.26	0.26	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
271.94	271.96	29/6/14-16	0.00	0.00	0.00	0.00	11.83	0.18	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.55
272.19	272.21	29CC/17-19	0.00	0.00	0.00	0.00	8.06	0.11	0.11	0.00	0.21	0.11	0.11	0.00	0.00	0.21	0.00	0.21	0.00	0.00	0.42
273.91	273.93	30/1/1-A7303	0.00	0.00	0.00	0.00	12.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.33
274.04	274.06	30/1/14-16	0.00	0.00	0.00	0.00	16.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
274.32	274.34	30/1/42-44	0.00	0.00	0.00	0.00	18.23	0.17	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	1.74	0.00	0.00	1.74
274.48	274.50	30/1/58-60	0.00	0.00	0.00	0.00	15.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.84	0.00	0.00	1.84
274.72	274.74	30/1/82-84	0.00	0.00	0.00	0.00	12.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	1.39	0.00	0.00	1.53
274.93	274.95	30/1/103-105	0.00	0.00	0.00	0.00	12.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.32
275.12	275.14	30/1/122-124	0.00	0.00	0.00	0.00	9.91	0.00	0.00	0.00	0.00	0.13	0.13	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.13
275.31	275.33	30/1/141-143	0.00	0.00	0.00	0.00	9.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
275.45	275.47	30/2/5-7	0.00	0.00	0.00	0.00	9.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
275.93	275.95	30/2/53-55	0.00	0.00	0.00	0.00	9.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
276.52	276.54	30/2/112-114	0.00	0.00	0.00	0.00	5.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.19
276.91	276.93	30/3/1-3	0.00	0.00	0.00	0.00	8.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.00	0.00	0.68
277.33	277.35	30/3/43-45	0.00	0.00	0.00	0.00	8.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.15
277.74	277.76	30/3/84-86	0.00	0.00	0.00	0.00	8.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.16
278.07	278.09	30/3/117-119	0.00	0.00	0.00	0.00	8.60	0.13	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.13	0.00	0.26
278.49	278.51	30/4/9-11	0.00	0.00	0.00	0.00	7.36	1.45	0.00	0.00	1.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
278.88	278.90	30/4/48-50	0.00	0.00	0.00	0.00	9.93	2.44	0.00	0.00	2.44	0.16	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
279.33	279.35	30/4/93-95	0.00	0.00	0.00	0.00	6.93	2.43	0.00	0.00	2.43	0.00	0.00	0.00	0.00	0.19	0.00	0.19	0.00	0.00	0.37
279.75	279.77	30/4/135-137	0.00	0.00	0.00	0.00	6.04	1.21	0.00	0.00	1.21	0.35	0.35	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0.35
280.05	280.07	30/5/15-17	0.00	0.00	0.00	0.00	7.00	0.49	0.00	0.00	0.49	0.25	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
280.25	280.27	30/5/35-37	0.00	0.00	0.00	0.00	4.77	0.53	0.00	0.00	0.53	0.21	0.21	0.00	0.00	0.11	0.00	0.42	0.00	0.11	0.64
280.92	280.94	30/5/102-104	0.00	0.00	0.00	0.00	7.50	0.36	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.36
283.51	283.53	31/1/1-3	0.00	0.00	0.00	0.00	10.40	0.44	0.00	0.00	0.44	0.15	0.15	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.15
283.94	283.96	31/1/44-46	0.00	0.00	0.00	0.00	9.28	1.20	0.00	0.00	1.20	0.45	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
284.33	284.35	31/1/83-85	0.00	0.00	0.00	0.00	8.59	0.77	0.00	0.00	0.77	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.31
284.55	284.57	31/1/105-107	0.00	0.00	0.00	0.00	9.82	0.47	0.00	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.24	0.36
284.88	284.90	31/1/138-140	0.00	0.00	0.00	0.00	4.98	0.81	0.00	0.00	0.81	0.67	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
285.29	285.31	31/2/29-31	0.00	0.00	0.00	0.00	5.47	1.72	0.00	0.00	1.72	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.00	0.47
285.73	285.75	31/2/73-75	0.00	0.00	0.00	0.00	11.51	1.86	0.00	0.00	1.86	0.17	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
286.10	286.12	31/2/110-112	0.00	0.00	0.00	0.00	9.71	1.14	0.00	0.00	1.14	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.43
286.51	286.53	31/3/1-3	0.00	0.00	0.00	0.00	8.39	0.74	0.00	0.00	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
286.88	286.90	31/3/38-40	0.00	0.00	0.00	0.00	7.17	1.25	0.00	0.00	1.25	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.18
287.32	287.34	31/3/82-84	0.00	0.00	0.00	0.00	9.36	0.71	0.00	0.00	0.71	0.18	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
287.67	287.69	31/3/117-119	0.00	0.00	0.00	0.00	7.02	0.83	0.00	0.00	0.83	3.45	3.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
288.08	288.10	31/4/8-10	0.00	0.00	0.00	0.00	8.49	0.42	0.00	0.00	0.42	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.21
288.55	288.57	31/4/55-57	0.00	0.00	0.00	0.00	6.51	1.45	0.00	0.00	1.45	0.10	0.10	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.10
288.89	288.91	31/4/89-91	0.00	0.00	0.00	0.00	26.42	4.04	0.00	0.00	4.04	0.00	0.00	0.27	0.27	0.00	0.00	0.00	0.00	0.00	0.00
289.34	289.36	31/4/134-136	0.00	0.00	0.00	0.00	4.78	2.15	0.00	0.00	2.15	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.12
289.73	289.75	31/5/23-25	0.00	0.00	0.00	0.00	8.51	1.64	0.00	0.00	1.64	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.15
290.12	290.14	31/5/62-64	0.00	0.00	0.00	0.00	7.78	2.92	0.00	0.00	2.92	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.00	0.00	0.49

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Globoconella puncticulata* s.l.	*Globoconella puncticulata* s.s.	*Globoconella sphericomiozea* s.l.	*Globoconella sphericomiozea* s.s.	***Globoconella***	*Globoquadrina dehiscens*	*Globoquadrina* sp.?	*Globoquadrina venezuelana*?	***Globoquadrina***	*Globorotalia* cf. *lenguaensis*	***Globorotalia***	*Globorotaloides hexagonus*	***Globorotaloides***	*Hirsutella* cf. *ichinosekiensis*	*Hirsutella margaritae*	*Hirsutella scitula*	*Hirsutella panda*	*Hirsutella* sp.	***Hirsutella***
290.51	290.53	31/5/101-103	0.00	0.00	0.00	0.00	7.66	0.74	0.00	0.00	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.25
290.74	290.76	31CC/0-2	0.00	0.00	0.00	0.00	9.91	0.64	0.00	0.00	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.64
293.11	293.13	32/1/1-3	0.00	0.00	0.00	0.00	10.06	0.32	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.65
293.33	293.35	32/1/23-25	0.00	0.00	0.00	0.00	9.25	0.29	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.00	0.44
293.71	293.73	32/1/61-63	0.00	0.00	0.00	0.00	4.48	1.16	0.00	0.00	1.16	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.33
294.12	294.14	32/1/102-104	0.00	0.00	0.00	0.00	9.63	3.33	0.00	0.00	3.33	0.00	0.00	0.00	0.00	0.00	0.00	1.58	0.00	0.00	1.58
294.51	294.53	32/1/141-143	0.00	0.00	0.00	0.00	3.57	1.27	0.00	0.00	1.27	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.32
294.90	294.92	32/2/30-32	0.00	0.00	0.00	0.00	9.47	0.49	0.00	0.00	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.00	0.00	0.74
295.33	295.35	32/2/73-75	0.00	0.00	0.00	0.00	9.23	0.95	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00	0.54
295.73	295.75	32/2/113-115	0.00	0.00	0.00	0.00	8.69	0.00	0.17	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
295.93	295.95	32/2/133-135	0.00	0.00	0.00	0.00	13.23	1.20	0.00	0.00	1.20	0.00	0.00	0.00	0.00	0.20	0.00	0.20	0.00	0.00	0.40
296.50	296.52	32/3/40-42	0.00	0.00	0.00	0.00	12.42	0.64	0.00	0.00	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.32
296.93	296.95	32/3/83-85	0.00	0.00	0.00	0.00	17.54	1.01	0.00	0.00	1.01	0.00	0.00	0.00	0.00	0.00	0.00	0.84	0.00	0.00	0.84
297.33	297.35	32/3/123-125	0.00	0.00	0.00	0.00	13.14	2.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.57
297.70	297.72	32/4/10-12	0.00	0.00	0.00	0.00	7.50	0.99	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
298.08	298.10	32/4/48-50	0.00	0.00	0.00	0.00	10.28	1.63	0.00	0.00	1.63	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.82	0.00	1.31
298.52	298.54	32/4/92-94	0.00	0.00	0.00	0.00	6.34	1.88	0.00	0.00	1.88	0.00	0.00	0.00	0.00	0.00	0.00	0.34	1.88	0.00	2.23
298.93	298.95	32/4/133-135	0.00	0.00	0.00	0.00	17.58	1.45	0.00	0.00	1.45	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.16	0.00	0.65
299.38	299.40	32/5/28-30	0.00	0.00	0.00	0.00	8.81	0.28	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.14	0.00	0.98	0.28	0.00	1.40
299.67	299.69	32CC/2-4	0.00	0.00	0.00	0.00	7.84	1.15	0.00	0.00	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.52	0.00	0.94
302.71	302.73	33/1/1-3	0.00	0.00	0.00	0.00	10.39	0.65	0.00	0.00	0.65	0.00	0.00	0.00	0.00	0.49	0.00	0.49	0.00	0.00	0.97
302.97	302.99	33/1/27-29	0.00	0.00	0.00	0.00	13.08	1.08	0.00	0.00	1.08	0.00	0.00	0.00	0.00	0.90	0.00	0.36	0.18	0.00	1.43
303.29	303.31	33/1/59-61	0.00	0.00	0.00	0.00	16.67	2.56	0.00	0.00	2.56	0.00	0.00	0.00	0.00	0.64	0.00	0.80	0.48	0.00	1.92
303.77	303.79	33/1/107-109	0.00	0.00	0.00	0.00	16.31	1.50	0.00	0.00	1.50	0.00	0.00	0.00	0.00	0.33	0.00	0.50	0.00	0.00	0.83
304.13	304.15	33/1/143-145	0.00	0.00	0.00	0.00	14.81	1.17	0.00	0.00	1.17	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.00	0.00	0.58
304.29	304.31	33/2/9-11	0.00	0.00	0.00	0.00	16.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.00	0.36	0.71	0.00	1.60
304.47	304.49	33/2/27-29	0.00	0.00	0.00	0.00	12.46	0.42	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.42	0.00	0.31	0.10	0.00	0.83
304.66	304.68	33/2/46-48	0.00	0.00	0.00	0.00	10.97	0.35	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.53	0.00	0.18	0.71	0.00	1.42
305.02	305.04	33/2/82-84	0.00	0.00	0.00	0.00	14.75	0.32	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.32	0.00	0.16	0.00	0.00	0.49
305.15	305.17	33/2/95-97	0.00	0.00	0.00	0.00	12.72	0.43	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.22	0.00	0.86
305.34	305.36	33/2/114-116	0.00	0.00	0.00	0.00	15.56	0.83	0.00	0.00	0.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.21
305.55	305.57	33/2/135-137	0.00	0.00	0.00	0.00	18.36	0.71	0.00	0.00	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.36
305.71	305.73	33/3/1-3	0.00	0.00	0.00	0.00	20.63	0.63	0.00	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.13	0.00	3.13
305.93	305.95	33/3/23-25	0.00	0.00	0.00	0.00	20.40	0.45	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.67	7.85	0.00	8.52
306.11	306.13	33/3/41-43	0.00	0.00	0.00	0.00	9.29	2.17	0.00	0.00	2.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.51	0.00	7.51
306.27	306.29	33/3/57-59	0.00	0.00	0.00	0.00	8.19	3.88	0.00	0.00	3.88	0.00	0.00	0.00	0.00	0.00	0.00	0.14	5.32	0.00	5.46
306.54	306.56	33/3/84-86	0.00	0.00	0.00	0.00	6.85	3.20	0.00	0.00	3.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.91	0.00	0.91
306.75	306.77	33/3/105-107	0.00	0.00	0.00	0.00	15.78	3.48	0.00	0.00	3.48	0.00	0.00	0.33	0.33	0.00	0.00	0.11	0.76	0.00	0.87
306.86	306.88	33/3/116-118	0.00	0.00	0.00	0.00	21.62	1.31	0.00	0.00	1.31	0.00	0.00	0.44	0.44	0.00	0.00	0.00	0.87	0.00	0.87
307.08	307.10	33/3/138-140	0.00	0.00	0.00	0.00	19.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.48	0.00	3.48
307.30	307.32	33/4/10-12	0.00	0.00	0.00	0.00	31.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.26
307.49	307.51	33/4/29-31	0.00	0.00	0.00	0.00	29.17	0.60	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.30	2.08	0.00	2.38
307.70	307.72	33/4/50-52	0.00	0.00	0.00	0.00	28.82	0.50	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.51	0.00	2.51
307.93	307.95	33/4/73-75	0.00	0.00	0.00	0.00	16.93	0.78	0.00	0.00	0.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.53	0.00	9.53
308.14	308.16	33/4/94-96	0.00	0.00	0.00	0.00	9.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	12.78	0.00	12.94
308.30	308.32	33/4/110-112	0.00	0.00	0.00	0.00	8.33	0.23	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.45	19.82	0.00	20.27
308.53	308.55	33/4/133-135	0.00	0.00	0.00	0.00	17.50	0.17	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.56	0.00	14.56
308.71	308.73	33/5/1-3	0.00	0.00	0.00	0.00	14.35	0.76	0.00	0.00	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.61	5.65	0.00	6.26
308.99	309.01	33/5/29-31	0.00	0.00	0.00	0.00	15.35	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.43	0.00	0.00	0.00	9.81	0.00	9.81
309.11	309.13	33/5/41-43	0.00	0.00	0.00	0.00	12.07	0.82	0.00	0.00	0.82	0.00	0.00	0.00	0.00	0.00	0.00	0.20	11.66	0.00	11.86
309.28	309.30	33/5/58-60	0.00	0.00	0.00	0.00	19.75	0.31	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.92	0.00	0.92
309.54	309.56	33/5/84-86	0.00	0.00	0.00	0.00	13.90	1.23	0.00	0.00	1.23	0.00	0.00	0.12	0.12	0.00	0.00	0.12	0.00	0.00	0.12
309.74	309.76	33/5/104-106	0.00	0.00	0.00	0.00	14.59	0.80	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
312.31	312.33	34/1/1-3	0.00	0.00	0.00	0.00	13.62	1.61	0.00	0.00	1.61	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.36	0.00	0.90
312.54	312.56	34/1/24-26	0.00	0.00	0.00	0.00	14.62	2.57	0.00	0.00	2.57	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.20
312.67	312.69	34/1/37-39	0.00	0.00	0.00	0.00	9.49	1.27	0.00	0.00	1.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
312.87	312.89	34/1/57-59	0.00	0.00	0.00	0.00	10.91	1.14	0.00	0.00	1.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
313.07	313.09	34/1/77-79	0.00	0.00	0.00	0.00	21.89	0.64	0.00	0.00	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.21	0.00	0.64
313.31	313.33	34/1/101-103	0.00	0.00	0.00	0.00	11.22	1.22	0.00	0.00	1.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
313.53	313.55	34/1/123-125	0.00	0.00	0.00	0.00	12.56	1.53	0.00	0.00	1.53	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.17
313.71	313.73	34/1/141-143	0.00	0.00	0.00	0.00	8.95	1.57	0.00	0.00	1.57	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.31	0.00	0.47
313.90	313.92	34/2/10-12	0.00	0.00	0.00	0.00	15.11	1.59	0.00	0.00	1.59	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.20	0.00	0.60
314.09	314.11	34/2/29-31	0.00	0.00	0.00	0.00	19.89	1.06	0.00	0.00	1.06	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.27
314.29	314.31	34/2/49-51	0.00	0.00	0.00	0.00	17.16	1.24	0.00	0.00	1.24	0.00	0.00	0.00	0.00	0.00	0.00	0.25	1.49	0.00	1.74
314.45	314.47	34/2/65-67	0.00	0.00	0.00	0.00	9.29	0.29	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.15	0.00	0.59
314.69	314.71	34/2/89-91	0.00	0.00	0.00	0.00	7.18	2.53	0.00	0.00	2.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.40
314.90	314.92	34/2/110-112	0.00	0.00	0.00	0.00	6.68	1.46	0.00	0.00	1.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.21
315.13	315.15	34/2/133-135	0.00	0.00	0.00	0.00	9.61	0.14	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.58	0.00	2.58
315.30	315.32	34/3/0-2	0.00	0.00	0.00	0.00	16.76	0.84	0.00	0.00	0.84	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.84	0.00	1.12
315.52	315.54	34/3/22-24	0.00	0.00	0.00	0.00	12.89	1.04	0.00	0.00	1.04	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.62	0.00	0.83
315.71	315.73	34/3/41-43	0.00	0.00	0.00	0.00	8.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.22	0.00	0.65
316.06	316.08	34/3/76-78	0.00	0.00	0.00	0.00	9.05	0.57	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.29
316.27	316.29	34/3/97-99	0.00	0.00	0.00	0.00	8.74	0.31	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
316.48	316.50	34/3/118-120	0.00	0.00	0.00	0.00	13.99	0.76	0.00	0.00	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
316.67	316.69	34/3/137-139	0.00	0.00	0.00	0.00	12.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
317.10	317.12	34/4/30-32	0.00	0.00	0.00	0.00	9.87	0.37	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.19
317.50	317.52	34/4/70-72	0.00	0.00	0.00	0.00	25.54	1.45	0.00	0.00	1.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Globoconella puncticulata* s.l.	*Globoconella puncticulata* s.s.	*Globoconella sphericomiozea* s.l.	*Globoconella sphericomiozea* s.s.	***Globoconella***	*Globoquadrina dehiscens*	*Globoquadrina* sp.?	*Globoquadrina venezuelana*?	***Globoquadrina***	*Globorotalia* cf. *lenguaensis*	***Globorotalia***	*Globorotaloides hexagonus*	***Globorotaloides***	*Hirsutella* cf. *ichinosekiensis*	*Hirsutella margaritae*	*Hirsutella scitula*	*Hirsutella panda*	*Hirsutella* sp.	***Hirsutella***
317.90	317.92	34/4/110-112	0.00	0.00	0.00	0.00	17.33	0.74	0.00	0.00	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.25
318.35	318.37	34/5/5-7	0.00	0.00	0.00	0.00	14.11	1.02	0.00	0.00	1.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.00	0.61
318.60	318.62	34/5/30-32	0.00	0.00	0.00	0.00	6.44	0.61	0.00	0.00	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.12
321.91	321.93	35/1/1-3	0.00	0.00	0.00	0.00	10.47	0.32	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.16
322.33	322.35	35/1/43-45	0.00	0.00	0.00	0.00	6.76	0.00	0.20	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
322.72	322.74	35/1/82-84	0.00	0.00	0.00	0.00	11.60	0.20	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
323.09	323.11	35/1/119-121	0.00	0.00	0.00	0.00	11.41	0.19	0.00	0.00	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
323.48	323.50	35/2/8-10	0.00	0.00	0.00	0.00	11.59	2.70	0.00	0.00	2.70	0.00	0.00	0.00	0.00	0.27	0.00	0.27	0.00	0.00	0.54
323.91	323.93	35/2/51-53	0.00	0.00	0.00	0.00	10.76	0.11	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
324.50	324.52	35/2/110-112	0.00	0.00	0.00	0.00	8.90	0.47	0.00	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
324.91	324.93	35/3/1-3	0.00	0.00	0.00	0.00	12.39	3.24	0.00	0.00	3.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
325.33	325.35	35/3/43-45	0.00	0.00	0.00	0.00	12.07	0.82	0.00	0.00	0.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
325.71	325.73	35/3/81-83	0.00	0.00	0.00	0.00	6.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
325.94	325.96	35/3/104-106	0.00	0.00	0.00	0.00	6.96	0.14	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.14
326.28	326.30	35/3/138-140	0.00	0.00	0.00	0.00	13.82	0.46	0.00	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.23
326.70	326.72	35/4/30-32	0.00	0.00	0.00	0.00	12.14	4.46	0.00	0.00	4.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.36
327.09	327.11	35/4/69-71	0.00	0.00	0.00	0.00	17.37	2.32	0.00	0.00	2.32	0.00	0.00	0.00	0.00	0.00	0.00	0.39	3.09	0.00	3.47
327.50	327.52	35/4/110-112	0.00	0.00	0.00	0.00	5.71	0.90	0.00	0.00	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.31	0.00	3.31
327.91	327.93	35/5/1-3	0.00	0.00	0.00	0.00	6.90	0.84	0.00	0.00	0.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.84	0.00	0.84
328.27	328.29	35/5/37-39	0.00	0.00	0.00	0.00	4.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
328.72	328.74	35/5/82-84	0.00	0.00	0.00	0.00	2.71	0.11	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
331.69	331.71	36/1/19-21	0.00	0.00	0.00	0.00	5.15	1.47	0.00	0.00	1.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.15
332.11	332.13	36/1/61-63	0.00	0.00	0.00	0.00	11.95	1.14	0.00	0.00	1.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
332.68	332.70	36/1/118-120	0.00	0.00	0.00	0.00	12.90	1.08	0.00	0.00	1.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.65	0.86
332.98	333.00	36/1/148-150	0.00	0.00	0.00	0.00	13.66	2.64	0.00	0.00	2.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.22
333.40	333.42	36/2/40-42	0.00	0.00	0.00	0.00	5.51	0.53	0.00	0.00	0.53	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.18	0.00	0.36
334.00	334.02	36/2/100-102	0.00	0.00	0.00	0.00	9.00	3.52	0.00	0.00	3.52	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.20
334.36	334.38	36/2/136-138	0.00	0.00	0.00	0.00	3.45	0.69	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.23
334.87	334.89	36/3/37-39	0.00	0.00	0.00	0.00	3.05	1.93	0.00	0.00	1.93	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.32
335.47	335.49	36/3/97-99	0.00	0.00	0.00	0.00	2.73	0.36	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
335.88	335.90	36/3/138-140	0.00	0.00	0.00	0.00	1.69	1.18	0.00	0.00	1.18	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.17	0.00	0.34
336.20	336.22	36/4/20-22	0.00	0.00	0.00	0.00	4.49	0.50	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.66	0.00	0.00	0.66
336.60	336.62	36/4/60-62	0.00	0.00	0.00	0.00	3.45	0.15	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.15

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Menardella* cf. *limbata*	*Menardella* cf. *limbata* ?	***Menardella***	*Neogloboquadrina dutertrei*	*Neogloboquadrina pachyderma*	*Neogloboquadrina m. continuosa*	*Neogloboquadrina mayeri* s.s.	*Neogloboquadrina m. nympha*	***Neogloboquadrina***	*Orbulina bilobata*	*Orbulina bilobata* ?	*Orbulina universa*	*Orbulina universa* "juvenile"	***Orbulina***	*Sphaeroidinellopsis paenedehiscens*	*Sphaeroidinellopsis seminulina*	*Sphaeroidinellopsis* sp.?	***Sphaeroidinellopsis***	*Truncorotalia* aff. *crassaconica*
120.30	120.33	14/1/0-3	0.00	0.00	0.00	0.25	11.17	0.00	0.00	0.00	11.42	0.00	0.00	0.00	2.03	2.03	0.00	0.00	0.00	0.00	0.00
120.51	120.54	14/1/21-24	0.00	0.00	0.00	0.20	10.84	0.00	0.00	0.00	11.04	0.00	0.00	0.20	0.20	0.41	0.00	0.00	0.00	0.00	0.00
120.69	120.72	14/1/39-42	0.00	0.00	0.00	0.45	12.02	0.00	0.00	0.00	12.47	0.00	0.00	0.45	0.91	1.36	0.00	0.00	0.00	0.00	0.00
120.90	120.93	14/1/60-63	0.00	0.00	0.00	0.00	15.77	0.00	0.00	0.00	15.77	0.00	0.00	0.22	0.65	0.86	0.00	0.00	0.00	0.00	0.00
121.11	121.14	14/1/81-84	0.00	0.00	0.00	0.23	14.39	0.00	0.00	0.00	14.62	0.00	0.00	0.23	1.62	1.86	0.00	0.00	0.00	0.00	0.23
121.26	121.29	14/1/96-99	0.00	0.00	0.00	0.43	9.01	0.00	0.00	0.00	9.44	0.00	0.00	0.21	1.72	1.93	0.00	0.00	0.00	0.00	0.21
121.49	121.52	14/1/119-122	0.00	0.00	0.00	0.00	6.36	0.00	0.00	0.00	6.36	0.00	0.00	0.58	2.02	2.60	0.00	0.00	0.00	0.00	0.29
121.69	121.72	14/1/139-142	0.00	0.00	0.00	0.19	9.67	0.00	0.00	0.00	9.85	0.00	0.00	0.74	1.86	2.60	0.00	0.00	0.00	0.00	0.00
121.90	121.93	14/2/10-13	0.00	0.00	0.00	0.00	7.89	0.00	0.00	0.00	7.89	0.00	0.00	1.01	1.62	2.63	0.00	0.00	0.00	0.00	0.20
122.09	122.12	14/2/29-32	0.00	0.00	0.00	0.00	8.05	0.00	0.00	0.00	8.05	0.00	0.00	1.57	1.57	3.13	0.00	0.00	0.00	0.00	0.00
122.26	122.29	14/2/46-49	0.00	0.00	0.00	0.23	5.79	0.00	0.00	0.00	6.02	0.23	0.00	0.23	0.46	0.93	0.00	0.00	0.00	0.00	1.16
122.51	122.55	14/2/71-75	0.00	0.00	0.00	0.23	9.58	0.00	0.00	0.00	9.81	0.00	0.00	1.17	1.64	2.80	0.00	0.00	0.00	0.00	0.23
122.71	122.74	14/2/91-94	0.00	0.00	0.00	0.00	12.41	0.00	0.00	0.00	12.41	0.00	0.00	0.00	1.27	1.27	0.00	0.00	0.00	0.00	0.14
122.92	122.95	14/2/112-115	0.00	0.00	0.00	0.36	12.82	0.00	0.00	0.00	13.18	0.00	0.00	0.54	0.90	1.44	0.00	0.00	0.00	0.00	0.18
123.10	123.13	14/2/130-133	0.00	0.00	0.00	0.00	12.40	0.00	0.00	0.00	12.40	0.00	0.00	0.00	1.29	1.29	0.00	0.00	0.00	0.00	0.32
123.30	123.33	14/3/0-3	0.00	0.00	0.00	0.67	11.33	0.00	0.00	0.00	12.00	0.00	0.00	0.22	1.56	1.78	0.00	0.00	0.00	0.00	0.00
123.53	123.56	14/3/23-26	0.00	0.00	0.00	0.16	10.77	0.00	0.00	0.00	10.93	0.00	0.00	0.00	2.57	2.57	0.00	0.00	0.00	0.00	0.32
123.69	123.72	14/3/39-42	0.00	0.00	0.00	0.00	8.13	0.00	0.00	0.00	8.13	0.00	0.00	0.20	2.03	2.24	0.00	0.00	0.00	0.00	0.00
123.88	123.91	14/3/58-61	0.00	0.00	0.00	0.00	14.67	0.00	0.00	0.00	14.67	0.00	0.00	0.49	0.98	1.47	0.00	0.00	0.00	0.00	0.00
124.11	124.14	14/3/81-84	0.00	0.00	0.00	0.00	12.62	0.00	0.00	0.00	12.62	0.00	0.00	0.39	1.97	2.37	0.00	0.00	0.00	0.00	0.00
124.30	124.33	14/3/100-103	0.00	0.00	0.00	0.00	6.87	0.00	0.00	0.00	6.87	0.00	0.00	0.15	1.34	1.49	0.00	0.00	0.00	0.00	0.00
124.50	124.53	14/3/120-123	0.00	0.00	0.00	0.22	8.71	0.00	0.00	0.00	8.93	0.00	0.00	0.44	0.65	1.09	0.00	0.00	0.00	0.00	0.00
124.68	124.71	14/3/138-141	0.00	0.00	0.00	0.00	11.16	0.00	0.00	0.00	11.16	0.00	0.00	0.42	2.74	3.16	0.00	0.00	0.00	0.00	0.00
124.90	124.93	14/4/10-13	0.00	0.00	0.00	0.33	13.66	0.00	0.00	0.00	13.98	0.00	0.00	0.33	0.98	1.30	0.00	0.00	0.00	0.00	0.33
125.10	125.13	14/4/30-33	0.00	0.00	0.00	0.17	8.33	0.00	0.00	0.00	8.51	0.00	0.00	0.00	1.74	1.74	0.00	0.00	0.00	0.00	0.17
125.30	125.33	14/4/50-53	0.00	0.00	0.00	0.00	7.31	0.00	0.00	0.00	7.31	0.00	0.00	0.00	0.76	0.76	0.00	0.00	0.00	0.00	0.15
125.48	125.51	14/4/68-71	0.00	0.00	0.00	0.15	10.21	0.00	0.00	0.00	10.37	0.00	0.00	0.30	1.52	1.83	0.00	0.00	0.00	0.00	0.00
125.71	125.74	14/4/91-94	0.00	0.00	0.00	0.00	13.03	0.00	0.00	0.00	13.03	0.00	0.00	0.00	0.71	0.71	0.00	0.00	0.00	0.00	0.00
125.91	125.94	14/4/111-114	0.00	0.00	0.00	0.00	9.63	0.00	0.00	0.00	9.63	0.00	0.00	0.22	0.78	1.01	0.00	0.00	0.00	0.00	0.00
126.10	126.13	14/4/130-133	0.00	0.00	0.00	0.00	9.27	0.00	0.00	0.00	9.27	0.00	0.00	0.22	1.55	1.77	0.00	0.00	0.00	0.00	0.44
126.30	126.33	14/5/0-3	0.00	0.00	0.00	0.00	9.56	0.00	0.00	0.00	9.56	0.00	0.00	0.52	2.58	3.10	0.00	0.00	0.00	0.00	0.00
126.56	126.59	14/5/26-29	0.00	0.00	0.00	0.00	8.19	0.00	0.00	0.00	8.19	0.00	0.00	0.00	0.78	0.78	0.00	0.00	0.00	0.00	0.19
126.70	126.73	14/5/40-43	0.00	0.00	0.00	0.00	4.96	0.00	0.00	0.00	4.96	0.00	0.00	0.26	0.78	1.04	0.00	0.00	0.00	0.00	0.52
126.90	126.93	14/5/60-63	0.00	0.00	0.00	0.00	4.60	0.00	0.00	0.00	4.60	0.00	0.00	0.00	0.74	0.74	0.00	0.00	0.00	0.00	0.74
127.12	127.15	14/5/82-85	0.00	0.00	0.00	0.16	5.80	0.00	0.00	0.00	5.96	0.00	0.00	0.00	2.19	2.19	0.00	0.00	0.00	0.00	0.00
127.30	127.33	14/5/100-103	0.00	0.00	0.00	0.00	4.51	0.00	0.00	0.00	4.51	0.00	0.00	0.54	1.08	1.62	0.00	0.00	0.00	0.00	0.00
127.51	127.54	14/5/121-124	0.00	0.00	0.00	0.00	6.96	0.00	0.00	0.00	6.96	0.00	0.00	0.39	0.39	0.77	0.00	0.00	0.00	0.00	0.00
127.70	127.73	14/5/140-143	0.00	0.00	0.00	0.00	6.96	0.00	0.00	0.00	6.96	0.00	0.00	0.00	1.46	1.46	0.00	0.00	0.00	0.00	0.00
127.90	127.93	14/6/10-13	0.00	0.00	0.00	0.15	9.43	0.00	0.00	0.00	9.58	0.00	0.00	0.15	0.60	0.75	0.00	0.00	0.00	0.00	0.00
128.29	128.32	14/6/49-52	0.00	0.00	0.00	0.00	6.41	0.00	0.00	0.00	6.41	0.00	0.00	0.18	1.07	1.25	0.00	0.00	0.00	0.00	0.00
128.72	128.75	14/6/92-95	0.00	0.00	0.00	0.21	6.26	0.00	0.00	0.00	6.47	0.00	0.00	0.21	0.42	0.63	0.00	0.00	0.00	0.00	0.00
129.10	129.13	14/6/130-133	0.00	0.00	0.00	0.00	2.67	0.00	0.00	0.00	2.67	0.00	0.00	0.22	0.22	0.45	0.00	0.00	0.00	0.00	0.00
129.50	129.53	14/7/20-23	0.00	0.00	0.00	0.00	3.97	0.00	0.00	0.00	3.97	0.00	0.00	0.14	0.14	0.27	0.00	0.00	0.00	0.00	0.00
129.90	129.93	15/1/0-3	0.00	0.00	0.00	0.00	1.80	0.00	0.00	0.00	1.80	0.00	0.00	0.52	0.00	0.52	0.00	0.00	0.00	0.00	0.00
130.29	130.32	15/1/39-42	0.00	0.00	0.00	0.00	1.84	0.00	0.00	0.00	1.84	0.00	0.00	0.00	0.18	0.18	0.00	0.00	0.00	0.00	0.00
130.69	130.72	15/1/79-82	0.00	0.00	0.00	0.00	4.06	0.00	0.00	0.00	4.06	0.00	0.00	0.00	1.88	1.88	0.00	0.00	0.00	0.00	0.00
131.10	131.13	15/1/120-123	0.00	0.00	0.00	0.00	4.62	0.00	0.00	0.00	4.62	0.00	0.00	0.00	0.36	0.36	0.00	0.00	0.00	0.00	0.00
131.51	131.54	15/2/11-14	0.00	0.00	0.00	0.00	4.12	0.00	0.00	0.00	4.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
131.91	131.93	15/2/51-53	0.00	0.00	0.00	0.16	1.80	0.00	0.00	0.00	1.97	0.00	0.00	0.33	0.33	0.66	0.00	0.00	0.00	0.00	0.00
132.33	132.36	15/2/93-96	0.00	0.00	0.00	0.17	2.44	0.00	0.00	0.00	2.62	0.00	0.00	0.00	0.35	0.35	0.00	0.00	0.00	0.00	0.00
132.74	132.76	15/2/134-136	0.00	0.00	0.00	0.00	3.86	0.00	0.00	0.00	3.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
133.07	133.10	15/3/17-20	0.00	0.00	0.00	0.00	2.32	0.00	0.00	0.00	2.32	0.00	0.00	0.19	0.00	0.19	0.00	0.00	0.00	0.00	0.00
133.46	133.49	15/3/56-59	0.00	0.00	0.00	0.00	0.93	0.00	0.00	0.00	0.93	0.00	0.00	0.13	0.13	0.27	0.00	0.00	0.00	0.00	0.00
133.89	133.92	15/3/99-102	0.00	0.00	0.00	0.00	3.91	0.00	0.00	0.00	3.91	0.00	0.00	0.21	0.21	0.41	0.00	0.00	0.00	0.00	0.00
134.30	134.33	15/3/140-143	0.00	0.00	0.00	0.00	1.72	0.00	0.00	0.00	1.72	0.00	0.00	1.03	0.17	1.20	0.00	0.00	0.00	0.00	0.00
134.70	134.73	15/4/30-33	0.00	0.00	0.00	0.18	4.71	0.00	0.00	0.00	4.89	0.00	0.00	0.00	0.91	0.91	0.00	0.00	0.00	0.00	0.00
135.10	135.13	15/4/70-73	0.00	0.00	0.00	0.00	3.85	0.00	0.00	0.00	3.85	0.00	0.00	0.00	0.23	0.23	0.00	0.00	0.00	0.00	0.23
135.30	135.33	15/4/90-93	0.00	0.00	0.00	0.00	3.32	0.00	0.00	0.00	3.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.87
135.50	135.53	15/4/110-113	0.00	0.00	0.00	0.22	1.34	0.00	0.00	0.00	1.57	0.00	0.00	0.00	0.45	0.45	0.00	0.00	0.00	0.00	0.00
135.70	135.73	15/4/130-133	0.00	0.00	0.00	0.00	5.03	0.00	0.00	0.00	5.03	0.00	0.00	0.32	0.32	0.65	0.00	0.00	0.00	0.00	0.00
135.90	135.93	15/5/0-3	0.00	0.00	0.00	0.00	6.57	0.00	0.00	0.00	6.57	0.00	0.00	0.00	0.35	0.35	0.00	0.00	0.00	0.00	0.00
136.06	136.09	15/5/16-19	0.00	0.00	0.00	0.00	7.39	0.00	0.00	0.00	7.39	0.00	0.00	0.65	0.65	1.30	0.00	0.00	0.00	0.00	0.00
136.32	136.35	15/5/42-45	0.00	0.00	0.00	0.37	5.59	0.00	0.00	0.00	5.96	0.00	0.00	0.37	0.37	0.74	0.00	0.00	0.00	0.00	0.00
136.51	136.53	15/5/61-63	0.00	0.00	0.00	0.00	11.08	0.00	0.00	0.00	11.08	0.00	0.00	0.14	0.56	0.70	0.00	0.00	0.00	0.00	0.00
136.92	136.95	15/5/102-105	0.00	0.00	0.00	0.39	6.85	0.00	0.00	0.00	7.24	0.00	0.00	0.00	0.59	0.59	0.00	0.00	0.00	0.00	0.00
137.13	137.16	15/5/123-126	0.00	0.00	0.00	0.00	3.70	0.00	0.00	0.00	3.70	0.00	0.00	0.44	0.44	0.87	0.00	0.00	0.00	0.00	0.00
137.52	137.55	15/6/12-15	0.00	0.00	0.00	0.00	1.02	0.00	0.00	0.00	1.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
137.91	137.94	15/6/51-54	0.00	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.19	0.19	0.00	0.00	0.00	0.00	0.00
138.27	138.30	15/6/87-90	0.00	0.00	0.00	0.20	1.02	0.00	0.00	0.00	1.23	0.00	0.00	0.20	0.20	0.41	0.00	0.00	0.00	0.00	0.00
138.66	138.69	15/6/126-129	0.00	0.00	0.00	0.00	1.41	0.00	0.00	0.00	1.41	0.00	0.00	0.00	0.18	0.18	0.00	0.00	0.00	0.00	0.00
139.07	139.10	15/7/17-20	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.16	0.00	0.00	0.31	0.16	0.47	0.00	0.00	0.00	0.00	0.00
139.50	139.53	16/1/0-3	0.00	0.00	0.00	0.00	1.19	0.00	0.00	0.00	1.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
139.93	139.96	16/1/43-46	0.00	0.00	0.00	0.00	0.47	0.00	0.00	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
140.34	140.37	16/1/84-87	0.00	0.00	0.00	0.00	0.87	0.00	0.00	0.00	0.87	0.00	0.00	0.22	0.00	0.22	0.00	0.00	0.00	0.00	0.00
140.73	140.76	16/1/123-126	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
141.13	141.15	16/2/13-16	0.00	0.00	0.00	0.00	2.19	0.00	0.00	0.00	2.19	0.00	0.00	0.00	0.94	0.94	0.00	0.00	0.00	0.00	0.00
141.54	141.57	16/2/54-57	0.00	0.00	0.00	0.00	1.03	0.00	0.00	0.00	1.03	0.00	0.00	0.21	0.41	0.62	0.00	0.00	0.00	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Menardella* cf. *limbata*	*Menardella* cf. *limbata?*	***Menardella***	*Neogloboquadrina dutertrei*	*Neogloboquadrina pachyderma*	*Neogloboquadrina m. continuosa*	*Neogloboquadrina mayeri* s.s.	*Neogloboquadrina m. nympha*	***Neogloboquadrina***	*Orbulina bilobata*	*Orbulina bilobata?*	*Orbulina universa*	*Orbulina universa* "juvenile"	***Orbulina***	*Sphaeroidinellopsis paenedehiscens*	*Sphaeroidinellopsis seminulina*	*Sphaeroidinellopsis* sp.?	***Sphaeroidinellopsis***	*Truncorotalia* aff. *crassaconica*
141.92	141.95	16/2/92-95	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.00	0.64	0.00	0.00	0.00	0.64	0.64	0.00	0.00	0.00	0.00	0.00
142.32	142.35	16/2/132-135	0.00	0.00	0.00	0.00	1.61	0.00	0.00	0.00	1.61	0.00	0.00	0.40	0.20	0.60	0.00	0.00	0.00	0.00	0.00
142.75	142.78	16/3/25-28	0.00	0.00	0.00	0.00	2.04	0.00	0.00	0.00	2.04	0.00	0.00	0.19	0.19	0.37	0.00	0.00	0.00	0.00	0.00
143.15	143.18	16/3/65-68	0.00	0.00	0.00	0.00	0.68	0.00	0.00	0.00	0.68	0.00	0.00	0.68	0.17	0.85	0.00	0.00	0.00	0.00	0.00
143.53	143.56	16/3/103-106	0.00	0.00	0.00	0.00	1.92	0.00	0.00	0.00	1.92	0.00	0.00	0.00	0.68	0.68	0.00	0.00	0.00	0.00	0.00
143.84	143.87	16/3/134-137	0.00	0.00	0.00	0.00	1.26	0.00	0.00	0.00	1.26	0.00	0.00	0.54	0.18	0.72	0.00	0.00	0.00	0.00	0.00
144.26	144.29	16/4/26-29	0.00	0.00	0.00	0.00	0.98	0.00	0.00	0.00	0.98	0.00	0.00	0.00	0.59	0.59	0.00	0.00	0.00	0.00	0.00
144.67	144.70	16/4/67-70	0.00	0.00	0.00	0.00	2.17	0.00	0.00	0.00	2.17	0.00	0.00	0.00	0.36	0.36	0.00	0.00	0.00	0.00	0.00
145.13	145.16	16/4/113-116	0.00	0.00	0.00	0.00	1.68	0.00	0.00	0.00	1.68	0.00	0.00	0.00	0.67	0.67	0.00	0.00	0.00	0.00	0.00
145.50	145.53	16/5/0-3	0.00	0.00	0.00	0.00	1.81	0.00	0.00	0.00	1.81	0.00	0.00	0.16	0.16	0.33	0.00	0.00	0.00	0.00	0.00
145.93	145.96	16/5/43-46	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.00	0.85	0.00	0.00	0.00	0.43	0.43	0.00	0.00	0.00	0.00	0.00
146.36	146.38	16/5/86-88	0.00	0.00	0.00	0.00	2.70	0.00	0.00	0.00	2.70	0.00	0.00	0.39	1.16	1.54	0.00	0.00	0.00	0.00	0.00
146.71	146.74	16/5/121-124	0.00	0.00	0.00	0.00	1.58	0.00	0.00	0.00	1.58	0.00	0.00	0.59	0.59	1.19	0.00	0.00	0.00	0.00	0.00
147.06	147.09	16/6/6-9	0.00	0.00	0.00	0.00	2.42	0.00	0.00	0.00	2.42	0.00	0.00	0.24	0.24	0.48	0.00	0.00	0.00	0.00	0.00
147.47	147.50	16/6/47-50	0.00	0.00	0.00	0.00	2.25	0.00	0.00	0.00	2.25	0.00	0.00	0.15	0.30	0.45	0.00	0.00	0.00	0.00	0.00
147.93	147.96	16/6/93-96	0.00	0.00	0.00	0.00	1.72	0.00	0.00	0.00	1.72	0.00	0.00	0.57	0.76	1.34	0.00	0.00	0.00	0.00	0.00
148.33	148.36	16/6/133-136	0.00	0.00	0.00	0.00	2.17	0.00	0.00	0.00	2.17	0.00	0.00	0.51	0.00	0.51	0.00	0.00	0.00	0.00	0.00
148.67	148.69	16/7/17-19	0.00	0.00	0.00	0.00	1.36	0.00	0.00	0.00	1.36	0.00	0.00	0.17	0.00	0.17	0.00	0.00	0.00	0.00	0.00
149.10	149.13	17/1/0-3	0.00	0.00	0.00	0.00	2.01	0.00	0.00	0.00	2.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
149.52	149.55	17/1/42-45	0.00	0.00	0.00	0.00	2.19	0.00	0.00	0.00	2.19	0.00	0.00	0.00	0.17	0.17	0.00	0.00	0.00	0.00	0.00
150.11	150.14	17/1/101-104	0.00	0.00	0.00	0.00	2.77	0.00	0.00	0.00	2.77	0.00	0.00	0.43	0.21	0.64	0.00	0.00	0.00	0.00	0.00
150.51	150.54	17/1/141-144	0.00	0.00	0.00	0.00	3.25	0.00	0.00	0.00	3.25	0.00	0.00	0.22	0.22	0.43	0.00	0.00	0.00	0.00	0.00
150.87	150.90	17/2/27-30	0.00	0.00	0.00	0.00	2.32	0.00	0.00	0.00	2.32	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00
151.07	151.10	17/2/47-50	0.00	0.00	0.00	0.00	1.71	0.00	0.00	0.00	1.71	0.00	0.00	0.57	0.19	0.76	0.00	0.00	0.00	0.00	0.00
151.52	151.55	17/2/92-95	0.00	0.00	0.00	0.00	1.94	0.00	0.00	0.00	1.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
151.96	151.98	17/2/136-138	0.00	0.00	0.00	0.22	2.37	0.00	0.00	0.00	2.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
152.10	152.13	17/3/0-3	0.00	0.00	0.00	0.00	2.24	0.00	0.00	0.00	2.24	0.00	0.00	0.00	0.32	0.32	0.00	0.00	0.00	0.00	0.00
152.25	152.28	17/3/15-18	0.00	0.00	0.00	0.00	2.70	0.00	0.00	0.00	2.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
152.47	152.50	17/3/37-40	0.00	0.00	0.00	0.00	2.17	0.00	0.00	0.00	2.17	0.00	0.00	0.00	0.65	0.65	0.00	0.00	0.00	0.00	0.00
152.75	152.77	17/3/65-67	0.00	0.00	0.00	0.00	4.23	0.00	0.00	0.00	4.23	0.00	0.00	0.00	0.35	0.35	0.00	0.00	0.00	0.00	0.00
152.91	152.94	17/3/81-84	0.00	0.00	0.00	0.00	2.41	0.00	0.00	0.00	2.41	0.00	0.00	1.00	0.40	1.41	0.00	0.00	0.00	0.00	0.00
153.12	153.15	17/3/102-105	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00
153.26	153.29	17/3/116-119	0.00	0.00	0.00	0.00	3.13	0.00	0.00	0.00	3.13	0.00	0.00	0.00	0.47	0.47	0.00	0.00	0.00	0.00	0.00
153.45	153.48	17/3/135-138	0.00	0.00	0.00	0.00	1.63	0.00	0.00	0.00	1.63	0.00	0.00	0.00	0.30	0.30	0.00	0.00	0.00	0.00	0.00
153.66	153.69	17/4/6-9	0.00	0.00	0.00	0.00	2.63	0.00	0.00	0.00	2.63	0.00	0.00	0.00	0.48	0.48	0.00	0.00	0.00	0.00	0.00
153.97	153.99	17/4/37-39	0.00	0.00	0.00	0.00	1.27	0.00	0.00	0.00	1.27	0.00	0.00	0.00	0.32	0.32	0.00	0.00	0.00	0.00	0.00
154.13	154.16	17/4/53-56	0.00	0.00	0.00	0.00	1.42	0.00	0.00	0.00	1.42	0.00	0.00	0.00	0.79	0.79	0.00	0.00	0.00	0.00	0.00
154.32	154.35	17/4/72-75	0.00	0.00	0.00	0.00	1.48	0.00	0.00	0.00	1.48	0.00	0.00	0.00	3.10	3.10	0.00	0.00	0.00	0.00	0.00
154.54	154.57	17/4/94-97	0.00	0.00	0.00	0.00	2.39	0.00	0.00	0.00	2.39	0.00	0.00	0.00	1.82	1.82	0.00	0.00	0.00	0.00	0.00
154.77	154.79	17/4/117-119	0.00	0.00	0.00	0.00	1.96	0.00	0.00	0.00	1.96	0.49	0.00	0.49	2.12	3.10	0.00	0.00	0.00	0.00	0.00
154.95	154.98	17/4/135-138	0.00	0.00	0.00	0.40	5.85	0.00	0.00	0.00	6.25	0.00	0.00	0.27	2.66	2.93	0.00	0.00	0.00	0.00	0.00
155.10	155.13	17/5/0-3	0.00	0.00	0.00	0.00	2.02	0.00	0.00	0.00	2.02	0.13	0.00	0.67	5.39	6.20	0.00	0.13	0.00	0.13	0.00
155.24	155.27	17/5/14-17	0.00	0.00	0.00	0.00	2.28	0.00	0.00	0.00	2.28	0.00	0.00	0.88	4.22	5.10	0.00	0.00	0.00	0.00	0.00
155.48	155.50	17/5/38-40	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.00	0.85	0.12	0.00	0.00	0.85	0.97	0.00	0.00	0.00	0.00	0.00
155.67	155.70	17/5/57-60	0.00	0.00	0.00	0.00	2.42	0.00	0.00	0.00	2.42	0.00	0.00	0.00	0.97	0.97	0.00	0.00	0.00	0.00	0.00
155.94	155.97	17/5/84-87	0.00	0.00	0.00	0.00	2.69	0.00	0.00	0.00	2.69	0.00	0.00	0.26	0.51	0.77	0.00	0.00	0.00	0.00	0.00
156.13	156.16	17/5/103-106	0.00	0.00	0.00	0.00	1.92	0.00	0.00	0.00	1.92	0.00	0.00	0.19	1.92	2.11	0.00	0.00	0.00	0.00	0.00
156.27	156.30	17/5/117-120	0.00	0.00	0.00	0.00	1.09	0.00	0.00	0.00	1.09	0.00	0.00	0.16	0.47	0.63	0.00	0.00	0.00	0.00	0.00
156.47	156.50	17/5/137-140	0.00	0.00	0.00	0.00	2.78	0.00	0.00	0.00	2.78	0.00	0.00	0.33	0.98	1.31	0.00	0.00	0.00	0.00	0.00
156.71	156.74	17/6/11-14	0.00	0.00	0.00	0.00	2.17	0.00	0.00	0.00	2.17	0.00	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00	0.00
156.95	156.98	17/6/35-38	0.00	0.00	0.00	0.00	1.66	0.00	0.00	0.00	1.66	0.00	0.00	0.00	1.11	1.11	0.00	0.00	0.00	0.00	0.00
157.12	157.15	17/6/52-55	0.00	0.00	0.00	0.00	3.29	0.00	0.00	0.00	3.29	0.00	0.00	0.29	0.71	1.00	0.00	0.00	0.00	0.00	0.00
157.37	157.39	17/6/77-79	0.00	0.00	0.00	0.20	3.03	0.00	0.00	0.00	3.23	0.00	0.00	0.00	0.40	0.40	0.00	0.00	0.00	0.00	0.00
157.52	157.55	17/6/92-95	0.00	0.00	0.00	0.21	2.28	0.00	0.00	0.00	2.49	0.00	0.00	0.00	0.41	0.41	0.00	0.00	0.00	0.00	0.00
157.76	157.79	17/6/116-119	0.00	0.00	0.00	0.15	6.24	0.00	0.00	0.00	6.39	0.00	0.00	0.15	0.61	0.76	0.00	0.00	0.00	0.00	0.00
157.93	157.96	17/6/133-136	0.00	0.00	0.00	0.00	3.10	0.00	0.00	0.00	3.10	0.00	0.00	0.22	0.11	0.33	0.00	0.00	0.00	0.00	0.00
158.10	158.13	17/7/0-3	0.00	0.00	0.00	0.12	3.89	0.00	0.00	0.00	4.01	0.00	0.00	0.00	0.49	0.49	0.00	0.00	0.00	0.00	0.00
158.27	158.30	17/7/17-20	0.00	0.00	0.00	0.00	5.43	0.00	0.00	0.00	5.43	0.00	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00	0.00
158.52	158.55	17CC/6-9	0.00	0.00	0.00	0.00	3.05	0.00	0.00	0.00	3.05	0.00	0.00	0.00	2.69	2.69	0.00	0.00	0.00	0.00	0.00
158.70	158.73	18/1/0-3	0.00	0.00	0.00	0.14	5.31	0.00	0.00	0.00	5.45	0.00	0.00	0.14	1.58	1.72	0.00	0.00	0.00	0.00	0.00
158.95	158.98	18/1/25-28	0.00	0.00	0.00	0.00	3.32	0.00	0.00	0.00	3.32	0.00	0.00	0.00	1.05	1.05	0.00	0.00	0.00	0.00	0.00
159.13	159.16	18/1/43-46	0.00	0.00	0.00	0.00	2.96	0.00	0.00	0.00	2.96	0.00	0.00	0.21	0.21	0.42	0.00	0.00	0.00	0.00	0.00
159.35	159.38	18/1/65-68	0.00	0.00	0.00	0.00	4.14	0.00	0.00	0.00	4.14	0.00	0.00	0.00	2.21	2.21	0.00	0.00	0.00	0.00	0.00
159.49	159.52	18/1/79-82	0.00	0.00	0.00	0.00	2.55	0.00	0.00	0.00	2.55	0.00	0.00	0.41	1.12	1.53	0.00	0.00	0.00	0.00	0.00
159.72	159.75	18/1/102-105	0.00	0.00	0.00	0.00	4.10	0.00	0.00	0.00	4.10	0.00	0.00	0.00	0.59	0.59	0.00	0.00	0.00	0.00	0.00
159.86	159.89	18/1/116-119	0.00	0.00	0.00	0.00	4.16	0.00	0.00	0.00	4.16	0.00	0.00	0.00	0.72	0.72	0.00	0.00	0.00	0.00	0.00
160.11	160.14	18/1/141-144	0.00	0.00	0.00	0.00	2.86	0.00	0.00	0.00	2.86	0.00	0.00	0.00	0.36	0.36	0.00	0.00	0.00	0.00	0.00
160.33	160.36	18/2/13-16	0.00	0.00	0.00	0.12	3.55	0.00	0.00	0.00	3.67	0.00	0.00	0.12	1.83	1.96	0.00	0.00	0.00	0.00	0.00
160.73	160.76	18/2/53-56	0.00	0.00	0.00	0.19	3.47	0.00	0.00	0.00	3.66	0.39	0.00	0.96	1.35	2.70	0.00	0.00	0.00	0.00	0.00
161.16	161.19	18/2/96-99	0.00	0.00	0.00	0.00	5.06	0.00	0.00	0.00	5.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
161.53	161.56	18/2/133-136	0.00	0.00	0.00	0.00	4.21	0.00	0.00	0.00	4.21	0.00	0.00	0.13	1.15	1.28	0.00	0.00	0.00	0.00	0.00
161.84	161.87	18/3/14-17	0.00	0.00	0.00	0.00	3.02	0.00	0.00	0.00	3.02	0.00	0.00	0.50	1.68	2.18	0.00	0.00	0.00	0.00	0.00
162.26	162.29	18/3/56-59	0.00	0.00	0.00	0.00	2.06	0.00	0.00	0.00	2.06	0.00	0.00	0.00	0.69	0.69	0.00	0.00	0.00	0.00	0.00
162.87	162.90	18/3/117-120	0.00	0.00	0.00	0.00	2.12	0.00	0.00	0.00	2.12	0.00	0.00	0.39	0.58	0.96	0.00	0.00	0.00	0.00	0.00
163.33	163.36	18/4/13-16	0.00	0.00	0.00	0.22	4.26	0.00	0.00	0.00	4.48	0.00	0.00	0.45	1.57	2.02	0.00	0.00	0.00	0.00	0.00
163.56	163.59	18/4/36-39	0.00	0.00	0.00	0.00	5.07	0.00	0.00	0.00	5.07	0.00	0.00	0.54	1.40	1.94	0.00	0.00	0.00	0.00	0.00
163.93	163.96	18/4/73-76	0.00	0.00	0.00	0.00	3.73	0.00	0.00	0.00	3.73	0.00	0.00	0.70	2.80	3.50	0.00	0.00	0.00	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Menardella* cf. *limbata*	*Menardella* cf. *limbata?*	***Menardella***	*Neogloboquadrina dutertrei*	*Neogloboquadrina pachyderma*	*Neogloboquadrina m. continuosa*	*Neogloboquadrina mayeri* s.s.	*Neogloboquadrina m. nympha*	***Neogloboquadrina***	*Orbulina bilobata*	*Orbulina bilobata?*	*Orbulina universa*	*Orbulina universa* "juvenile"	***Orbulina***	*Sphaeroidinellopsis paenedehiscens*	*Sphaeroidinellopsis seminulina*	*Sphaeroidinellopsis* sp.?	***Sphaeroidinellopsis***	*Truncorotalia* aff. *crassaconica*
164.31	164.33	18/4/111-113	0.00	0.00	0.00	0.00	1.32	0.00	0.00	0.00	1.32	0.00	0.00	0.44	2.19	2.63	0.00	0.00	0.00	0.00	0.00
164.70	164.73	18/5/0-3	0.00	0.00	0.00	0.00	1.72	0.00	0.00	0.00	1.72	0.00	0.00	0.52	0.69	1.20	0.00	0.00	0.00	0.00	0.00
165.13	165.16	18/5/43-46	0.00	0.00	0.00	0.00	4.55	0.00	0.00	0.00	4.55	0.00	0.00	0.25	0.76	1.01	0.00	0.00	0.00	0.00	0.00
165.50	165.53	18/5/80-83	0.00	0.00	0.00	0.00	3.65	0.00	0.00	0.00	3.65	0.00	0.00	0.00	0.46	0.46	0.00	0.00	0.11	0.11	0.00
165.95	165.97	18/5/125-127	0.00	0.00	0.00	0.00	2.23	0.00	0.00	0.00	2.23	0.00	0.00	0.00	0.16	0.16	0.00	0.00	0.00	0.00	0.00
166.26	166.29	18/6/6-9	0.00	0.00	0.00	0.00	4.08	0.00	0.00	0.00	4.08	0.00	0.00	0.18	1.42	1.60	0.00	0.00	0.00	0.00	0.00
166.66	166.69	18/6/46-49	0.00	0.00	0.00	0.00	4.87	0.00	0.00	0.00	4.87	0.00	0.00	0.17	0.00	0.17	0.00	0.00	0.00	0.00	0.00
167.06	167.09	18/6/86-89	0.00	0.00	0.00	0.00	4.52	0.00	0.00	0.00	4.52	0.00	0.00	0.14	1.27	1.41	0.00	0.00	0.00	0.00	0.00
167.44	167.47	18/6/124-127	0.00	0.00	0.00	0.00	4.33	0.00	0.00	0.00	4.33	0.00	0.00	0.55	0.78	1.33	0.00	0.00	0.00	0.00	0.00
168.30	168.33	19/1/0-3	0.00	0.00	0.00	0.00	1.80	0.00	0.00	0.00	1.80	0.00	0.00	0.18	1.80	1.98	0.00	0.00	0.00	0.00	0.00
168.71	168.74	19/1/41-44	0.00	0.00	0.00	0.13	3.21	0.00	0.00	0.00	3.34	0.00	0.00	0.00	0.77	0.77	0.00	0.00	0.00	0.00	0.00
169.13	169.15	19/1/83-85	0.00	0.00	0.00	0.00	4.28	0.00	0.00	0.00	4.28	0.00	0.00	0.33	0.00	0.33	0.00	0.00	0.00	0.00	0.00
169.51	169.54	19/1/121-124	0.00	0.00	0.00	0.00	1.72	0.00	0.00	0.00	1.72	0.00	0.00	0.29	0.00	0.29	0.00	0.00	0.00	0.00	0.00
169.85	169.88	19/2/5-8	0.00	0.00	0.00	0.00	2.72	0.00	0.00	0.00	2.72	0.00	0.00	0.34	0.51	0.85	0.00	0.00	0.00	0.00	0.00
170.32	170.35	19/2/52-55	0.00	0.00	0.00	0.00	1.33	0.00	0.00	0.00	1.33	0.00	0.00	0.00	1.33	1.33	0.00	0.00	0.00	0.00	0.00
170.73	170.76	19/2/93-96	0.00	0.00	0.00	0.00	1.97	0.00	0.00	0.00	1.97	0.00	0.00	0.00	0.76	0.76	0.00	0.00	0.00	0.00	0.00
171.15	171.18	19/2/135-138	0.00	0.00	0.00	0.00	2.29	0.00	0.00	0.00	2.29	0.00	0.00	0.16	1.80	1.96	0.00	0.00	0.00	0.00	0.00
171.57	171.59	19/3/27-29	0.00	0.00	0.00	0.00	2.56	0.00	0.00	0.00	2.56	0.00	0.00	0.30	1.05	1.35	0.00	0.00	0.00	0.00	0.00
171.92	171.94	19/3/62-64	0.00	0.00	0.00	0.00	3.29	0.00	0.00	0.00	3.29	0.00	0.00	0.00	0.70	0.70	0.00	0.00	0.00	0.00	0.00
172.32	172.35	19/3/102-105	0.00	0.00	0.00	0.00	3.25	0.00	0.00	0.00	3.25	0.00	0.00	0.00	0.77	0.77	0.00	0.00	0.00	0.00	0.00
172.66	172.68	19/3/136-138	0.00	0.00	0.00	0.00	5.36	0.00	0.00	0.00	5.36	0.00	0.00	0.00	1.53	1.53	0.00	0.00	0.00	0.00	0.00
173.07	173.09	19/4/27-29	0.00	0.00	0.00	0.00	3.12	0.00	0.00	0.00	3.12	0.00	0.00	0.00	0.83	0.83	0.00	0.00	0.00	0.00	0.00
173.52	173.54	19/4/72-74	0.00	0.00	0.00	0.00	2.49	0.00	0.00	0.00	2.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
173.93	173.95	19/4/113-115	0.00	0.00	0.00	0.00	3.85	0.00	0.00	0.00	3.85	0.00	0.00	0.20	0.81	1.01	0.00	0.00	0.00	0.00	0.00
174.30	174.33	19/5/0-3	0.00	0.00	0.00	0.00	2.12	0.00	0.00	0.00	2.12	0.00	0.00	0.64	1.49	2.12	0.00	0.00	0.00	0.00	0.00
174.72	174.75	19/5/42-45	0.00	0.00	0.00	0.00	4.73	0.00	0.00	0.00	4.73	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00
175.26	175.28	19/5/96-99	0.00	0.00	0.00	0.00	1.24	0.00	0.00	0.00	1.24	0.00	0.00	0.21	1.44	1.65	0.00	0.00	0.00	0.00	0.00
175.71	175.74	19/5/141-144	0.00	0.00	0.00	0.00	2.89	0.00	0.00	0.00	2.89	0.00	0.00	0.00	0.52	0.52	0.00	0.00	0.00	0.00	0.00
176.06	176.09	19/6/26-29	0.00	0.00	0.00	0.00	3.02	0.00	0.00	0.00	3.02	0.00	0.00	0.00	0.46	0.46	0.00	0.00	0.00	0.00	0.00
176.47	176.49	19/6/67-69	0.00	0.00	0.00	0.00	3.44	0.00	0.00	0.00	3.44	0.00	0.00	0.00	1.53	1.53	0.00	0.00	0.00	0.00	0.00
176.92	176.94	19/6/112-114	0.00	0.00	0.00	0.00	7.24	0.00	0.00	0.00	7.24	0.00	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00	0.00
177.30	177.33	19/7/0-3	0.00	0.00	0.00	0.00	3.61	0.00	0.00	0.00	3.61	0.24	0.00	0.24	0.96	1.44	0.00	0.00	0.00	0.00	0.00
177.52	177.55	19/7/22-25	0.00	0.00	0.00	0.07	2.62	0.00	0.00	0.00	2.69	0.00	0.00	0.07	0.90	0.97	0.00	0.00	0.00	0.00	0.00
177.90	177.93	20/1/0-3	0.00	0.00	0.00	0.00	9.72	0.00	0.00	0.00	9.72	0.00	0.00	0.00	0.46	0.46	0.00	0.00	0.00	0.00	0.00
178.27	178.30	20/1/37-40	0.00	0.00	0.00	0.00	6.94	0.00	0.00	0.00	6.94	0.00	0.00	0.20	1.98	2.18	0.00	0.00	0.00	0.00	0.00
178.68	178.70	20/1/78-80	0.00	0.00	0.00	0.00	10.04	0.00	0.00	0.00	10.04	0.00	0.00	0.00	2.09	2.09	0.00	0.00	0.00	0.00	0.00
179.08	179.10	20/1/118-120	0.00	0.00	0.00	0.00	5.39	0.00	0.00	0.00	5.39	0.00	0.00	0.00	2.90	2.90	0.00	0.00	0.00	0.00	0.00
179.45	179.47	20/2/5-7	0.00	0.00	0.00	0.00	3.32	0.00	0.00	0.00	3.32	0.00	0.00	0.00	2.46	2.46	0.00	0.00	0.00	0.00	0.00
179.86	179.88	20/2/46-48	0.00	0.00	0.00	0.00	8.01	0.00	0.00	0.00	8.01	0.00	0.00	0.00	1.67	1.67	0.00	0.00	0.00	0.00	0.00
180.33	180.35	20/2/93-95	0.00	0.00	0.00	0.00	7.41	0.00	0.00	0.00	7.41	0.00	0.00	0.00	1.60	1.60	0.00	0.00	0.00	0.00	0.00
180.73	180.75	20/2/133-135	0.00	0.00	0.00	0.00	4.33	0.00	0.00	0.00	4.33	0.00	0.00	0.43	1.95	2.38	0.00	0.00	0.00	0.00	0.00
181.14	181.16	20/3/24-26	0.00	0.00	0.00	0.00	4.82	0.00	0.00	0.00	4.82	0.00	0.00	0.00	0.28	0.28	0.00	0.00	0.00	0.00	0.00
181.57	181.59	20/3/67-69	0.00	0.00	0.00	0.22	4.92	0.00	0.00	0.00	5.15	0.00	0.00	0.00	4.47	4.47	0.00	0.00	0.00	0.00	0.00
181.86	181.88	20/3/96-98	0.00	0.00	0.00	0.00	7.35	0.00	0.00	0.00	7.35	0.18	0.00	0.18	1.29	1.65	0.00	0.00	0.00	0.00	0.00
182.23	182.25	20/3/133-135	0.00	0.00	0.00	0.00	6.46	0.00	0.00	0.00	6.46	0.00	0.00	0.00	2.39	2.39	0.24	0.00	0.00	0.24	0.00
182.68	182.70	20/4/28-30	0.00	0.00	0.00	0.00	7.57	0.00	0.00	0.00	7.57	0.00	0.00	0.27	1.35	1.62	0.00	0.00	0.00	0.00	0.00
183.08	183.10	20/4/68-70	0.00	0.00	0.00	0.00	2.93	0.00	0.00	0.00	2.93	0.00	0.00	0.00	1.22	1.22	0.00	0.00	0.00	0.00	0.00
183.45	183.47	20/4/105-107	0.00	0.00	0.00	0.26	5.69	0.00	0.00	0.00	5.95	0.00	0.00	0.26	2.72	2.98	0.00	0.00	0.00	0.00	0.00
183.91	183.93	20/5/1-3	0.00	0.00	0.00	0.00	6.94	0.00	0.00	0.00	6.94	0.00	0.00	0.18	2.14	2.31	0.00	0.00	0.00	0.00	0.00
184.32	184.34	20/5/42-44	0.00	0.00	0.00	0.18	4.59	0.00	0.00	0.00	4.77	0.00	0.00	0.00	2.39	2.39	0.00	0.00	0.00	0.00	0.00
184.72	184.74	20/5/82-84	0.00	0.00	0.00	0.00	6.40	0.00	0.00	0.00	6.40	0.00	0.00	0.00	3.40	3.40	0.00	0.00	0.00	0.00	0.00
185.07	185.09	20/5/117-119	0.00	0.00	0.00	0.00	4.06	0.00	0.00	0.00	4.06	0.00	0.00	0.00	2.11	2.11	0.00	0.00	0.00	0.00	0.00
185.47	185.49	20/6/7-9	0.00	0.00	0.00	0.00	1.67	0.00	0.00	0.00	1.67	0.00	0.00	0.00	1.67	1.67	0.00	0.00	0.00	0.00	0.00
185.92	185.94	20/6/52-54	0.00	0.00	0.00	0.00	4.02	0.00	0.00	0.00	4.02	0.19	0.00	0.00	3.83	4.02	0.00	0.00	0.00	0.00	0.00
186.32	186.34	20/6/92-94	0.00	0.00	0.00	0.00	3.95	0.00	0.00	0.00	3.95	0.00	0.00	0.36	4.13	4.49	0.00	0.00	0.00	0.00	0.00
186.72	186.74	20/6/132-134	0.00	0.00	0.00	0.00	4.42	0.00	0.00	0.00	4.42	0.00	0.00	0.17	1.53	1.70	0.00	0.00	0.00	0.00	0.00
187.07	187.09	20/7/17-19	0.00	0.00	0.00	0.00	8.72	0.00	0.00	0.00	8.72	0.00	0.00	0.14	2.67	2.81	0.00	0.00	0.00	0.00	0.00
187.51	187.53	21/1/1-3	0.00	0.00	0.00	0.00	9.40	0.00	0.00	0.00	9.40	0.00	0.00	0.00	4.50	4.50	0.00	0.00	0.00	0.00	0.00
187.93	187.95	21/1/43-45	0.00	0.00	0.00	0.12	5.21	0.00	0.00	0.00	5.33	0.00	0.00	0.00	3.52	3.52	0.00	0.00	0.00	0.00	0.00
188.32	188.34	21/182-84	0.00	0.00	0.00	0.00	4.92	0.00	0.00	0.00	4.92	0.00	0.00	0.00	2.46	2.46	0.00	0.00	0.00	0.00	0.00
188.67	188.69	21/1/117-119	0.00	0.00	0.00	0.00	3.57	0.00	0.00	0.00	3.57	0.00	0.00	0.32	2.27	2.59	0.00	0.00	0.00	0.00	0.00
189.08	189.10	21/2/8-10	0.00	0.00	0.00	0.00	3.92	0.00	0.00	0.00	3.92	0.00	0.00	0.00	0.69	0.69	0.00	0.00	0.00	0.00	0.00
189.46	189.48	21/2/46-48	0.00	0.00	0.00	0.00	3.64	0.00	0.00	0.00	3.64	0.00	0.00	0.17	1.65	1.82	0.00	0.00	0.00	0.00	0.00
189.93	189.96	21/2/93-96	0.00	0.00	0.00	0.00	3.12	0.00	0.00	0.00	3.12	0.00	0.00	0.00	1.72	1.72	0.00	0.00	0.00	0.00	0.00
190.42	190.44	21/2/142-144	0.00	0.00	0.00	0.00	4.07	0.00	0.00	0.00	4.07	0.00	0.00	1.02	2.20	3.22	0.00	0.00	0.00	0.00	0.00
190.66	190.68	21/3/16-18	0.00	0.00	0.00	0.00	2.61	0.00	0.00	0.00	2.61	0.00	0.00	0.17	1.05	1.22	0.00	0.00	0.00	0.00	0.00
191.12	191.14	21/3/62-64	0.00	0.00	0.00	0.00	4.03	0.00	0.00	0.00	4.03	0.00	0.00	0.00	2.28	2.28	0.00	0.00	0.00	0.00	0.00
191.52	191.54	21/3/102-104	0.00	0.00	0.00	0.00	5.43	0.00	0.00	0.00	5.43	0.00	0.00	0.26	1.94	2.20	0.00	0.00	0.00	0.00	0.00
191.86	191.89	21/3/136-139	0.00	0.00	0.00	0.00	5.91	0.00	0.00	0.00	5.91	0.00	0.00	0.00	0.66	0.66	0.00	0.00	0.00	0.00	0.00
192.36	192.38	21/4/36-38	0.00	0.00	0.00	0.00	4.90	0.00	0.00	0.00	4.90	0.00	0.00	0.00	2.52	2.52	0.00	0.00	0.00	0.00	0.00
192.73	192.75	21/4/73-75	0.00	0.00	0.00	0.00	2.40	0.00	0.00	0.00	2.40	0.00	0.00	0.76	1.14	1.89	0.00	0.00	0.00	0.00	0.00
193.12	193.14	21/4/112-114	0.00	0.00	0.00	0.17	3.64	0.00	0.00	0.00	3.81	0.00	0.00	1.21	0.52	1.73	0.17	0.00	0.00	0.17	0.00
193.50	193.52	21/5/0-2	0.00	0.00	0.00	0.00	5.05	0.00	0.00	0.00	5.05	0.00	0.00	0.51	0.71	1.21	0.00	0.00	0.00	0.00	0.00
193.92	193.94	21/5/42-44	0.00	0.00	0.00	0.00	3.17	0.00	0.00	0.00	3.17	0.00	0.00	0.32	1.90	2.22	0.00	0.00	0.00	0.00	0.00
194.34	194.26	21/5/84-86	0.00	0.00	0.00	0.00	3.33	0.00	0.00	0.00	3.33	0.00	0.00	0.44	1.56	2.00	0.00	0.00	0.00	0.00	0.00
194.72	194.74	21/5/122-124	0.00	0.00	0.00	0.00	5.83	0.00	0.00	0.00	5.83	0.00	0.00	0.00	1.14	1.14	0.00	0.00	0.00	0.00	0.00
195.07	195.09	21/6/7-9	0.00	0.00	0.00	0.00	3.74	0.00	0.00	0.00	3.74	0.00	0.00	0.28	1.25	1.52	0.00	0.00	0.00	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Menardella* cf. *limbata*	*Menardella* cf. *limbata*?	***Menardella***	*Neogloboquadrina dutertrei*	*Neogloboquadrina pachyderma*	*Neogloboquadrina m. continuosa*	*Neogloboquadrina mayeri* s.s.	*Neogloboquadrina m. nympha*	***Neogloboquadrina***	*Orbulina bilobata*	*Orbulina bilobata*?	*Orbulina universa*	*Orbulina universa* "juvenile"	***Orbulina***	*Sphaeroidinellopsis paenedehiscens*	*Sphaeroidinellopsis seminulina*	*Sphaeroidinellopsis* sp.?	***Sphaeroidinellopsis***	*Truncorotalia* aff. *crassaconica*
195.49	195.51	21/6/49-51	0.00	0.00	0.00	0.40	4.72	0.00	0.00	0.00	5.13	0.00	0.00	0.00	0.81	0.81	0.00	0.00	0.00	0.00	0.00
195.87	195.89	21/6/87-89	0.00	0.00	0.00	0.22	7.69	0.00	0.00	0.00	7.91	0.00	0.00	0.22	0.00	0.22	0.00	0.00	0.00	0.00	0.00
196.34	196.36	21/6/134-136	0.00	0.00	0.00	0.19	5.21	0.00	0.00	0.00	5.40	0.00	0.00	0.00	0.37	0.37	0.00	0.00	0.00	0.00	0.00
196.72	196.74	21/7/22-24	0.00	0.00	0.00	0.18	9.34	0.00	0.00	0.00	9.52	0.00	0.00	0.18	2.33	2.51	0.00	0.00	0.00	0.00	0.00
197.11	197.13	22/1/1-3	0.00	0.00	0.00	0.00	4.53	0.00	0.00	0.00	4.53	0.00	0.00	0.00	1.81	1.81	0.00	0.00	0.00	0.00	0.00
197.48	197.50	22/1/38-40	0.00	0.00	0.00	0.23	6.21	0.00	0.00	0.00	6.43	0.00	0.00	0.11	0.79	0.90	0.00	0.00	0.00	0.00	0.00
197.94	197.96	22/1/84-86	0.00	0.00	0.00	0.00	6.54	0.00	0.00	0.00	6.54	0.00	0.00	0.14	1.56	1.71	0.00	0.00	0.00	0.00	0.00
198.32	198.34	22/1/122-124	0.00	0.00	0.00	0.38	4.79	0.00	0.00	0.00	5.17	0.00	0.00	1.01	1.39	2.40	0.00	0.00	0.00	0.00	0.00
198.73	198.75	22/2/13-15	0.00	0.00	0.00	0.00	6.51	0.00	0.00	0.00	6.51	0.00	0.00	0.38	0.38	0.77	0.00	0.00	0.00	0.00	0.00
199.14	199.16	22/2/54-56	0.00	0.00	0.00	0.12	9.92	0.00	0.00	0.00	10.03	0.00	0.00	0.12	2.31	2.42	0.00	0.00	0.00	0.00	0.00
199.53	199.55	22/2/93-95	0.00	0.00	0.00	0.33	3.62	0.00	0.00	0.00	3.95	0.00	0.00	0.00	0.99	0.99	0.00	0.00	0.00	0.00	0.00
199.93	199.95	22/2/133-135	0.00	0.00	0.00	0.00	18.54	0.00	0.00	0.00	18.54	0.00	0.00	0.59	0.59	1.18	0.00	0.00	0.00	0.00	0.00
200.25	200.27	22/3/15-17	0.00	0.00	0.00	0.00	14.45	0.00	0.00	0.00	14.45	0.00	0.00	0.13	1.15	1.28	0.00	0.00	0.00	0.00	0.00
200.66	200.68	22/3/56-58	0.00	0.00	0.00	0.00	7.57	0.00	0.00	0.00	7.57	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00
201.05	201.07	22/3/95-97	0.00	0.00	0.00	0.30	15.25	0.00	0.00	0.00	15.55	0.00	0.00	0.15	1.64	1.79	0.00	0.00	0.00	0.00	0.00
201.42	201.44	22/3/132-134	0.00	0.00	0.00	0.10	2.01	0.00	0.00	0.00	2.11	0.00	0.00	0.60	1.50	2.11	0.00	0.00	0.00	0.00	0.00
201.93	201.95	22/4/33-35	0.00	0.00	0.00	0.00	3.80	0.00	0.00	0.00	3.80	0.00	0.00	0.15	1.61	1.75	0.00	0.00	0.15	0.15	0.00
202.52	202.55	22/4/92-95	0.00	0.00	0.00	0.00	3.40	0.00	0.00	0.00	3.40	0.00	0.00	0.59	2.69	3.28	0.00	0.00	0.00	0.00	0.00
202.93	202.95	22/4/133-135	0.00	0.00	0.00	0.00	5.16	0.00	0.00	0.00	5.16	0.00	0.00	0.26	1.85	2.12	0.00	0.00	0.00	0.00	0.00
203.17	203.20	22CC/7-10	0.00	0.00	0.00	0.00	2.12	0.00	0.00	0.00	2.12	0.12	0.00	0.12	2.47	2.70	0.12	0.00	0.00	0.12	0.00
206.71	206.73	23/1/1-3	0.00	0.00	0.00	0.00	1.85	0.00	0.00	0.00	1.85	0.09	0.00	0.09	1.67	1.85	0.00	0.00	0.00	0.00	0.00
207.13	207.15	23/1/43-45	0.00	0.00	0.00	0.00	1.50	0.00	0.00	0.00	1.50	0.00	0.00	0.00	1.91	1.91	0.00	0.00	0.00	0.00	0.00
207.48	207.50	23/1/78-80	0.00	0.00	0.00	0.00	0.99	0.00	0.00	0.00	0.99	0.00	0.00	0.17	4.29	4.46	0.00	0.00	0.00	0.00	0.00
207.88	207.90	23/1/118-120	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.51	0.00	0.00	0.00	1.16	1.16	0.00	0.00	0.00	0.00	0.00
208.26	208.28	23/2/6-8	0.00	0.00	0.00	0.00	1.16	0.00	0.00	0.00	1.16	0.00	0.00	0.13	0.64	0.77	0.00	0.00	0.00	0.00	0.00
208.52	208.54	23/2/32-34	0.00	0.00	0.00	0.00	1.41	0.00	0.00	0.00	1.41	0.00	0.00	0.00	0.96	0.96	0.00	0.00	0.00	0.00	0.00
209.06	209.08	23/2/86-88	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.00	0.65	0.00	0.00	0.39	1.30	1.69	0.00	0.00	0.00	0.00	0.00
209.54	209.56	23/2/134-136	0.00	0.00	0.00	0.00	1.86	0.00	0.00	0.00	1.86	0.00	0.00	0.00	0.86	0.86	0.00	0.00	0.00	0.00	0.00
209.85	209.87	23/3/15-17	0.00	0.00	0.00	0.00	1.27	0.00	0.00	0.00	1.27	0.00	0.14	0.14	1.97	2.25	0.00	0.00	0.00	0.00	0.00
210.33	210.35	23/3/63-65	0.00	0.00	0.00	0.00	1.31	0.00	0.00	0.00	1.31	0.00	0.00	0.00	1.74	1.74	0.00	0.00	0.00	0.00	0.00
210.53	210.55	23/3/83-85	0.00	0.00	0.00	0.00	1.84	0.00	0.00	0.00	1.84	0.00	0.00	0.20	1.23	1.43	0.00	0.00	0.00	0.00	0.00
210.87	210.89	23/3/117-119	0.00	0.00	0.00	0.00	1.79	0.00	0.00	0.00	1.79	0.00	0.00	0.00	1.55	1.55	0.00	0.00	0.00	0.00	0.00
211.27	211.29	23/4/7-9	0.00	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.46	0.00	0.00	0.31	2.47	2.78	0.00	0.00	0.00	0.00	0.00
211.72	211.74	23/4/52-54	0.00	0.00	0.00	0.00	1.98	0.00	0.00	0.00	1.98	0.00	0.00	0.12	3.09	3.21	0.00	0.00	0.00	0.00	0.00
212.13	212.15	23/4/93-95	0.00	0.00	0.00	0.16	0.79	0.00	0.00	0.00	0.95	0.00	0.00	0.16	3.01	3.16	0.00	0.00	0.00	0.00	0.00
212.32	212.34	23/4/112-114	0.20	0.00	0.20	0.10	2.91	0.00	0.00	0.00	3.02	0.10	0.00	0.00	1.51	1.61	0.00	0.00	0.00	0.00	0.00
212.71	212.73	23/5/1-3	0.00	0.00	0.00	0.00	3.57	0.00	0.00	0.00	3.57	0.15	0.00	0.00	0.74	0.89	0.00	0.00	0.00	0.00	0.00
213.12	213.14	23/5/42-44	0.00	0.00	0.00	0.00	3.59	0.00	0.00	0.00	3.59	0.10	0.00	0.00	1.23	1.33	0.00	0.00	0.00	0.00	0.00
213.72	213.74	23/5/102-104	0.00	0.00	0.00	0.00	4.40	0.00	0.00	0.00	4.40	0.00	0.00	0.18	2.01	2.20	0.00	0.00	0.00	0.00	0.00
214.12	214.14	23/5/142-144	0.00	0.00	0.00	0.00	3.27	0.00	0.00	0.00	3.27	0.00	0.00	0.47	1.24	1.71	0.00	0.00	0.00	0.00	0.00
214.51	214.53	23/6/31-33	0.00	0.00	0.00	0.00	3.86	0.00	0.00	0.00	3.86	0.00	0.00	0.09	1.03	1.12	0.00	0.00	0.00	0.00	0.00
215.05	215.07	23/6/85-87	0.00	0.00	0.00	0.00	1.54	0.00	0.00	0.00	1.54	0.00	0.00	0.19	2.50	2.70	0.00	0.00	0.00	0.00	0.00
215.53	215.55	23/6/133-135	0.14	0.00	0.14	0.00	1.56	0.00	0.00	0.00	1.56	0.00	0.00	0.14	4.13	4.27	0.00	0.00	0.00	0.00	0.00
215.93	215.95	23/7/23-25	0.00	0.00	0.00	0.00	1.57	0.00	0.00	0.00	1.57	0.00	0.00	0.16	5.03	5.19	0.00	0.00	0.00	0.00	0.00
216.31	216.33	24/1/1-3	0.00	0.00	0.00	0.00	3.76	0.00	0.00	0.00	3.76	0.00	0.00	0.54	1.08	1.61	0.00	0.00	0.00	0.00	0.00
216.57	216.59	24/1/27-29	0.00	0.00	0.00	0.00	7.31	0.00	0.00	0.00	7.31	0.00	0.00	0.14	3.16	3.31	0.00	0.00	0.00	0.00	0.00
216.94	216.96	24/1/64-66	0.00	0.00	0.00	0.00	2.98	0.00	0.00	0.00	2.98	0.00	0.00	0.00	0.89	0.89	0.00	0.00	0.00	0.00	0.00
217.34	217.36	24/1/104-106	0.00	0.00	0.00	0.00	3.78	0.00	0.00	0.00	3.78	0.00	0.00	0.00	0.86	0.86	0.00	0.00	0.00	0.00	0.00
217.72	217.74	24/1/142-144	0.00	0.00	0.00	0.00	2.42	0.00	0.00	0.00	2.42	0.00	0.00	0.16	0.64	0.81	0.00	0.00	0.00	0.00	0.00
218.08	218.10	24/2/28-30	0.00	0.00	0.00	0.00	1.65	0.00	0.00	0.00	1.65	0.00	0.00	0.30	1.50	1.80	0.00	0.00	0.00	0.00	0.00
218.52	218.54	24/2/72-74	0.00	0.00	0.00	0.00	4.34	0.00	0.00	0.00	4.34	0.00	0.00	0.00	2.13	2.13	0.00	0.00	0.00	0.00	0.00
218.87	218.89	24/2/107-109	0.00	0.00	0.00	0.00	3.77	0.00	0.00	0.00	3.77	0.00	0.00	0.11	2.06	2.17	0.00	0.00	0.00	0.00	0.00
219.31	219.33	24/3/1-3	0.00	0.00	0.00	0.44	10.78	0.00	0.00	0.00	11.22	0.00	0.00	0.22	1.31	1.53	0.00	0.00	0.00	0.00	0.00
219.72	219.74	24/3/42-44	0.00	0.00	0.00	0.79	14.42	0.00	0.00	0.00	15.20	0.00	0.00	0.26	1.70	1.97	0.00	0.00	0.00	0.00	0.00
220.12	220.14	24/3/82-84	0.00	0.00	0.00	0.36	8.95	0.00	0.00	0.00	9.31	0.00	0.00	0.24	2.86	3.10	0.00	0.00	0.00	0.00	0.00
220.46	220.48	24/3/116-118	0.00	0.00	0.00	0.43	11.83	0.00	0.00	0.00	12.26	0.00	0.00	0.11	1.61	1.72	0.00	0.00	0.00	0.00	0.00
220.87	220.89	24/4/7-9	0.00	0.00	0.00	0.47	8.24	0.00	0.00	0.00	8.71	0.00	0.00	0.16	1.56	1.71	0.00	0.00	0.00	0.00	0.00
221.27	221.29	24/4/47-49	0.00	0.00	0.00	0.11	6.98	0.00	0.00	0.00	7.09	0.00	0.00	0.53	2.33	2.86	0.00	0.00	0.00	0.00	0.00
221.66	221.68	24/4/86-88	0.00	0.00	0.00	0.12	5.95	0.00	0.00	0.00	6.08	0.00	0.00	0.24	3.65	3.89	0.00	0.00	0.00	0.00	0.00
222.13	222.15	24/4/133-135	0.00	0.00	0.00	0.12	5.66	0.00	0.00	0.00	5.78	0.00	0.00	0.25	0.86	1.11	0.00	0.00	0.00	0.00	0.00
222.45	222.47	24/5/15-17	0.00	0.00	0.00	0.21	7.84	0.00	0.00	0.00	8.05	0.00	0.00	0.00	0.74	0.74	0.00	0.00	0.00	0.00	0.00
222.93	222.95	24/5/63-65	0.00	0.00	0.00	0.13	4.86	0.00	0.00	0.00	4.99	0.00	0.00	0.13	0.66	0.79	0.00	0.00	0.00	0.00	0.00
223.33	223.35	24/5/103-105	0.00	0.00	0.00	0.16	8.46	0.00	0.00	0.00	8.62	0.00	0.00	0.16	0.78	0.94	0.00	0.16	0.00	0.16	0.00
223.72	223.74	24/5/142-144	0.00	0.00	0.00	0.14	11.90	0.00	0.00	0.00	12.04	0.00	0.00	0.42	1.26	1.68	0.00	0.00	0.00	0.00	0.00
224.07	224.09	24/6/27-29	0.00	0.00	0.00	0.35	11.65	0.00	0.00	0.00	12.00	0.00	0.00	0.35	2.26	2.61	0.00	0.00	0.00	0.00	0.00
224.47	224.49	24/6/67-69	0.00	0.00	0.00	0.00	11.75	0.00	0.00	0.00	11.75	0.00	0.00	0.00	1.26	1.26	0.00	0.00	0.00	0.00	0.00
224.87	224.89	24/6/107-109	0.00	0.00	0.00	0.21	6.61	0.00	0.00	0.00	6.82	0.00	0.00	0.41	1.45	1.86	0.00	0.00	0.00	0.00	0.00
225.36	225.38	24CC/9-11	0.00	0.00	0.00	0.17	7.35	0.00	0.00	0.00	7.51	0.00	0.00	0.33	1.84	2.17	0.00	0.00	0.00	0.00	0.00
226.13	226.15	25/1/23-25	0.00	0.00	0.00	0.31	5.67	0.00	0.00	0.00	5.98	0.00	0.00	0.00	1.38	1.38	0.00	0.00	0.00	0.00	0.00
226.53	226.55	25/1/63-65	0.00	0.00	0.00	0.00	6.16	0.00	0.00	0.00	6.16	0.00	0.00	0.24	1.38	1.62	0.00	0.00	0.16	0.16	0.00
226.93	226.95	25/1/103-105	0.00	0.00	0.00	0.00	7.37	0.00	0.00	0.00	7.37	0.00	0.00	0.18	2.11	2.28	0.00	0.00	0.00	0.00	0.00
227.34	227.36	25/1/144-146	0.00	0.00	0.00	0.32	3.94	0.00	0.00	0.00	4.26	0.00	0.00	0.00	2.21	2.21	0.00	0.00	0.00	0.00	0.00
227.72	227.74	25/2/-32-34	0.00	0.00	0.00	0.00	4.14	0.00	0.00	0.00	4.14	0.00	0.00	0.19	3.20	3.38	0.00	0.00	0.00	0.00	0.00
228.12	228.14	25/2/72-74	0.00	0.00	0.00	0.62	3.70	0.00	0.00	0.00	4.32	0.00	0.00	0.12	2.72	2.84	0.00	0.00	0.00	0.00	0.00
228.52	228.54	25/2/112-114	0.00	0.00	0.00	0.82	3.18	0.00	0.00	0.00	4.00	0.00	0.00	0.41	3.28	3.69	0.00	0.00	0.00	0.00	0.00
228.90	228.92	25/3/0-2	0.00	0.00	0.00	0.78	6.01	0.00	0.00	0.00	6.78	0.00	0.00	0.00	4.65	4.65	0.00	0.00	0.00	0.00	0.00
229.33	229.35	25/3/43-45	0.00	0.00	0.00	0.12	2.00	0.00	0.00	0.00	2.12	0.00	0.00	0.59	3.65	4.24	0.00	0.00	0.00	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Menardella* cf. *limbata*	*Menardella* cf. *limbata?*	***Menardella***	*Neogloboquadrina dutertrei*	*Neogloboquadrina pachyderma*	*Neogloboquadrina m. continuosa*	*Neogloboquadrina mayeri* s.s.	*Neogloboquadrina m. nympha*	***Neogloboquadrina***	*Orbulina bilobata*	*Orbulina bilobata?*	*Orbulina universa*	*Orbulina universa* "juvenile"	***Orbulina***	*Sphaeroidinellopsis paenedehiscens*	*Sphaeroidinellopsis seminulina*	*Sphaeroidinellopsis* sp.?	***Sphaeroidinellopsis***	*Truncorotalia* aff. *crassaconica*
229.85	229.87	25/3/95-97	0.00	0.00	0.00	0.27	1.92	0.00	0.00	0.00	2.19	0.00	0.00	0.69	4.66	5.35	0.00	0.00	0.00	0.00	0.00
230.27	230.29	25/3/137-139	0.00	0.00	0.00	0.18	2.75	0.00	0.00	0.00	2.94	0.00	0.00	0.37	4.95	5.32	0.00	0.00	0.00	0.00	0.00
230.47	230.49	25/4/7-9	0.00	0.00	0.00	0.98	3.01	0.00	0.00	0.00	3.99	0.00	0.00	0.53	6.29	6.83	0.00	0.00	0.00	0.00	0.00
230.93	230.95	25/4/53-55	0.00	0.00	0.00	0.36	3.81	0.00	0.00	0.00	4.17	0.00	0.00	0.18	2.72	2.90	0.00	0.00	0.00	0.00	0.00
231.33	231.35	25/4/93-95	0.00	0.00	0.00	0.25	3.06	0.00	0.00	0.00	3.31	0.00	0.00	0.61	4.53	5.15	0.00	0.00	0.00	0.00	0.00
231.73	231.75	25/4/133-135	0.00	0.15	0.15	1.16	12.34	0.00	0.00	0.00	13.50	0.00	0.00	0.29	3.19	3.48	0.00	0.00	0.00	0.00	0.00
232.06	232.08	25/5/16-18	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.48	0.00	0.00	0.32	2.26	2.58	0.00	0.00	0.00	0.00	0.00
232.52	232.54	25/5/62-64	0.00	0.00	0.00	0.11	0.89	0.00	0.00	0.00	1.00	0.00	0.00	0.45	4.79	5.24	0.00	0.00	0.00	0.00	0.00
232.92	232.94	25/5/102-104	0.00	0.21	0.21	0.41	6.21	0.00	0.00	0.00	6.63	0.00	0.00	0.21	3.11	3.31	0.00	0.00	0.00	0.00	0.00
233.27	233.29	25/5137-139	0.18	0.00	0.18	1.06	5.49	0.00	0.00	0.00	6.55	0.00	0.00	0.00	2.12	2.12	0.00	0.00	0.00	0.00	0.00
233.67	233.69	25/6/27-29	0.00	0.00	0.00	0.00	0.54	0.00	0.00	0.00	0.54	0.00	0.00	0.27	2.01	2.28	0.00	0.00	0.00	0.00	0.00
234.15	234.17	25/6/75-77	0.00	0.00	0.00	0.12	0.36	0.00	0.00	0.00	0.49	0.00	0.00	0.36	2.19	2.55	0.00	0.00	0.00	0.00	0.00
234.52	234.54	25/6/112-114	0.00	0.00	0.00	0.00	1.07	0.00	0.00	0.00	1.07	0.00	0.00	0.53	2.57	3.10	0.00	0.00	0.00	0.00	0.00
234.91	234.93	25/7/1-3	0.00	0.00	0.00	0.14	1.57	0.00	0.00	0.00	1.71	0.00	0.00	0.57	1.71	2.28	0.00	0.00	0.00	0.00	0.00
235.26	235.28	25CC/10-22	0.00	0.16	0.16	0.00	3.26	0.00	0.00	0.00	3.26	0.00	0.00	0.81	3.42	4.23	0.00	0.00	0.00	0.00	0.00
235.73	235.75	26/1/23-25	0.00	0.00	0.00	0.00	7.87	0.00	0.00	0.00	7.87	0.00	0.00	0.46	1.85	2.31	0.00	0.00	0.00	0.00	0.00
236.08	236.10	26/1/58-60	0.00	0.00	0.00	0.32	9.00	0.00	0.00	0.00	9.32	0.00	0.00	0.32	2.89	3.22	0.00	0.00	0.00	0.00	0.00
236.52	236.54	26/1/102-104	0.00	0.00	0.00	0.29	3.23	0.00	0.00	0.00	3.52	0.00	0.00	0.00	3.37	3.37	0.00	0.00	0.00	0.00	0.00
236.92	236.94	26/1/142-144	0.00	0.24	0.24	0.48	1.69	0.00	0.00	0.00	2.17	0.00	0.00	0.00	2.17	2.17	0.00	0.00	0.00	0.00	0.00
237.32	237.34	26/2/32-34	0.00	0.00	0.00	0.14	7.53	0.00	0.00	0.00	7.67	0.00	0.00	0.85	2.84	3.69	0.00	0.00	0.00	0.00	0.00
237.93	237.95	26/2/93-95	0.00	0.00	0.00	0.00	4.10	0.00	0.00	0.00	4.10	0.00	0.00	0.82	1.84	2.66	0.00	0.00	0.00	0.00	0.00
238.33	238.35	26/2/133-135	0.00	0.00	0.00	0.19	8.10	0.00	0.00	0.00	8.29	0.00	0.00	0.94	1.32	2.26	0.00	0.00	0.00	0.00	0.00
238.51	238.53	26/3/1-3	0.00	0.00	0.00	0.93	7.91	0.00	0.00	0.00	8.84	0.00	0.00	0.23	1.86	2.09	0.00	0.00	0.00	0.00	0.00
238.93	238.95	26/3/43-45	0.00	0.00	0.00	0.00	2.45	0.00	0.00	0.00	2.45	0.00	0.00	0.14	1.15	1.29	0.00	0.00	0.00	0.00	0.00
239.32	239.34	26/3/82-84	0.00	0.00	0.00	0.27	7.36	0.00	0.00	0.00	7.63	0.00	0.00	0.14	1.63	1.77	0.00	0.00	0.00	0.00	0.00
239.67	239.69	26/3/117-119	0.00	0.00	0.00	0.00	2.79	0.00	0.00	0.00	2.79	0.00	0.00	0.70	1.74	2.44	0.00	0.00	0.00	0.00	0.00
240.07	240.09	26/4/7-9	0.00	2.62	2.62	0.00	3.54	0.00	0.00	0.00	3.54	0.00	0.00	0.62	2.00	2.62	0.00	0.00	0.00	0.00	0.00
240.52	240.54	26/4/52-54	0.00	0.00	0.00	0.48	4.73	0.00	0.00	0.00	5.21	0.00	0.00	0.00	0.68	0.68	0.00	0.00	0.00	0.00	0.00
240.92	240.94	26/4/92-94	0.00	0.11	0.11	0.00	1.97	0.00	0.00	0.00	1.97	0.00	0.00	0.44	1.10	1.54	0.00	0.00	0.00	0.00	0.00
241.32	241.34	26/4/132-134	0.00	0.00	0.00	0.00	1.67	0.00	0.00	0.00	1.67	0.00	0.00	0.30	2.12	2.43	0.00	0.00	0.00	0.00	0.00
241.65	241.67	26/5/15-17	0.00	0.00	0.00	0.00	4.90	0.00	0.00	0.00	4.90	0.00	0.00	0.30	1.48	1.78	0.00	0.00	0.00	0.00	0.00
242.13	242.15	26/5/63-65	0.00	0.87	0.87	0.00	2.39	0.00	0.00	0.00	2.39	0.00	0.00	0.65	1.52	2.17	0.00	0.00	0.00	0.00	0.00
242.52	242.54	26/5/102-104	0.00	0.00	0.00	0.36	2.90	0.00	0.00	0.00	3.27	0.00	0.00	0.36	0.91	1.27	0.00	0.00	0.00	0.00	0.00
242.92	242.94	26/5/142-144	0.00	0.00	0.00	0.45	8.07	0.00	0.00	0.00	8.52	0.00	0.00	0.00	1.94	1.94	0.00	0.00	0.00	0.00	0.00
243.26	243.28	26/6/26-28	0.00	0.00	0.00	0.00	6.15	0.00	0.00	0.00	6.15	0.00	0.00	0.38	0.58	0.96	0.00	0.00	0.00	0.00	0.00
243.63	243.65	26/6/63-65	0.00	0.00	0.00	1.37	16.67	0.00	0.00	0.00	18.04	0.00	0.00	0.23	0.46	0.68	0.00	0.00	0.00	0.00	0.00
243.86	243.88	26CC/13-15	0.00	0.00	0.00	1.66	9.02	0.00	0.00	0.00	10.68	0.00	0.00	0.74	1.47	2.21	0.00	0.00	0.00	0.00	0.00
245.11	245.13	27/1/1-3	0.00	0.00	0.00	0.31	14.31	0.00	0.00	0.00	14.62	0.00	0.00	0.15	0.77	0.92	0.00	0.00	0.00	0.00	0.00
245.53	245.55	27/1/43-45	0.00	0.00	0.00	0.14	6.89	0.00	0.00	0.00	7.03	0.00	0.00	0.56	0.84	1.41	0.00	0.00	0.00	0.00	0.00
245.91	245.93	27/1/81-83	0.00	0.00	0.00	0.00	4.67	0.00	0.00	0.00	4.67	0.00	0.00	0.00	0.42	0.42	0.00	0.00	0.00	0.00	0.00
246.27	246.29	27/1/117-119	0.00	0.00	0.00	0.14	1.74	0.00	0.00	0.00	1.88	0.00	0.00	0.43	2.32	2.75	0.00	0.00	0.00	0.00	0.00
246.52	246.54	27/1/142-144	0.00	0.00	0.00	0.21	3.55	0.00	0.00	0.00	3.75	0.00	0.00	0.00	2.29	2.29	0.00	0.00	0.00	0.00	0.00
246.87	246.89	27/2/27-29	0.00	0.00	0.00	0.00	5.69	0.00	0.00	0.00	5.69	0.00	0.00	0.24	1.45	1.69	0.00	0.00	0.00	0.00	0.00
247.33	247.35	27/2/73-76	0.00	0.00	0.00	0.00	8.36	0.00	0.00	0.00	8.36	0.00	0.00	0.00	2.42	2.42	0.00	0.00	0.00	0.00	0.00
247.67	247.69	27/2/107-109	0.00	0.00	0.00	0.36	7.50	0.00	0.00	0.00	7.86	0.00	0.00	0.24	1.45	1.69	0.00	0.00	0.00	0.00	0.00
248.11	248.13	27/3/1-3	0.00	0.00	0.00	0.00	6.37	0.00	0.00	0.00	6.37	0.00	0.00	0.19	0.94	1.12	0.00	0.00	0.00	0.00	0.00
248.47	248.49	27/3/37-39	0.00	0.00	0.00	0.74	7.77	0.00	0.00	0.00	8.51	0.00	0.00	0.00	0.74	0.74	0.00	0.00	0.00	0.00	0.00
248.93	248.95	27/3/83-85	0.00	0.00	0.00	0.24	9.16	0.00	0.00	0.00	9.40	0.00	0.00	0.00	0.72	0.72	0.00	0.00	0.00	0.00	0.00
249.27	249.27	27/3/117-119	0.00	0.00	0.00	0.27	8.42	0.00	0.00	0.00	8.70	0.00	0.00	0.00	0.27	0.27	0.00	0.00	0.00	0.00	0.00
249.67	249.69	27/4/7-9	0.00	0.00	0.00	0.00	6.51	0.00	0.00	0.00	6.51	0.00	0.00	0.34	1.23	1.57	0.00	0.00	0.00	0.00	0.00
250.12	250.14	27/4/52-54	0.00	0.00	0.00	0.00	3.66	0.00	0.00	0.00	3.66	0.00	0.00	0.14	0.70	0.85	0.00	0.00	0.00	0.00	0.00
250.46	250.48	27/4/86-88	0.00	0.00	0.00	0.40	5.73	0.00	0.00	0.00	6.13	0.00	0.00	0.20	1.38	1.58	0.00	0.00	0.00	0.00	0.00
250.92	250.94	27/4/132-134	0.00	0.00	0.00	0.00	9.57	0.00	0.00	0.00	9.57	0.00	0.00	0.74	1.47	2.21	0.00	0.00	0.00	0.00	0.00
251.33	251.36	27/5/23-26	0.00	0.00	0.00	0.63	14.22	0.00	0.00	0.00	14.85	0.00	0.00	0.00	1.42	1.42	0.00	0.00	0.00	0.00	0.00
251.67	251.69	27/5/57-59	0.00	0.00	0.00	0.73	21.68	0.00	0.00	0.00	22.40	0.00	0.00	0.18	1.09	1.28	0.00	0.00	0.00	0.00	0.00
252.13	252.15	27/5/103-105	0.00	0.00	0.00	0.00	16.74	0.00	0.00	0.00	16.74	0.00	0.00	0.73	1.31	2.04	0.00	0.00	0.00	0.00	0.00
252.53	252.55	27/5/143-145	0.00	0.00	0.00	0.16	5.92	0.00	0.00	0.00	6.09	0.00	0.00	0.00	0.82	0.82	0.00	0.00	0.00	0.00	0.00
252.92	252.94	27/6/32-34	0.00	0.00	0.00	0.00	10.32	0.00	0.00	0.00	10.32	0.00	0.00	0.33	1.00	1.33	0.00	0.00	0.00	0.00	0.00
253.33	253.35	27/6/73-75	0.00	0.00	0.00	0.00	8.15	0.00	0.00	0.00	8.15	0.00	0.00	0.28	1.12	1.40	0.00	0.00	0.00	0.00	0.00
253.67	253.69	27/6/107-109	0.00	0.00	0.00	0.00	3.29	0.00	0.00	0.00	3.29	0.00	0.00	0.27	1.64	1.92	0.00	0.00	0.00	0.00	0.00
254.10	254.12	27/7/0-2	0.00	0.00	0.00	0.00	4.13	0.00	0.00	0.00	4.13	0.00	0.00	0.00	1.27	1.27	0.00	0.00	0.00	0.00	0.00
254.49	254.51	27CC/10-12	0.00	0.00	0.00	0.72	10.51	0.00	0.00	0.00	11.23	0.00	0.00	0.24	0.97	1.21	0.00	0.00	0.00	0.00	0.00
254.93	254.95	28/1/23-25	0.00	0.00	0.00	0.00	4.15	0.00	0.00	0.00	4.15	0.00	0.00	0.00	2.46	2.46	0.00	0.00	0.00	0.00	0.00
255.28	255.30	28/1/58-60	0.00	0.00	0.00	0.00	7.12	0.00	0.00	0.00	7.12	0.00	0.00	0.15	0.61	0.76	0.00	0.00	0.00	0.00	0.00
255.73	255.75	28/1/103-105	0.00	0.00	0.00	0.00	6.40	0.00	0.00	0.00	6.40	0.00	0.00	0.00	0.94	0.94	0.00	0.00	0.00	0.00	0.00
256.11	256.13	28/1/141-143	0.00	0.00	0.00	0.00	3.26	0.00	0.00	0.00	3.26	0.23	0.00	0.23	1.16	1.63	0.00	0.00	0.00	0.00	0.00
256.53	256.55	28/2/33-35	0.00	0.00	0.00	0.35	1.91	0.00	0.00	0.00	2.25	0.00	0.00	0.17	2.95	3.12	0.00	0.00	0.00	0.00	0.00
257.03	257.05	28/2/83-85	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.00	0.65	0.00	0.00	0.22	0.22	0.43	0.00	0.00	0.00	0.00	0.00
257.33	257.35	28/2/113-115	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.23	0.00	0.00	0.23	0.93	1.16	0.00	0.00	0.00	0.00	0.00
257.71	257.73	28/3/1-3	0.00	0.00	0.00	0.00	0.63	0.00	0.00	0.00	0.63	0.00	0.00	0.00	2.08	2.08	0.00	0.00	0.00	0.00	0.00
258.12	258.14	28/3/42-44	0.00	0.17	0.17	0.00	0.50	0.00	0.00	0.00	0.50	0.00	0.00	0.50	1.51	2.01	0.00	0.00	0.00	0.00	0.00
258.54	258.56	28/3/84-86	0.00	0.00	0.00	0.00	1.31	0.00	0.00	0.00	1.31	0.00	0.00	0.00	1.31	1.31	0.26	0.00	0.00	0.26	0.00
259.07	259.09	28/3/137-139	0.00	0.00	0.00	0.00	8.70	0.00	0.00	0.00	8.70	0.00	0.00	0.00	2.30	2.30	0.00	0.00	0.00	0.00	0.00
259.53	259.55	28/4/33-35	0.00	0.00	0.00	0.33	7.67	0.00	0.00	0.00	7.99	0.00	0.00	0.33	3.43	3.75	0.00	0.00	0.00	0.00	0.00
259.86	259.88	28/4/66-68	0.00	0.00	0.00	0.00	5.88	0.00	0.00	0.00	5.88	0.00	0.00	0.00	1.28	1.28	0.00	0.00	0.00	0.00	0.00
260.28	260.30	28/4/108-110	0.00	0.00	0.00	0.16	6.53	0.00	0.00	0.00	6.69	0.00	0.00	0.31	1.71	2.02	0.00	0.00	0.00	0.00	0.00
260.54	260.56	28/4/134-136	0.00	0.00	0.00	0.15	0.44	0.00	0.00	0.00	0.59	0.00	0.00	0.15	1.62	1.77	0.00	0.00	0.00	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Menardella* cf. *limbata*	*Menardella* cf. *limbata?*	***Menardella***	*Neogloboquadrina dutertrei*	*Neogloboquadrina pachyderma*	*Neogloboquadrina m. continuosa*	*Neogloboquadrina mayeri* s.s.	*Neogloboquadrina m. nympha*	***Neogloboquadrina***	*Orbulina bilobata*	*Orbulina bilobata?*	*Orbulina universa*	*Orbulina universa* "juvenile"	***Orbulina***	*Sphaeroidinellopsis paenedehiscens*	*Sphaeroidinellopsis seminulina*	*Sphaeroidinellopsis* sp.?	***Sphaeroidinellopsis***	*Truncorotalia* aff. *crassaconica*
260.86	260.88	28/5/16-18	0.00	0.00	0.00	0.00	1.93	0.00	0.00	0.00	1.93	0.00	0.00	0.86	1.71	2.57	0.00	0.00	0.00	0.00	0.00
261.31	261.33	28/5/61-63	0.00	0.00	0.00	0.00	5.49	0.00	0.00	0.00	5.49	0.00	0.00	0.46	2.74	3.20	0.00	0.00	0.00	0.00	0.00
261.72	261.74	28/5/102-104	0.00	0.00	0.00	0.00	2.60	0.00	0.00	0.00	2.60	0.00	0.00	0.26	2.08	2.34	0.00	0.00	0.00	0.00	0.00
262.11	262.13	28/5/141-143	0.00	0.00	0.00	0.00	4.80	0.00	0.00	0.00	4.80	0.00	0.00	0.19	1.34	1.54	0.00	0.00	0.00	0.00	0.00
262.45	262.47	28CC/8-10	0.00	0.00	0.00	0.11	1.92	0.00	0.00	0.00	2.02	0.00	0.00	0.21	1.92	2.13	0.00	0.00	0.00	0.00	0.00
264.30	264.32	29/1/0-2	0.00	0.00	0.00	0.00	2.06	0.00	0.00	0.00	2.06	0.00	0.00	0.26	1.55	1.80	0.00	0.00	0.00	0.00	0.00
264.64	264.66	29/1/34-36	0.00	0.00	0.00	0.00	5.41	0.00	0.00	0.00	5.41	0.00	0.00	0.77	1.85	2.63	0.00	0.00	0.00	0.00	0.00
264.88	264.90	29/1/58-60	0.00	0.16	0.16	0.00	6.09	0.00	0.00	0.00	6.09	0.00	0.00	0.32	1.12	1.44	0.00	0.00	0.00	0.00	0.00
265.26	265.28	29/1/96-98	0.00	0.00	0.00	0.00	12.17	0.00	0.00	0.00	12.17	0.00	0.00	0.00	0.66	0.66	0.00	0.00	0.00	0.00	0.00
265.72	265.74	29/1/142-144	0.00	0.00	0.00	0.00	9.14	0.00	0.00	0.00	9.14	0.00	0.00	0.19	1.56	1.75	0.00	0.00	0.00	0.00	0.00
266.12	266.14	29/2/32-34	0.00	0.00	0.00	0.00	8.66	0.00	0.00	0.00	8.66	0.22	0.00	0.22	1.08	1.52	0.00	0.00	0.00	0.00	0.00
266.44	266.46	29/2/64-66	0.00	0.00	0.00	0.89	8.05	0.00	0.00	0.00	8.95	0.00	0.00	0.22	2.01	2.24	0.00	0.00	0.00	0.00	0.00
266.87	266.89	29/2/107-109	0.00	0.00	0.00	0.00	9.85	0.00	0.00	0.00	9.85	0.00	0.00	0.25	0.99	1.23	0.00	0.00	0.00	0.00	0.00
267.31	267.33	29/3/1-3	0.00	0.00	0.00	0.00	8.67	0.00	0.00	0.00	8.67	0.00	0.00	0.51	1.53	2.04	0.00	0.00	0.00	0.00	0.00
267.53	267.55	29/3/23-25	0.00	0.00	0.00	0.00	7.41	0.00	0.00	0.00	7.41	0.00	0.00	0.18	1.23	1.41	0.00	0.00	0.00	0.00	0.00
267.72	267.74	29/3/42-44	0.00	0.00	0.00	0.00	6.52	0.00	0.00	0.00	6.52	0.00	0.00	0.14	1.84	1.99	0.00	0.00	0.00	0.00	0.00
267.87	267.89	29/3/57-59	0.00	0.00	0.00	0.00	7.71	0.00	0.00	0.00	7.71	0.00	0.00	0.00	2.45	2.45	0.00	0.00	0.00	0.00	0.00
268.14	268.16	29/3/84-86	0.00	0.00	0.00	0.00	6.76	0.00	0.00	0.00	6.76	0.00	0.00	0.00	0.37	0.37	0.00	0.00	0.00	0.00	0.00
268.34	268.36	29/3/104-106	0.00	0.00	0.00	0.00	4.54	0.00	0.00	0.00	4.54	0.00	0.00	0.00	1.09	1.09	0.00	0.00	0.00	0.00	0.00
268.47	268.49	29/3/117-119	0.00	0.00	0.00	0.21	3.08	0.00	0.00	0.00	3.29	0.00	0.00	0.11	1.48	1.59	0.00	0.00	0.00	0.00	0.00
268.68	268.70	29/3/138-140	0.00	0.00	0.00	0.26	3.64	0.00	0.00	0.00	3.90	0.00	0.00	0.00	2.08	2.08	0.00	0.00	0.00	0.00	0.00
268.86	268.88	29/4/6-8	0.00	0.00	0.00	0.00	3.21	0.00	0.00	0.00	3.21	0.00	0.00	0.00	1.46	1.46	0.00	0.00	0.00	0.00	0.00
269.28	269.30	29/4/48-50	0.00	0.00	0.00	0.28	1.70	0.00	0.00	0.00	1.99	0.00	0.00	0.00	1.42	1.42	0.00	0.00	0.00	0.00	0.00
269.52	269.54	29/4/72-74	0.00	0.00	0.00	0.72	5.30	0.00	0.00	0.00	6.02	0.00	0.00	0.00	5.30	5.30	0.00	0.00	0.00	0.00	0.00
269.75	269.77	29/4/95-97	0.00	0.00	0.00	0.00	3.11	0.00	0.00	0.00	3.11	0.18	0.00	0.18	4.76	5.13	0.00	0.00	0.00	0.00	0.00
269.87	269.89	29/4/107-109	0.00	0.00	0.00	0.00	1.85	0.00	0.00	0.00	1.85	0.00	0.00	0.00	2.47	2.47	0.00	0.00	0.00	0.00	0.00
270.15	270.17	29/4/135-137	0.00	0.00	0.00	0.00	2.88	0.00	0.00	0.00	2.88	0.00	0.00	0.00	3.38	3.38	0.00	0.00	0.00	0.00	0.00
270.31	270.33	29/5/1-3	0.00	0.00	0.00	0.00	2.33	0.00	0.00	0.00	2.33	0.00	0.00	0.15	1.31	1.46	0.00	0.00	0.00	0.00	0.00
270.45	270.47	29/5/15-17	0.00	0.00	0.00	0.00	2.70	0.00	0.00	0.00	2.70	0.00	0.00	0.00	2.48	2.48	0.00	0.00	0.00	0.00	0.00
270.72	270.74	29/5/42-44	0.00	0.00	0.00	0.00	2.71	0.00	0.00	0.00	2.71	0.00	0.00	0.00	2.03	2.03	0.00	0.00	0.00	0.00	0.00
270.91	270.93	29/5/61-63	0.00	0.00	0.00	0.00	2.33	0.00	0.00	0.00	2.33	0.36	0.00	0.36	2.87	3.58	0.00	0.00	0.00	0.00	0.00
271.15	271.17	29/5/85-87	0.00	0.00	0.00	0.00	7.00	0.00	0.00	0.00	7.00	0.00	0.00	0.00	3.13	3.13	0.00	0.00	0.00	0.00	0.00
271.34	271.36	29/5/104-106	0.00	0.00	0.00	0.00	2.80	0.00	0.00	0.00	2.80	0.00	0.00	0.40	3.60	4.00	0.00	0.00	0.00	0.00	0.00
271.48	271.50	29/5/118-120	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.20	0.00	0.00	0.00	2.95	2.95	0.00	0.00	0.00	0.00	0.00
271.72	271.74	29/5/142-144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30	1.30	0.00	0.00	0.00	0.00	0.00
271.94	271.96	29/6/14-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.03	2.03	0.00	0.00	0.00	0.00	0.00
272.19	272.21	29CC/17-19	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.11	0.00	0.00	0.42	1.70	2.12	0.00	0.00	0.00	0.00	0.00
273.91	273.93	30/1/1-A7303	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.33	0.00	0.00	0.17	1.32	1.49	0.00	0.00	0.00	0.00	0.00
274.04	274.06	30/1/14-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	2.02	2.24	0.00	0.00	0.00	0.00	0.00
274.32	274.34	30/1/42-44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.74	1.74	0.00	0.00	0.00	0.00	0.00
274.48	274.50	30/1/58-60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	2.45	2.86	0.00	0.00	0.00	0.00	0.00
274.72	274.74	30/1/82-84	0.00	0.00	0.00	0.00	2.64	0.00	0.00	0.00	2.64	0.00	0.00	0.14	2.50	2.64	0.00	0.00	0.00	0.00	0.00
274.93	274.95	30/1/103-105	0.00	0.16	0.16	0.00	4.05	0.00	0.00	0.00	4.05	0.00	0.00	0.16	0.97	1.13	0.00	0.00	0.00	0.00	0.00
275.12	275.14	30/1/122-124	0.00	0.00	0.00	0.00	0.54	0.00	0.00	0.00	0.54	0.00	0.00	0.00	2.41	2.41	0.00	0.00	0.00	0.00	0.00
275.31	275.33	30/1/141-143	0.00	0.00	0.00	0.00	2.30	0.00	0.00	0.00	2.30	0.00	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00	0.00
275.45	275.47	30/2/5-7	0.00	0.00	0.00	0.00	5.78	0.00	0.00	0.00	5.78	0.00	0.00	0.36	2.35	2.71	0.00	0.00	0.00	0.00	0.00
275.93	275.95	30/2/53-55	0.00	0.00	0.00	0.00	4.92	0.00	0.00	0.00	4.92	0.00	0.00	0.33	0.82	1.15	0.00	0.00	0.00	0.00	0.00
276.52	276.54	30/2/112-114	0.00	0.00	0.00	0.38	3.05	0.00	0.00	0.00	3.43	0.00	0.00	0.00	1.14	1.14	0.00	0.00	0.00	0.00	0.00
276.91	276.93	30/3/1-3	0.00	0.00	0.00	0.00	5.96	0.00	0.00	0.00	5.96	0.00	0.00	0.17	1.36	1.53	0.00	0.00	0.00	0.00	0.00
277.33	277.35	30/3/43-45	0.00	0.15	0.15	0.00	3.98	0.00	0.00	0.00	3.98	0.00	0.00	0.00	0.92	0.92	0.00	0.00	0.00	0.00	0.00
277.74	277.76	30/3/84-86	0.00	0.16	0.16	0.00	4.22	0.00	0.00	0.00	4.22	0.00	0.00	0.00	1.41	1.41	0.00	0.00	0.00	0.00	0.00
278.07	278.09	30/3/117-119	0.00	0.66	0.66	0.00	3.17	0.00	0.00	0.00	3.17	0.00	0.00	0.40	1.06	1.46	0.00	0.00	0.00	0.00	0.00
278.49	278.51	30/4/9-11	0.45	0.00	0.45	0.00	3.68	0.00	0.00	0.00	3.68	0.00	0.00	0.00	0.89	0.89	0.00	0.00	0.00	0.00	0.00
278.88	278.90	30/4/48-50	0.00	0.65	0.65	0.00	5.05	0.00	0.00	0.00	5.05	0.00	0.00	0.33	1.63	1.95	0.00	0.00	0.00	0.00	0.00
279.33	279.35	30/4/93-95	0.00	0.00	0.00	0.00	3.18	0.00	0.00	0.00	3.18	0.00	0.00	0.00	1.31	1.31	0.00	0.00	0.00	0.00	0.00
279.75	279.77	30/4/135-137	0.00	0.00	0.00	0.00	3.80	0.00	0.00	0.00	3.80	0.00	0.00	0.17	1.55	1.73	0.00	0.00	0.00	0.00	0.00
280.05	280.07	30/5/15-17	0.00	0.00	0.00	0.00	2.33	0.00	0.00	0.00	2.33	0.00	0.00	0.00	0.49	0.49	0.00	0.00	0.00	0.00	0.00
280.25	280.27	30/5/35-37	0.00	0.00	0.00	0.53	3.81	0.00	0.00	0.00	4.34	0.00	0.00	0.00	1.06	1.06	0.00	0.00	0.00	0.00	0.00
280.92	280.94	30/5/102-104	0.00	0.00	0.00	0.00	11.07	0.00	0.00	0.00	11.07	0.00	0.00	0.18	2.86	3.04	0.00	0.00	0.00	0.00	0.00
283.51	283.53	31/1/1-3	0.00	0.00	0.00	0.44	8.35	0.00	0.00	0.00	8.78	0.00	0.00	0.00	1.76	1.76	0.00	0.00	0.00	0.00	0.00
283.94	283.96	31/1/44-46	0.00	0.00	0.00	0.00	10.18	0.00	0.00	0.00	10.18	0.00	0.00	0.00	1.50	1.50	0.00	0.00	0.00	0.00	0.00
284.33	284.35	31/1/83-85	0.00	0.15	0.15	0.00	9.51	0.00	0.00	0.00	9.51	0.00	0.00	0.15	1.07	1.23	0.00	0.00	0.00	0.00	0.00
284.55	284.57	31/1/105-107	0.00	0.00	0.00	0.59	9.11	0.00	0.00	0.00	9.70	0.00	0.00	0.24	1.54	1.78	0.00	0.00	0.00	0.00	0.00
284.88	284.90	31/1/138-140	0.00	0.00	0.00	0.00	12.38	0.00	0.00	0.00	12.38	0.00	0.00	0.00	2.42	2.42	0.00	0.00	0.00	0.00	0.00
285.29	285.31	31/2/29-31	0.00	0.00	0.00	0.00	6.88	0.00	0.00	0.00	6.88	0.00	0.00	0.31	0.63	0.94	0.00	0.00	0.00	0.00	0.00
285.73	285.75	31/2/73-75	0.00	0.00	0.00	0.00	1.52	0.00	0.00	0.00	1.52	0.00	0.00	0.00	0.51	0.51	0.00	0.00	0.00	0.00	0.00
286.10	286.12	31/2/110-112	0.00	0.00	0.00	0.00	3.29	0.00	0.00	0.00	3.29	0.00	0.00	0.14	1.43	1.57	0.00	0.00	0.00	0.00	0.00
286.51	286.53	31/3/1-3	0.00	0.00	0.00	0.11	2.55	0.00	0.00	0.00	2.65	0.00	0.00	0.00	0.64	0.64	0.00	0.00	0.00	0.00	0.00
286.88	286.90	31/3/38-40	0.00	0.00	0.00	0.00	4.12	0.00	0.00	0.00	4.12	0.00	0.00	0.00	0.54	0.54	0.00	0.00	0.00	0.00	0.00
287.32	287.34	31/3/82-84	0.00	0.00	0.00	0.00	7.42	0.00	0.00	0.00	7.42	0.00	0.00	0.00	1.24	1.24	0.00	0.00	0.00	0.00	0.00
287.67	287.69	31/3/117-119	0.00	0.00	0.00	0.00	11.06	0.00	0.00	0.00	11.06	0.00	0.00	0.00	0.24	0.24	0.00	0.00	0.00	0.00	0.00
288.08	288.10	31/4/8-10	0.00	0.00	0.00	0.00	3.98	0.00	0.00	0.00	3.98	0.00	0.00	0.00	1.05	1.05	0.00	0.00	0.00	0.00	0.00
288.55	288.57	31/4/55-57	0.00	0.00	0.00	0.00	5.79	0.00	0.00	0.00	5.79	0.00	0.00	0.00	1.34	1.34	0.00	0.00	0.00	0.00	0.00
288.89	288.91	31/4/89-91	0.00	0.00	0.00	0.27	3.77	0.00	0.00	0.00	4.04	0.00	0.00	0.00	1.62	1.62	0.00	0.00	0.00	0.00	0.00
289.34	289.36	31/4/134-136	0.00	0.00	0.00	0.36	17.22	0.00	0.00	0.00	17.58	0.00	0.00	0.00	0.48	0.48	0.00	0.00	0.00	0.00	0.00
289.73	289.75	31/5/23-25	0.00	0.00	0.00	0.00	17.31	0.00	0.00	0.00	17.31	0.00	0.00	0.00	1.79	1.79	0.00	0.00	0.00	0.00	0.00
290.12	290.14	31/5/62-64	0.00	0.00	0.00	0.00	6.65	0.00	0.00	0.00	6.65	0.00	0.00	0.00	1.46	1.46	0.00	0.00	0.00	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Menardella* cf. *limbata*	*Menardella* cf. *limbata* ?	***Menardella***	*Neogloboquadrina dutertrei*	*Neogloboquadrina pachyderma*	*Neogloboquadrina m. continuosa*	*Neogloboquadrina mayeri* s.s.	*Neogloboquadrina m. nympha*	***Neogloboquadrina***	*Orbulina bilobata*	*Orbulina bilobata* ?	*Orbulina universa*	*Orbulina universa* "juvenile"	***Orbulina***	*Sphaeroidinellopsis paenedehiscens*	*Sphaeroidinellopsis seminulina*	*Sphaeroidinellopsis* sp.?	***Sphaeroidinellopsis***	*Truncorotalia* aff. *crassaconica*
290.51	290.53	31/5/101-103	0.00	0.00	0.00	0.87	6.30	0.00	0.00	0.00	7.17	0.00	0.00	0.00	0.87	0.87	0.00	0.00	0.00	0.00	0.00
290.74	290.76	31CC/0-2	0.00	0.00	0.00	0.13	13.47	0.00	0.00	0.00	13.60	0.00	0.00	0.13	0.89	1.02	0.00	0.00	0.00	0.00	0.00
293.11	293.13	32/1/1-3	0.00	0.00	0.00	0.81	8.93	0.00	0.00	0.00	9.74	0.00	0.00	0.00	1.95	1.95	0.00	0.00	0.16	0.16	0.00
293.33	293.35	32/1/23-25	0.00	0.00	0.00	0.15	14.54	0.00	0.00	0.00	14.68	0.00	0.00	0.00	0.44	0.44	0.00	0.00	0.00	0.00	0.00
293.71	293.73	32/1/61-63	0.00	0.00	0.00	0.33	21.23	0.00	0.00	0.00	21.56	0.17	0.00	0.00	1.00	1.16	0.00	0.00	0.00	0.00	0.00
294.12	294.14	32/1/102-104	0.00	0.00	0.00	0.18	13.31	0.00	0.00	0.00	13.49	0.00	0.00	0.00	1.05	1.05	0.00	0.00	0.00	0.00	0.00
294.51	294.53	32/1/141-143	0.00	0.00	0.00	0.08	13.74	0.00	0.00	0.00	13.82	0.00	0.00	0.00	0.56	0.56	0.00	0.00	0.00	0.00	0.00
294.90	294.92	32/2/30-32	0.00	0.00	0.00	0.00	5.90	0.00	0.00	0.00	5.90	0.00	0.00	0.00	1.48	1.48	0.00	0.00	0.00	0.00	0.00
295.33	295.35	32/2/73-75	0.00	0.00	0.00	0.00	2.04	0.00	0.00	0.00	2.04	0.14	0.00	0.00	0.68	0.81	0.00	0.00	0.00	0.00	0.00
295.73	295.75	32/2/113-115	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.87	1.87	0.00	0.00	0.00	0.00	0.00
295.93	295.95	32/2/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	1.20	1.40	0.00	0.00	0.00	0.00	0.00
296.50	296.52	32/3/40-42	0.32	0.00	0.32	0.00	0.16	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.32	0.32	0.00	0.00	0.00	0.00	0.00
296.93	296.95	32/3/83-85	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.84	0.84	0.00	0.00	0.00	0.00	0.00
297.33	297.35	32/3/123-125	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.86	0.86	0.00	0.00	0.00	0.00	0.00
297.70	297.72	32/4/10-12	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.28	0.28	0.00	0.00	0.00	0.00	0.00
298.08	298.10	32/4/48-50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.12	2.12	0.00	0.00	0.00	0.00	0.00
298.52	298.54	32/4/92-94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.86	0.86	0.00	0.00	0.00	0.00	0.00
298.93	298.95	32/4/133-135	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.97	0.97	0.00	0.00	0.00	0.00	0.00
299.38	299.40	32/5/28-30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.24	2.24	0.00	0.00	0.00	0.00	0.00
299.67	299.69	32CC/2-4	0.00	0.00	0.00	0.10	3.13	0.00	0.00	0.00	3.24	0.00	0.00	0.00	1.78	1.78	0.00	0.00	0.00	0.00	0.00
302.71	302.73	33/1/1-3	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	2.11	2.11	0.00	0.00	0.00	0.00	0.00
302.97	302.99	33/1/27-29	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00	0.54	0.00	0.00	0.00	2.51	2.51	0.00	0.00	0.00	0.00	0.00
303.29	303.31	33/1/59-61	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.16	0.00	0.00	0.00	1.44	1.44	0.00	0.00	0.00	0.00	0.00
303.77	303.79	33/1/107-109	0.00	0.00	0.00	0.00	0.00	0.00	1.16	0.00	1.16	0.17	0.00	0.00	1.66	1.83	0.00	0.00	0.00	0.00	0.00
304.13	304.15	33/1/143-145	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.39	0.00	0.00	0.00	3.31	3.31	0.00	0.00	0.00	0.00	0.00
304.29	304.31	33/2/9-11	0.00	0.00	0.00	0.00	0.00	0.18	0.18	0.00	0.36	0.00	0.00	0.00	1.60	1.60	0.00	0.00	0.00	0.00	0.00
304.47	304.49	33/2/27-29	0.00	0.00	0.00	0.10	0.00	0.00	0.21	0.00	0.31	0.00	0.00	0.00	1.87	1.87	0.00	0.00	0.00	0.00	0.00
304.66	304.68	33/2/46-48	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.00	0.53	0.00	0.00	0.00	2.12	2.12	0.00	0.00	0.00	0.00	0.00
305.02	305.04	33/2/82-84	0.00	0.00	0.00	0.00	0.00	0.32	0.16	0.00	0.49	0.00	0.00	0.00	1.94	1.94	0.00	0.00	0.00	0.00	0.00
305.15	305.17	33/2/95-97	0.00	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.65	0.00	0.00	0.00	1.08	1.08	0.00	0.00	0.00	0.00	0.00
305.34	305.36	33/2/114-116	0.00	0.00	0.00	0.00	0.00	0.00	0.83	0.00	0.83	0.00	0.00	0.00	2.90	2.90	0.00	0.00	0.00	0.00	0.00
305.55	305.57	33/2/135-137	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.00	0.53	0.00	0.00	0.00	2.32	2.32	0.00	0.00	0.00	0.00	0.00
305.71	305.73	33/3/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.67	1.67	0.00	0.00	0.00	0.00	0.00
305.93	305.95	33/3/23-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.69	2.69	0.00	0.00	0.00	0.00	0.00
306.11	306.13	33/3/41-43	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.00	0.59	0.00	0.00	0.00	1.98	1.98	0.00	0.00	0.00	0.00	0.00
306.27	306.29	33/3/57-59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.30	3.30	0.00	0.00	0.00	0.00	0.00
306.54	306.56	33/3/84-86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.20	3.20	0.00	0.00	0.00	0.00	0.00
306.75	306.77	33/3/105-107	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.85	1.85	0.00	0.00	0.00	0.00	0.00
306.86	306.88	33/3/116-118	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.00	2.62	2.84	0.00	0.00	0.00	0.00	0.00
307.08	307.10	33/3/138-140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.30	4.30	0.00	0.00	0.00	0.00	0.00
307.30	307.32	33/4/10-12	0.00	0.00	0.00	0.00	0.00	0.26	0.26	0.00	0.52	0.00	0.00	0.00	10.31	10.31	0.00	0.00	0.00	0.00	0.00
307.49	307.51	33/4/29-31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.76	4.76	0.00	0.00	0.00	0.00	0.00
307.70	307.72	33/4/50-52	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.25	0.00	0.00	0.00	4.76	4.76	0.00	0.00	0.00	0.00	0.00
307.93	307.95	33/4/73-75	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.58	0.00	0.00	0.00	2.53	2.53	0.00	0.00	0.00	0.00	0.00
308.14	308.16	33/4/94-96	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.16	0.00	0.00	0.00	0.97	0.97	0.00	0.00	0.00	0.00	0.00
308.30	308.32	33/4/110-112	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.23	0.00	0.00	0.00	4.05	4.05	0.00	0.00	0.00	0.00	0.00
308.53	308.55	33/4/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.29	3.29	0.00	0.00	0.00	0.00	0.00
308.71	308.73	33/5/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.92	3.05	3.97	0.00	0.00	0.00	0.00	0.00
308.99	309.01	33/5/29-31	0.00	0.00	0.00	0.00	0.00	0.43	0.21	0.00	0.64	0.00	0.00	0.00	3.84	3.84	0.00	0.00	0.00	0.00	0.00
309.11	309.13	33/5/41-43	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.20	0.00	0.00	0.00	2.45	2.45	0.00	0.00	0.00	0.00	0.00
309.28	309.30	33/5/58-60	0.00	0.00	0.00	0.00	0.00	0.61	0.31	0.00	0.92	0.00	0.00	0.00	1.53	1.53	0.00	0.00	0.00	0.00	0.00
309.54	309.56	33/5/84-86	0.00	0.00	0.00	0.00	0.00	0.98	0.74	0.62	2.34	0.12	0.00	0.00	1.60	1.72	0.00	0.00	0.00	0.00	0.00
309.74	309.76	33/5/104-106	0.00	0.00	0.00	0.00	0.00	2.12	0.80	0.13	3.05	0.00	0.00	0.00	2.92	2.92	0.00	0.00	0.00	0.00	0.00
312.31	312.33	34/1/1-3	0.00	0.00	0.00	0.00	0.00	3.05	0.72	0.00	3.76	0.18	0.00	0.00	3.58	3.76	0.00	0.00	0.00	0.00	0.00
312.54	312.56	34/1/24-26	0.00	0.00	0.00	0.00	0.00	0.79	1.78	0.20	2.77	0.00	0.00	0.00	4.55	4.55	0.00	0.00	0.00	0.00	0.00
312.67	312.69	34/1/37-39	0.00	0.00	0.00	0.00	0.00	1.48	1.48	0.63	3.59	0.00	0.00	0.00	5.27	5.27	0.00	0.00	0.00	0.00	0.00
312.87	312.89	34/1/57-59	0.00	0.00	0.00	0.00	0.00	1.36	1.59	0.91	3.86	0.00	0.00	0.00	3.86	3.86	0.00	0.00	0.00	0.00	0.00
313.07	313.09	34/1/77-79	0.00	0.00	0.00	0.00	0.00	0.86	1.07	0.21	2.15	0.00	0.00	0.00	4.29	4.29	0.00	0.00	0.00	0.00	0.00
313.31	313.33	34/1/101-103	0.00	0.00	0.00	0.00	0.00	2.24	1.63	0.82	4.69	0.00	0.00	0.00	2.86	2.86	0.00	0.00	0.00	0.00	0.00
313.53	313.55	34/1/123-125	0.00	0.00	0.00	0.00	0.00	3.23	1.53	0.34	5.09	0.00	0.00	0.00	5.09	5.09	0.00	0.00	0.00	0.00	0.00
313.71	313.73	34/1/141-143	0.00	0.00	0.00	0.00	0.00	3.77	2.04	0.63	6.44	0.00	0.00	0.00	4.55	4.55	0.00	0.00	0.00	0.00	0.00
313.90	313.92	34/2/10-12	0.00	0.00	0.00	0.00	0.00	4.37	4.37	2.19	10.93	0.00	0.00	0.00	3.38	3.38	0.00	0.00	0.00	0.00	0.00
314.09	314.11	34/2/29-31	0.00	0.00	0.00	0.00	0.00	7.69	4.51	1.86	14.06	0.00	0.00	0.00	5.84	5.84	0.00	0.00	0.00	0.00	0.00
314.29	314.31	34/2/49-51	0.00	0.00	0.00	0.00	0.00	6.22	2.49	2.49	11.19	0.00	0.00	0.00	4.73	4.73	0.00	0.00	0.00	0.00	0.00
314.45	314.47	34/2/65-67	0.00	0.00	0.00	0.00	0.00	16.81	9.88	5.16	31.86	0.00	0.00	0.00	1.92	1.92	0.00	0.00	0.00	0.00	0.00
314.69	314.71	34/2/89-91	0.00	0.00	0.00	0.00	0.00	12.10	5.72	2.53	20.35	0.00	0.00	0.00	1.20	1.20	0.00	0.00	0.00	0.00	0.00
314.90	314.92	34/2/110-112	0.00	0.00	0.00	0.00	0.00	10.65	2.92	1.46	15.03	0.00	0.00	0.00	2.51	2.51	0.00	0.00	0.00	0.00	0.00
315.13	315.15	34/2/133-135	0.00	0.00	0.00	0.00	0.00	9.61	3.87	3.01	16.50	0.00	0.00	0.00	1.43	1.43	0.00	0.00	0.00	0.00	0.00
315.30	315.32	34/3/0-2	0.00	0.00	0.00	0.00	0.00	5.87	1.68	0.56	8.10	0.00	0.00	0.00	1.68	1.68	0.00	0.00	0.00	0.00	0.00
315.52	315.54	34/3/22-24	0.00	0.00	0.00	0.00	0.00	2.49	2.29	2.49	7.28	0.21	0.00	0.00	3.33	3.53	0.00	0.00	0.00	0.00	0.00
315.71	315.73	34/3/41-43	0.00	0.00	0.00	0.00	0.00	3.67	2.16	0.43	6.26	0.00	0.00	0.00	3.02	3.02	0.00	0.00	0.00	0.00	0.00
316.06	316.08	34/3/76-78	0.00	0.00	0.00	0.00	0.00	4.74	1.72	0.86	7.33	0.14	0.00	0.00	1.87	2.01	0.00	0.00	0.00	0.00	0.00
316.27	316.29	34/3/97-99	0.00	0.00	0.00	0.00	0.00	9.04	2.77	1.75	13.57	0.00	0.00	0.00	2.67	2.67	0.00	0.00	0.00	0.00	0.00
316.48	316.50	34/3/118-120	0.00	0.00	0.00	0.00	0.00	10.02	2.84	0.57	13.42	0.00	0.00	0.00	2.08	2.08	0.00	0.00	0.00	0.00	0.00
316.67	316.69	34/3/137-139	0.00	0.00	0.00	0.00	0.00	9.95	4.98	1.58	16.52	0.00	0.00	0.00	2.71	2.71	0.00	0.00	0.00	0.00	0.00
317.10	317.12	34/4/30-32	0.00	0.00	0.00	0.00	0.00	9.12	5.03	1.12	15.27	0.00	0.00	0.19	2.23	2.42	0.00	0.00	0.00	0.00	0.00
317.50	317.52	34/4/70-72	0.00	0.00	0.00	0.00	0.00	10.60	3.37	3.13	17.11	0.00	0.00	0.00	1.93	1.93	0.00	0.00	0.00	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Menardella* cf. *limbata*	*Menardella* cf. *limbata*?	***Menardella***	*Neogloboquadrina dutertrei*	*Neogloboquadrina pachyderma*	*Neogloboquadrina m. continuosa*	*Neogloboquadrina mayeri* s.s.	*Neogloboquadrina m. nympha*	***Neogloboquadrina***	*Orbulina bilobata*	*Orbulina bilobata*?	*Orbulina universa*	*Orbulina universa* "juvenile"	***Orbulina***	*Sphaeroidinellopsis paenedehiscens*	*Sphaeroidinellopsis seminulina*	*Sphaeroidinellopsis* sp.?	***Sphaeroidinellopsis***	*Truncorotalia* aff. *crassaconica*
317.90	317.92	34/4/110-112	0.00	0.00	0.00	0.00	0.00	9.90	5.45	2.23	17.57	0.00	0.00	0.00	0.99	0.99	0.00	0.00	0.00	0.00	0.00
318.35	318.37	34/5/5-7	0.00	0.00	0.00	0.00	0.00	9.82	6.13	3.07	19.02	0.00	0.00	0.00	3.68	3.68	0.00	0.00	0.00	0.00	0.00
318.60	318.62	34/5/30-32	0.00	0.00	0.00	0.00	0.00	8.75	3.52	0.85	13.12	0.00	0.00	0.00	3.40	3.40	0.00	0.00	0.00	0.00	0.00
321.91	321.93	35/1/1-3	0.00	0.00	0.00	0.00	0.00	8.53	5.48	0.81	14.81	0.16	0.00	0.00	3.06	3.22	0.00	0.00	0.00	0.00	0.00
322.33	322.35	35/1/43-45	0.00	0.00	0.00	0.00	0.00	5.84	3.59	1.23	10.66	0.00	0.00	0.00	3.07	3.07	0.00	0.00	0.00	0.00	0.00
322.72	322.74	35/1/82-84	0.00	0.00	0.00	0.00	0.00	9.20	2.20	1.80	13.20	0.40	0.00	0.00	2.40	2.80	0.00	0.00	0.00	0.00	0.00
323.09	323.11	35/1/119-121	0.00	0.00	0.00	0.00	0.00	7.98	3.42	1.71	13.12	0.00	0.00	0.00	3.99	3.99	0.00	0.00	0.00	0.00	0.00
323.48	323.50	35/2/8-10	0.00	0.00	0.00	0.00	0.00	17.25	5.12	2.16	24.53	0.00	0.00	0.00	7.82	7.82	0.00	0.00	0.00	0.00	0.00
323.91	323.93	35/2/51-53	0.00	0.00	0.00	0.00	0.00	28.96	7.97	9.15	46.07	0.00	0.00	0.00	2.15	2.15	0.00	0.00	0.00	0.00	0.00
324.50	324.52	35/2/110-112	0.00	0.00	0.00	0.00	0.00	26.70	5.39	4.22	36.30	0.00	0.00	0.00	3.04	3.04	0.00	0.00	0.00	0.00	0.00
324.91	324.93	35/3/1-3	0.00	0.00	0.00	0.00	0.00	22.12	5.01	4.42	31.56	0.00	0.00	0.00	1.18	1.18	0.00	0.00	0.00	0.00	0.00
325.33	325.35	35/3/43-45	0.00	0.00	0.00	0.00	0.00	22.84	7.67	5.22	35.73	0.00	0.00	0.00	1.79	1.79	0.00	0.00	0.00	0.00	0.00
325.71	325.73	35/3/81-83	0.00	0.00	0.00	0.00	0.00	18.10	7.91	3.75	29.76	0.00	0.00	0.00	1.21	1.21	0.00	0.00	0.00	0.00	0.00
325.94	325.96	35/3/104-106	0.00	0.00	0.00	0.00	0.00	26.33	13.64	2.86	42.84	0.00	0.00	0.00	2.59	2.59	0.00	0.00	0.00	0.00	0.00
326.28	326.30	35/3/138-140	0.00	0.00	0.00	0.00	0.00	14.06	7.14	3.23	24.42	0.00	0.00	0.00	0.69	0.69	0.00	0.00	0.00	0.00	0.00
326.70	326.72	35/4/30-32	0.00	0.00	0.00	0.00	0.00	12.14	4.64	1.07	17.86	0.00	0.00	0.00	0.36	0.36	0.00	0.18	0.00	0.18	0.00
327.09	327.11	35/4/69-71	0.00	0.00	0.00	0.00	0.00	7.72	3.86	2.70	14.29	0.00	0.00	0.00	2.70	2.70	0.00	0.00	0.00	0.00	0.00
327.50	327.52	35/4/110-112	0.00	0.00	0.00	0.00	0.00	7.52	21.65	3.61	32.78	0.00	0.00	0.00	1.50	1.50	0.00	0.00	0.00	0.00	0.00
327.91	327.93	35/5/1-3	0.00	0.00	0.00	0.00	0.00	11.11	6.06	1.68	18.86	0.00	0.00	0.00	1.52	1.52	0.00	0.00	0.00	0.00	0.00
328.27	328.29	35/5/37-39	0.00	0.00	0.00	0.00	0.00	33.57	5.90	3.79	43.26	0.00	0.00	0.00	3.79	3.79	0.14	0.00	0.00	0.14	0.00
328.72	328.74	35/5/82-84	0.00	0.00	0.00	0.00	0.00	36.04	15.58	4.33	55.95	0.00	0.00	0.00	1.52	1.52	0.00	0.00	0.00	0.00	0.00
331.69	331.71	36/1/19-21	0.00	0.00	0.00	0.00	0.00	28.87	6.92	3.53	39.32	0.00	0.00	0.00	1.62	1.62	0.00	0.00	0.00	0.00	0.00
332.11	332.13	36/1/61-63	0.00	0.00	0.00	0.00	0.00	10.44	3.80	1.71	15.94	0.00	0.00	0.19	3.61	3.80	0.00	0.00	0.00	0.00	0.00
332.68	332.70	36/1/118-120	0.00	0.00	0.00	0.00	0.00	8.39	6.02	0.22	14.62	0.22	0.00	0.43	1.72	2.37	0.00	0.00	0.00	0.00	0.00
332.98	333.00	36/1/148-150	0.00	0.00	0.00	0.00	0.00	9.03	10.35	4.85	24.23	0.00	0.00	0.00	1.76	1.76	0.00	0.00	0.00	0.00	0.00
333.40	333.42	36/2/40-42	0.00	0.00	0.00	0.00	0.00	32.86	12.61	6.93	52.40	0.00	0.00	0.00	0.36	0.36	0.00	0.00	0.00	0.00	0.00
334.00	334.02	36/2/100-102	0.00	0.00	0.00	0.00	0.00	19.18	10.96	4.31	34.44	0.00	0.00	0.00	1.37	1.37	0.00	0.00	0.00	0.00	0.00
334.36	334.38	36/2/136-138	0.00	0.00	0.00	0.00	0.00	31.03	11.03	4.37	46.44	0.00	0.00	0.23	2.07	2.30	0.00	0.00	0.00	0.00	0.00
334.87	334.89	36/3/37-39	0.00	0.00	0.00	0.00	0.00	3.05	2.89	0.00	5.94	0.00	0.00	0.00	1.28	1.28	0.00	0.00	0.00	0.00	0.00
335.47	335.49	36/3/97-99	0.00	0.00	0.00	0.00	0.00	3.64	1.09	0.00	4.74	0.00	0.00	0.18	2.91	3.10	0.00	0.00	0.00	0.00	0.00
335.88	335.90	36/3/138-140	0.00	0.00	0.00	0.00	0.00	3.89	3.05	0.00	6.94	0.00	0.00	0.00	3.72	3.72	0.00	0.00	0.00	0.00	0.00
336.20	336.22	36/4/20-22	0.00	0.00	0.00	0.00	0.00	3.65	2.16	0.17	5.98	0.00	0.00	0.00	2.16	2.16	0.00	0.00	0.00	0.00	0.00
336.60	336.62	36/4/60-62	0.00	0.00	0.00	0.00	0.00	2.85	2.55	0.60	6.00	0.00	0.00	0.00	4.05	4.05	0.00	0.00	0.00	0.00	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Truncorotalia* aff. *crassaformis*	*Truncorotalia crassaformis*	*Truncorotalia juanai*	*Truncorotalia juanai?*	*Truncorotalia praecrassaformis*	*Truncorotalia praecrassaformis?*	***Truncorotalia***	*Zeaglobigerina nepenthes*	*Zeaglobigerina nepenthes?*	*Zeaglobigerina* sp.	*Zeaglobigerina woodi apertura*	*Zeaglobigerina woodi apertura?*	*Zeaglobigerina woodi decoraperta*	*Zeaglobigerina wodi decoraperta?*	*Zeaglobigerina woodi woodi*	*Zeaglobigerina wooodi woodi?*	***Zeaglobigerina***	Misc: unidentified planktics
120.30	120.33	14/1/0-3	0.00	0.25	0.00	0.00	0.00	0.00	0.25	0.25	0.00	19.04	0.00	0.00	0.00	0.00	2.54	0.00	21.83	0.00
120.51	120.54	14/1/21-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.29	0.00	0.00	0.00	0.00	1.84	0.00	24.13	0.00
120.69	120.72	14/1/39-42	0.00	0.00	0.00	0.23	0.00	0.00	0.23	0.00	0.23	21.77	0.00	0.00	0.00	0.00	1.36	0.00	23.36	0.00
120.90	120.93	14/1/60-63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.44	0.22	0.00	0.00	0.00	1.94	0.00	21.60	0.00
121.11	121.14	14/1/81-84	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.00	17.63	0.00	0.00	0.00	0.00	2.09	0.00	19.72	0.00
121.26	121.29	14/1/96-99	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	20.82	0.00	0.00	0.00	0.21	4.94	0.00	25.97	0.00
121.49	121.52	14/1/119-122	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	0.00	19.36	0.00	0.00	0.00	0.00	4.34	0.00	23.70	0.00
121.69	121.72	14/1/139-142	0.00	0.37	0.00	0.00	0.00	0.00	0.37	0.00	0.00	20.63	0.00	0.00	0.00	0.00	5.20	0.00	25.84	0.00
121.90	121.93	14/2/10-13	0.00	0.61	0.00	0.61	0.00	0.00	1.42	0.00	0.00	18.22	0.00	0.00	0.00	0.00	2.02	0.00	20.24	0.00
122.09	122.12	14/2/29-32	0.00	0.67	0.22	0.89	0.00	0.00	1.79	0.00	0.00	16.55	0.00	0.00	0.00	0.00	1.79	0.00	18.34	0.00
122.26	122.29	14/2/46-49	0.00	0.00	0.00	0.00	0.00	0.00	1.16	0.00	0.00	17.82	0.00	0.00	0.00	0.23	2.08	0.00	20.14	0.00
122.51	122.55	14/2/71-75	0.00	0.00	1.40	0.00	0.00	0.00	1.64	0.00	0.00	21.73	0.00	0.00	0.00	0.00	1.64	0.00	23.36	0.00
122.71	122.74	14/2/91-94	0.00	0.00	3.95	0.00	0.00	0.00	4.09	0.00	0.00	20.03	0.00	0.00	0.00	0.00	2.12	0.00	22.14	0.00
122.92	122.95	14/2/112-115	0.00	0.00	4.33	0.00	0.00	0.00	4.51	0.00	0.00	21.12	0.00	0.00	0.36	0.00	1.44	0.00	22.92	0.00
123.10	123.13	14/2/130-133	0.00	0.00	0.97	0.00	0.00	0.00	1.29	0.00	0.32	19.00	0.16	0.00	0.00	0.00	3.38	0.00	22.87	0.00
123.30	123.33	14/3/0-3	0.00	0.00	1.78	0.00	0.00	0.00	1.78	0.00	0.00	17.56	0.22	0.00	0.00	0.00	2.67	0.00	20.44	0.00
123.53	123.56	14/3/23-26	0.00	0.00	8.04	0.00	0.00	0.00	8.36	0.00	0.00	20.58	0.16	0.00	0.00	0.00	2.25	0.00	22.99	0.00
123.69	123.72	14/3/39-42	0.00	0.00	4.07	0.00	0.00	0.00	4.07	0.00	0.00	21.54	0.00	0.00	0.00	0.00	4.27	0.00	25.81	0.00
123.88	123.91	14/3/58-61	0.24	0.00	0.98	0.00	0.00	0.00	1.22	0.00	0.00	17.36	0.49	0.00	0.00	0.00	3.91	0.00	21.76	0.00
124.11	124.14	14/3/81-84	0.00	0.00	0.20	0.00	0.00	0.00	0.20	0.00	0.00	19.92	0.39	0.00	0.00	0.00	2.56	0.00	22.88	0.00
124.30	124.33	14/3/100-103	0.15	0.00	0.00	0.00	0.00	0.00	0.15	0.15	0.00	18.66	0.00	0.00	0.00	0.00	4.93	0.00	23.73	0.00
124.50	124.53	14/3/120-123	0.44	0.00	0.22	0.00	0.00	0.00	0.65	0.00	0.00	18.74	0.00	0.00	0.22	0.00	3.27	0.00	22.22	0.00
124.68	124.71	14/3/138-141	0.00	0.00	1.26	0.00	0.00	0.00	1.26	0.00	0.00	20.21	0.21	0.00	0.00	0.42	1.47	0.00	22.32	0.00
124.90	124.93	14/4/10-13	0.16	0.00	1.95	0.00	0.49	0.00	2.93	0.00	0.00	19.67	0.00	0.00	0.00	0.00	1.63	0.00	21.30	0.00
125.10	125.13	14/4/30-33	0.00	0.00	5.73	0.00	1.22	0.00	7.12	0.00	0.00	20.49	0.00	0.00	0.00	0.00	0.69	0.00	21.18	0.00
125.30	125.33	14/4/50-53	0.15	0.00	9.13	0.00	0.61	0.00	10.05	0.00	0.00	22.83	0.00	0.15	0.00	0.30	1.98	0.00	25.27	0.00
125.48	125.51	14/4/68-71	0.00	0.00	8.99	0.00	0.15	0.00	9.15	0.00	0.00	26.07	0.00	0.00	0.00	0.00	1.22	0.00	27.29	0.00
125.71	125.74	14/4/91-94	0.00	0.00	7.58	0.00	0.24	0.00	7.82	0.24	0.00	24.41	0.00	0.00	0.00	0.00	0.95	0.00	25.59	0.00
125.91	125.94	14/4/111-114	0.00	0.00	7.95	0.00	1.23	0.00	9.18	0.00	0.00	23.63	0.00	0.00	0.00	0.00	0.90	0.00	24.52	0.00
126.10	126.13	14/4/130-133	0.44	0.22	10.15	0.00	0.88	0.00	12.14	0.00	0.00	20.53	0.00	0.00	0.00	0.22	0.00	0.00	20.75	0.00
126.30	126.33	14/5/0-3	0.00	0.00	8.79	0.00	0.78	0.00	9.56	0.26	0.00	21.71	0.00	0.00	0.00	0.00	0.00	0.00	21.96	0.00
126.56	126.59	14/5/26-29	0.00	0.00	10.33	0.00	0.58	0.00	11.11	0.00	0.00	22.22	0.00	0.00	0.00	0.00	0.19	0.00	22.42	0.00
126.70	126.73	14/5/40-43	0.00	0.00	10.70	0.00	0.78	0.00	12.01	0.00	0.00	19.32	0.00	0.00	0.00	0.00	1.57	0.00	20.89	0.00
126.90	126.93	14/5/60-63	0.00	0.00	7.37	0.00	1.84	0.00	9.94	0.18	0.00	22.28	0.18	0.00	0.00	0.55	1.84	0.00	25.05	0.00
127.12	127.15	14/5/82-85	0.00	0.16	7.68	0.00	1.25	0.00	9.09	0.00	0.00	21.94	0.16	0.00	0.00	0.00	1.57	0.00	23.67	0.00
127.30	127.33	14/5/100-103	0.00	0.00	9.03	0.00	0.90	0.00	9.93	0.00	0.00	23.65	0.00	0.00	0.00	0.00	0.54	0.00	24.19	0.00
127.51	127.54	14/5/121-124	0.00	0.00	7.54	0.00	1.16	0.00	8.70	0.00	0.00	22.05	0.00	0.00	0.00	0.19	0.97	0.00	23.21	0.00
127.70	127.73	14/5/140-143	0.00	0.00	4.37	0.00	0.65	0.00	5.02	0.32	0.00	20.55	0.00	0.00	0.00	0.00	2.75	0.00	23.62	0.00
127.90	127.93	14/6/10-13	0.00	0.00	5.09	0.00	1.65	0.00	6.74	0.15	0.30	21.71	0.00	0.00	0.00	0.15	1.50	0.00	23.80	0.00
128.29	128.32	14/6/49-52	0.00	0.00	6.41	0.00	1.60	0.00	8.01	0.00	0.00	23.67	0.00	0.00	0.00	0.36	1.42	0.00	25.44	0.00
128.72	128.75	14/6/92-95	0.00	0.00	6.89	0.00	0.00	0.63	7.52	0.00	0.00	21.50	0.00	0.00	0.00	0.00	0.42	0.00	21.92	0.00
129.10	129.13	14/6/130-133	0.00	0.22	6.68	0.00	1.78	0.00	8.69	0.00	0.00	23.16	0.00	0.00	0.00	0.00	0.22	0.00	23.39	0.00
129.50	129.53	14/7/20-23	0.00	0.00	4.65	0.00	0.00	0.00	4.65	0.00	0.00	22.16	0.00	0.00	0.00	0.00	1.92	0.00	24.08	0.00
129.90	129.93	15/1/0-3	0.00	0.00	7.73	0.00	1.55	0.00	9.28	0.00	0.00	27.58	0.00	0.00	0.00	0.00	0.52	0.00	28.09	0.00
130.29	130.32	15/1/39-42	0.00	0.00	8.47	0.00	3.87	0.00	12.34	0.00	0.00	28.36	0.00	0.00	0.00	0.00	1.10	0.00	29.47	0.00
130.69	130.72	15/1/79-82	0.00	0.00	6.88	0.00	2.19	0.00	9.06	0.00	0.00	28.28	0.00	0.00	0.00	0.00	1.72	0.00	30.00	0.00
131.10	131.13	15/1/120-123	0.00	0.00	6.75	0.00	1.78	0.00	8.53	0.00	0.00	28.06	0.00	0.00	0.00	0.00	2.13	0.00	30.20	0.00
131.51	131.54	15/2/11-14	0.00	0.00	7.55	0.00	0.86	0.00	8.40	0.00	0.17	29.50	0.00	0.00	0.00	0.00	1.54	0.00	31.22	0.00
131.91	131.93	15/2/51-53	0.00	0.00	3.28	0.00	0.98	0.00	4.26	0.16	0.00	28.03	0.00	0.00	0.00	0.00	1.64	0.00	29.84	0.00
132.33	132.36	15/2/93-96	0.00	0.00	11.87	0.00	1.75	0.00	13.61	0.00	0.00	30.54	0.00	0.00	0.00	0.00	0.17	0.00	30.72	0.00
132.74	132.76	15/2/134-136	0.00	0.00	3.18	0.00	0.91	0.00	4.09	0.00	0.23	32.27	0.00	0.00	0.00	0.00	0.45	0.00	32.95	0.00
133.07	133.10	15/3/17-20	0.00	0.00	5.61	0.00	1.35	0.00	6.96	0.39	0.00	27.08	0.00	0.00	0.00	0.00	2.51	0.00	29.98	0.00
133.46	133.49	15/3/56-59	0.00	0.00	5.73	0.00	1.20	0.00	6.92	0.53	0.00	25.97	0.00	0.00	0.00	0.00	4.39	0.00	30.89	0.00
133.89	133.92	15/3/99-102	0.41	0.00	6.38	0.00	1.44	0.00	8.23	0.00	0.21	25.51	0.00	0.00	0.00	0.00	2.06	0.00	27.78	0.00
134.30	134.33	15/3/140-143	0.00	0.00	7.23	0.00	4.48	0.00	11.70	0.17	0.00	22.38	0.00	0.00	0.00	0.00	1.89	0.00	24.44	0.00
134.70	134.73	15/4/30-33	0.00	0.00	4.17	0.00	2.36	0.00	6.52	0.00	0.00	27.36	0.00	0.00	0.00	0.00	1.81	0.00	29.17	0.00
135.10	135.13	15/4/70-73	0.00	0.00	0.91	0.00	0.45	0.00	1.59	0.00	0.00	23.13	0.00	0.00	0.00	0.00	1.59	0.00	24.72	0.00
135.30	135.33	15/4/90-93	0.00	0.00	5.24	0.00	0.70	0.00	6.82	0.00	0.17	18.18	0.00	0.00	0.00	0.00	1.92	0.00	20.28	0.00
135.50	135.53	15/4/110-113	0.00	0.00	1.79	0.00	1.12	0.00	2.91	0.00	0.22	20.13	0.00	0.22	0.00	0.00	1.34	0.00	21.92	0.00
135.70	135.73	15/4/130-133	0.00	0.00	1.79	0.00	0.16	0.00	1.95	0.00	0.00	24.51	0.00	0.00	0.00	0.00	1.95	0.00	26.46	0.00
135.90	135.93	15/5/0-3	0.00	0.00	2.08	0.00	1.38	0.00	3.46	0.00	0.00	22.84	0.00	0.17	0.00	0.00	2.25	0.00	25.26	0.00
136.06	136.09	15/5/16-19	0.00	0.00	3.26	0.00	0.65	0.00	3.91	0.00	0.00	22.61	0.00	0.00	0.00	0.00	3.48	0.00	26.09	0.00
136.32	136.35	15/5/42-45	0.00	0.00	3.72	0.00	0.74	0.00	4.47	0.19	0.00	22.72	0.00	0.00	0.00	0.00	2.05	0.00	24.95	0.00
136.51	136.53	15/5/61-63	0.00	0.00	1.40	0.00	0.28	0.00	1.68	0.00	0.14	23.00	0.00	0.00	0.28	0.00	1.96	0.00	25.39	0.00
136.92	136.95	15/5/102-105	0.00	0.00	4.89	0.00	1.37	0.00	6.26	0.20	0.00	21.92	0.00	0.00	0.00	0.00	0.20	0.00	22.31	0.00
137.13	137.16	15/5/123-126	0.00	0.00	7.84	0.00	1.74	0.00	9.59	0.00	0.00	23.53	0.00	0.00	0.00	0.00	0.00	0.00	23.53	0.00
137.52	137.55	15/6/12-15	0.00	0.00	7.00	0.00	3.41	0.00	10.41	0.00	0.00	22.01	0.00	0.00	0.00	0.00	0.51	0.00	22.53	0.00
137.91	137.94	15/6/51-54	0.00	0.00	6.00	0.00	3.00	0.00	9.01	0.00	0.00	25.52	0.00	0.00	0.00	0.19	0.56	0.00	26.27	0.00
138.27	138.30	15/6/87-90	0.00	0.00	5.74	0.00	2.05	0.00	7.79	0.00	0.00	26.43	0.00	0.00	0.00	0.00	0.61	0.00	27.05	0.00
138.66	138.69	15/6/126-129	0.00	0.00	5.27	0.00	0.70	0.00	5.98	0.00	0.00	26.71	0.18	0.00	0.00	0.00	0.53	0.00	27.42	0.00
139.07	139.10	15/7/17-20	0.00	0.00	4.81	0.00	1.09	0.00	5.90	0.00	0.00	25.47	0.00	0.16	0.00	0.00	2.17	0.00	27.80	0.00
139.50	139.53	16/1/0-3	0.00	0.00	2.38	0.00	0.71	0.00	3.10	0.00	0.00	27.38	0.00	0.00	0.00	0.00	0.71	0.00	28.10	0.00
139.93	139.96	16/1/43-46	0.00	0.00	6.38	0.00	1.24	0.00	7.62	0.00	0.00	25.82	0.00	0.00	0.00	0.00	0.00	0.00	25.82	0.00
140.34	140.37	16/1/84-87	0.00	0.00	8.08	0.00	0.44	0.00	8.52	0.00	0.00	21.40	0.00	0.00	0.00	0.00	0.22	0.00	21.62	0.00
140.73	140.76	16/1/123-126	0.00	0.00	8.10	0.00	4.14	0.00	12.24	0.00	0.00	27.24	0.00	0.00	0.00	0.00	0.17	0.00	27.41	0.00
141.13	141.15	16/2/13-16	0.00	0.00	2.82	0.00	3.13	0.00	5.96	0.00	0.00	23.20	0.00	0.00	0.00	0.00	0.00	0.00	23.20	0.00
141.54	141.57	16/2/54-57	0.00	0.00	4.12	0.00	0.41	0.00	4.53	0.00	0.00	18.72	0.00	0.00	0.00	0.00	0.62	0.00	19.34	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Truncorotalia* aff. *crassaformis*	*Truncorotalia crassaformis*	*Truncorotalia juanai*	*Truncorotalia juanai?*	*Truncorotalia praecrassaformis*	*Truncorotalia praecrassaformis?*	***Truncorotalia***	*Zeaglobigerina nepenthes*	*Zeaglobigerina nepenthes?*	*Zeaglobigerina* sp.	*Zeaglobigerina woodi apertura*	*Zeaglobigerina woodi apertura?*	*Zeaglobigerina woodi decoraperta*	*Zeaglobigerina wodi decoraperta?*	*Zeaglobigerina woodi woodi*	*Zeaglobigerina wooodi woodi?*	***Zeaglobigerina***	Misc: unidentified planktics
141.92	141.95	16/2/92-95	0.00	0.00	6.71	0.00	0.00	0.00	6.71	0.00	0.00	17.89	0.00	0.00	0.00	0.00	0.00	0.00	17.89	0.00
142.32	142.35	16/2/132-135	0.00	0.00	4.84	0.00	0.20	0.00	5.04	0.00	0.00	23.39	0.00	0.00	0.00	0.00	0.20	0.00	23.59	0.00
142.75	142.78	16/3/25-28	0.00	0.00	1.86	0.00	0.37	0.00	2.23	0.00	0.00	28.57	0.00	0.00	0.00	0.00	0.00	0.00	28.57	0.00
143.15	143.18	16/3/65-68	0.00	0.00	3.38	0.00	0.85	0.00	4.23	0.00	0.00	27.92	0.00	0.00	0.00	0.00	0.00	0.00	27.92	0.00
143.53	143.56	16/3/103-106	0.00	0.00	3.15	0.00	1.10	0.00	4.25	0.00	0.00	26.16	0.00	0.00	0.00	0.00	0.55	0.00	26.71	0.00
143.84	143.87	16/3/134-137	0.00	0.00	6.82	0.00	0.18	0.00	7.00	0.00	0.18	28.01	0.00	0.00	0.00	0.00	0.72	0.00	28.90	0.00
144.26	144.29	16/4/26-29	0.00	0.00	6.30	0.00	0.00	0.00	6.30	0.00	0.00	24.21	0.00	0.00	0.00	0.00	1.38	0.00	25.59	0.00
144.67	144.70	16/4/67-70	0.00	0.00	2.53	0.00	0.36	0.00	2.89	0.00	0.00	19.86	0.00	0.00	0.00	0.00	0.00	0.00	19.86	0.00
145.13	145.16	16/4/113-116	0.00	0.00	5.03	0.00	0.00	0.00	5.03	0.00	0.34	25.29	0.00	0.00	0.00	0.00	3.35	0.00	28.98	0.00
145.50	145.53	16/5/0-3	0.00	0.00	0.16	0.00	0.16	0.00	0.33	0.00	0.16	29.77	0.00	0.00	0.00	0.00	0.49	0.00	30.43	0.00
145.93	145.96	16/5/43-46	0.00	0.00	1.49	0.00	0.00	0.00	1.49	0.00	0.00	24.89	0.00	0.00	0.00	0.00	0.21	0.00	25.11	0.00
146.36	146.38	16/5/86-88	0.00	0.00	0.19	0.00	0.00	0.00	0.19	0.19	0.00	27.94	0.00	0.00	0.00	0.19	0.00	0.00	28.32	0.00
146.71	146.74	16/5/121-124	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.99	0.20	0.00	0.00	0.00	0.40	0.00	34.58	0.00
147.06	147.09	16/6/6-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.57	0.00	0.00	0.00	0.00	0.00	0.00	28.57	0.00
147.47	147.50	16/6/47-50	0.00	0.00	0.90	0.00	0.00	0.00	0.90	0.00	0.00	22.37	0.00	0.00	0.00	0.15	4.50	0.00	27.03	0.00
147.93	147.96	16/6/93-96	0.00	0.00	4.59	0.00	0.00	0.00	4.59	0.19	0.00	23.71	0.00	0.00	0.00	0.19	3.44	0.00	27.53	0.00
148.33	148.36	16/6/133-136	0.00	0.00	0.26	0.00	0.00	0.00	0.26	0.00	0.00	29.97	0.00	0.00	0.00	0.00	2.55	0.00	32.53	0.00
148.67	148.69	16/7/17-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.15	0.00	0.00	0.00	0.00	3.73	0.00	32.88	0.00
149.10	149.13	17/1/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.97	0.00	0.00	0.00	0.17	0.50	0.00	28.64	0.00
149.52	149.55	17/1/42-45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.63	0.00	0.00	0.00	0.00	0.51	0.00	30.13	0.00
150.11	150.14	17/1/101-104	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30.85	0.00	0.00	0.00	0.00	0.21	0.00	31.06	0.00
150.51	150.54	17/1/141-144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.07	0.00	0.00	0.00	0.22	0.00	0.00	29.28	0.00
150.87	150.90	17/2/27-30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	24.54	0.00	0.00	0.00	0.17	0.17	0.00	25.04	0.00
151.07	151.10	17/2/47-50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.33	0.00	0.00	0.00	0.00	1.14	0.00	30.48	0.00
151.52	151.55	17/2/92-95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	31.88	0.00	0.00	0.00	0.12	0.97	0.00	33.21	0.00
151.96	151.98	17/2/136-138	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30.75	0.00	0.00	0.00	0.00	0.00	0.00	30.75	0.00
152.10	152.13	17/3/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.76	0.00	0.00	0.00	0.00	0.48	0.00	30.24	0.00
152.25	152.28	17/3/15-18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30.41	0.00	0.00	0.00	0.34	1.52	0.00	32.26	0.00
152.47	152.50	17/3/37-40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00	26.03	0.00	0.00	0.65	0.00	6.51	0.00	33.84	0.00
152.75	152.77	17/3/65-67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.29	0.00	0.00	0.00	0.00	2.46	0.00	29.75	0.00
152.91	152.94	17/3/81-84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.12	0.00	0.00	0.00	0.20	0.60	0.00	29.92	0.00
153.12	153.15	17/3/102-105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.45	0.00	0.00	0.00	0.00	1.40	0.00	27.86	0.00
153.26	153.29	17/3/116-119	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.95	0.00	0.00	0.00	0.00	1.41	0.00	30.36	0.00
153.45	153.48	17/3/135-138	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.74	0.00	0.00	0.00	0.15	3.86	0.00	31.75	0.00
153.66	153.69	17/4/6-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30.86	0.00	0.00	0.00	0.00	2.63	0.00	33.49	0.00
153.97	153.99	17/4/37-39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	32.80	0.00	0.00	0.00	0.00	3.18	0.00	35.99	0.00
154.13	154.16	17/4/53-56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	32.12	0.00	0.00	0.00	0.00	2.06	0.00	34.18	0.00
154.32	154.35	17/4/72-75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30.15	0.27	0.00	0.00	0.00	3.77	0.00	34.19	0.00
154.54	154.57	17/4/94-97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.22	0.23	0.00	0.00	0.00	2.96	0.00	36.41	0.00
154.77	154.79	17/4/117-119	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.08	0.00	0.00	0.00	0.00	7.34	0.00	34.42	0.00
154.95	154.98	17/4/135-138	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.73	0.00	0.00	0.00	0.40	4.92	0.00	32.05	0.00
155.10	155.13	17/5/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	26.55	0.27	0.00	0.00	0.13	6.33	0.00	33.42	0.00
155.24	155.27	17/5/14-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.17	0.00	0.18	0.00	0.00	5.98	0.00	35.33	0.00
155.48	155.50	17/5/38-40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.06	0.00	0.00	0.00	0.24	9.94	0.00	32.24	0.00
155.67	155.70	17/5/57-60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.88	0.00	0.24	0.00	0.24	2.66	0.00	28.02	0.00
155.94	155.97	17/5/84-87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.05	0.13	0.00	0.00	0.00	6.28	0.00	33.46	0.00
156.13	156.16	17/5/103-106	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	23.61	0.00	0.00	0.00	0.00	6.33	0.00	30.13	0.00
156.27	156.30	17/5/117-120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.41	0.00	0.00	0.00	0.00	2.81	0.00	34.22	0.00
156.47	156.50	17/5/137-140	0.00	0.00	0.00	0.16	0.00	0.00	0.16	0.00	0.00	28.81	0.00	0.00	0.00	0.00	3.60	0.00	32.41	0.00
156.71	156.74	17/6/11-14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.08	0.00	0.00	0.00	0.00	3.97	0.00	31.05	0.00
156.95	156.98	17/6/35-38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	28.41	0.00	0.00	0.00	0.00	4.06	0.00	32.66	0.00
157.12	157.15	17/6/52-55	0.00	0.00	0.00	0.14	0.00	0.00	0.14	0.00	0.00	23.29	0.29	0.00	0.00	0.00	6.71	0.00	30.29	0.00
157.37	157.39	17/6/77-79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.68	0.00	0.00	0.00	0.00	2.02	0.00	29.70	0.00
157.52	157.55	17/6/92-95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.35	0.00	0.00	0.00	0.41	3.32	0.00	30.08	0.00
157.76	157.79	17/6/116-119	0.00	0.00	0.00	0.15	0.00	0.00	0.15	0.00	0.15	30.29	0.00	0.00	0.00	0.00	2.13	0.00	32.57	0.00
157.93	157.96	17/6/133-136	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	32.15	0.11	0.00	0.00	0.44	5.54	0.00	38.25	0.00
158.10	158.13	17/7/0-3	0.00	0.00	0.00	0.24	0.00	0.00	0.24	0.00	0.00	31.63	0.00	0.00	0.00	0.00	4.26	0.00	35.89	0.00
158.27	158.30	17/7/17-20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.11	0.00	0.00	0.00	0.00	2.04	0.00	33.15	0.00
158.52	158.55	17CC/6-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.57	0.18	0.00	0.00	0.00	5.03	0.00	31.78	0.00
158.70	158.73	18/1/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	26.26	0.00	0.00	0.00	0.14	4.59	0.00	31.13	0.00
158.95	158.98	18/1/25-28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.80	0.00	0.00	0.00	0.17	2.45	0.00	30.42	0.00
159.13	159.16	18/1/43-46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.39	0.00	0.00	0.00	0.00	1.90	0.00	31.29	0.00
159.35	159.38	18/1/65-68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	27.86	0.00	0.00	0.00	0.00	3.03	0.00	31.03	0.00
159.49	159.52	18/1/79-82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.16	0.10	0.00	0.00	0.00	7.44	0.00	31.70	0.00
159.72	159.75	18/1/102-105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.21	0.00	0.00	0.00	0.00	5.86	0.00	32.06	0.00
159.86	159.89	18/1/116-119	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	24.41	0.36	0.00	0.00	0.00	2.17	0.00	27.12	0.00
160.11	160.14	18/1/141-144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.33	0.00	0.00	0.00	0.00	1.61	0.00	25.94	0.00
160.33	160.36	18/2/13-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.14	0.37	0.00	0.00	0.24	5.87	0.00	33.62	0.00
160.73	160.76	18/2/53-56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.42	0.96	0.00	0.00	0.00	7.71	0.00	29.09	0.00
161.16	161.19	18/2/96-99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.72	0.00	0.00	0.00	0.28	1.83	0.00	28.83	0.00
161.53	161.56	18/2/133-136	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.55	0.13	0.00	0.13	0.26	5.61	0.00	33.67	0.00
161.84	161.87	18/3/14-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.94	0.34	0.00	0.00	0.00	4.86	0.00	26.13	0.00
162.26	162.29	18/3/56-59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.32	0.34	0.00	0.00	0.00	4.64	0.00	32.30	0.00
162.87	162.90	18/3/117-120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.28	0.00	0.00	0.00	0.00	2.70	0.00	26.97	0.00
163.33	163.36	18/4/13-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.30	0.00	0.00	0.00	0.00	4.04	0.00	25.34	0.00
163.56	163.59	18/4/36-39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.62	0.00	0.00	0.00	0.22	5.39	0.00	29.23	0.00
163.93	163.96	18/4/73-76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.68	0.00	0.00	0.23	0.23	2.10	0.00	24.24	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Truncorotalia* aff. *crassaformis*	*Truncorotalia crassaformis*	*Truncorotalia juanai*	*Truncorotalia juanai?*	*Truncorotalia praecrassaformis*	*Truncorotalia praecrassaformis?*	***Truncorotalia***	*Zeaglobigerina nepenthes*	*Zeaglobigerina nepenthes?*	*Zeaglobigerina* sp.	*Zeaglobigerina woodi apertura*	*Zeaglobigerina woodi apertura?*	*Zeaglobigerina woodi decoraperta*	*Zeaglobigerina wodi decoraperta?*	*Zeaglobigerina woodi woodi*	*Zeaglobigerina wooodi woodi?*	***Zeaglobigerina***	Misc: unidentified planktics
164.31	164.33	18/4/111-113	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	17.54	0.00	0.00	0.00	0.00	6.36	0.00	24.12	0.00
164.70	164.73	18/5/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.76	0.52	0.00	0.34	0.00	7.73	0.00	28.35	0.00
165.13	165.16	18/5/43-46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.74	0.25	0.00	0.13	0.25	4.04	0.00	28.41	0.00
165.50	165.53	18/5/80-83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	15.87	0.34	0.00	0.00	0.57	12.10	0.00	29.11	0.00
165.95	165.97	18/5/125-127	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.14	0.32	0.00	0.00	0.00	5.56	0.00	27.03	0.00
166.26	166.29	18/6/6-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	20.39	0.89	0.00	0.00	0.89	7.62	0.00	29.96	0.00
166.66	166.69	18/6/46-49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.66	0.00	0.17	0.00	0.00	6.04	0.00	29.87	0.00
167.06	167.09	18/6/86-89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.34	0.28	0.00	0.00	0.00	10.59	0.00	31.21	0.00
167.44	167.47	18/6/124-127	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	21.64	0.33	0.00	0.00	0.00	8.55	0.00	30.97	0.00
168.30	168.33	19/1/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.99	0.18	0.00	0.00	0.18	9.89	0.00	28.24	0.00
168.71	168.74	19/1/41-44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.92	0.39	0.00	0.26	0.00	10.28	0.00	30.85	0.00
169.13	169.15	19/1/83-85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	20.56	0.16	0.00	0.00	0.33	9.38	0.00	30.76	0.00
169.51	169.54	19/1/121-124	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.05	0.86	0.00	0.14	0.14	14.76	0.00	33.95	0.00
169.85	169.88	19/2/5-8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	18.37	0.68	0.00	0.00	0.17	10.88	0.00	30.27	0.00
170.32	170.35	19/2/52-55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.44	0.17	0.00	0.00	0.00	6.81	0.00	26.41	0.00
170.73	170.76	19/2/93-96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.69	0.00	0.00	0.00	0.46	10.47	0.00	27.62	0.00
171.15	171.18	19/2/135-138	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.54	0.00	0.00	0.00	0.00	9.48	0.00	24.02	0.00
171.57	171.59	19/3/27-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.90	15.04	0.30	0.00	0.00	0.75	11.43	0.00	28.42	0.00
171.92	171.94	19/3/62-64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.89	0.23	0.00	0.00	0.00	7.51	0.00	28.64	0.00
172.32	172.35	19/3/102-105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	19.78	0.31	0.00	0.00	0.00	10.97	0.00	31.22	0.00
172.66	172.68	19/3/136-138	0.00	0.00	0.00	0.00	0.00	0.26	0.26	0.00	0.00	15.31	0.00	0.26	0.00	0.00	4.85	0.00	20.41	0.00
173.07	173.09	19/4/27-29	0.00	0.00	0.21	0.00	0.00	0.00	0.21	0.00	0.21	20.58	0.00	0.00	0.00	0.00	5.61	0.00	26.40	0.00
173.52	173.54	19/4/72-74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	14.64	0.62	0.00	0.00	0.31	8.10	0.00	23.99	0.00
173.93	173.95	19/4/113-115	0.00	0.00	0.41	0.00	0.20	0.00	0.61	0.00	0.00	19.68	0.20	0.00	0.00	0.00	2.64	0.00	22.52	0.00
174.30	174.33	19/5/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	13.59	0.42	0.00	0.64	0.00	4.46	0.00	19.53	0.00
174.72	174.75	19/5/42-45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.23	0.20	0.00	0.00	0.00	10.06	0.00	22.49	0.00
175.26	175.28	19/5/96-99	0.00	0.00	0.62	0.00	0.00	0.00	0.62	0.21	0.00	19.79	0.00	0.00	0.00	0.00	9.28	0.00	29.28	0.00
175.71	175.74	19/5/141-144	0.00	0.00	1.31	0.00	0.00	0.00	1.31	0.00	0.00	17.59	0.00	0.00	0.00	0.26	7.87	0.00	25.72	0.00
176.06	176.09	19/6/26-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.58	0.46	0.00	0.46	0.00	7.89	0.00	30.39	0.00
176.47	176.49	19/6/67-69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	30.34	0.00	0.00	0.00	0.00	4.20	0.00	34.73	0.00
176.92	176.94	19/6/112-114	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	26.01	0.54	0.00	0.27	0.00	3.75	0.00	30.83	0.00
177.30	177.33	19/7/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	23.56	0.00	0.00	0.24	0.48	4.57	0.00	29.09	0.00
177.52	177.55	19/7/22-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.72	0.00	20.33	0.00	0.00	0.00	0.52	10.61	0.00	33.18	0.00
177.90	177.93	20/1/0-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.54	0.00	0.00	0.00	0.00	1.39	0.00	25.93	0.00
178.27	178.30	20/1/37-40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.01	0.00	0.00	0.00	0.20	2.18	0.00	26.39	0.00
178.68	178.70	20/1/78-80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.78	0.00	0.00	0.00	0.00	1.46	0.00	19.25	0.00
179.08	179.10	20/1/118-120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.99	0.21	0.00	0.00	0.00	4.56	0.00	26.76	0.00
179.45	179.47	20/2/5-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	18.06	0.00	0.00	0.00	0.58	9.83	0.00	28.76	0.00
179.86	179.88	20/2/46-48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	16.86	0.67	0.00	0.00	0.00	9.35	0.00	27.05	0.00
180.33	180.35	20/2/93-95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.24	0.20	0.00	0.00	0.00	4.81	0.00	24.25	0.00
180.73	180.75	20/2/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.77	0.65	0.00	0.00	0.22	14.50	0.00	28.14	0.00
181.14	181.16	20/3/24-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.33	0.85	0.00	0.00	0.00	15.30	0.00	27.48	0.00
181.57	181.59	20/3/67-69	0.00	0.00	0.89	0.00	0.00	0.00	0.89	0.00	0.00	14.77	0.22	0.00	0.00	0.00	14.77	0.00	29.75	0.00
181.86	181.88	20/3/96-98	0.00	0.00	0.18	0.00	0.00	0.00	0.18	0.00	0.00	14.34	0.37	0.00	0.00	0.00	13.05	0.00	27.76	0.00
182.23	182.25	20/3/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.20	0.48	0.00	0.00	0.00	11.24	0.00	23.92	0.00
182.68	182.70	20/4/28-30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.68	0.27	0.00	0.00	0.00	11.62	0.00	27.57	0.00
183.08	183.10	20/4/68-70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.37	0.00	0.00	0.00	0.00	13.41	0.00	28.78	0.00
183.45	183.47	20/4/105-107	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.01	0.00	0.00	0.00	0.00	15.14	0.00	30.14	0.00
183.91	183,93	20/5/1-3	0.00	0.00	0.00	0.00	0.00	0.18	0.18	0.00	0.00	17.44	0.00	0.00	0.00	0.00	10.50	0.00	27.94	0.00
184.32	184.34	20/5/42-44	0.00	0.00	0.18	0.00	0.00	0.73	0.92	0.00	0.18	21.83	0.18	0.00	0.18	0.00	7.89	0.00	30.28	0.00
184.72	184.74	20/5/82-84	0.00	0.00	0.20	0.00	0.00	0.40	0.60	0.00	0.00	16.00	0.00	0.00	0.00	0.00	6.80	0.00	22.80	0.00
185.07	185.09	20/5/117-119	0.00	0.00	0.65	0.00	0.00	0.16	0.81	0.00	0.16	18.18	0.32	0.00	0.00	0.32	6.66	0.00	25.65	0.00
185.47	185.49	20/6/7-9	0.00	0.00	2.04	0.00	0.00	0.00	2.04	0.00	0.00	22.45	0.00	0.00	0.00	0.56	9.83	0.00	32.84	0.00
185.92	185.94	20/6/52-54	0.00	0.00	6.70	0.00	0.00	0.77	7.47	0.00	0.00	11.69	0.57	0.00	0.00	0.00	8.43	0.00	20.69	0.00
186.32	186.34	20/6/92-94	0.00	0.00	6.64	0.00	0.00	0.18	6.82	0.18	0.00	14.36	0.00	0.00	0.00	0.54	8.98	0.00	24.06	0.00
186.72	186.74	20/6/132-134	0.00	0.00	2.21	0.00	0.00	0.51	2.72	0.00	0.00	19.05	0.00	0.17	0.00	0.17	7.82	0.00	27.21	0.00
187.07	187.09	20/7/17-19	0.00	0.00	1.13	0.00	0.00	0.14	1.27	0.00	0.14	23.63	0.00	0.00	0.00	0.14	7.74	0.00	31.65	0.00
187.51	187.53	21/1/1-3	0.00	0.00	7.46	0.00	0.00	0.00	7.46	0.00	0.00	17.76	0.00	0.00	0.00	0.39	10.94	0.00	29.09	0.00
187.93	187.95	21/1/43-45	0.00	0.00	6.42	0.00	0.00	0.00	6.42	0.00	0.00	21.82	0.00	0.00	0.00	0.00	9.45	0.00	31.27	0.00
188.32	188.34	21/182-84	0.00	0.00	3.89	0.00	0.00	0.00	3.89	0.00	0.00	23.36	0.20	0.00	0.41	0.00	7.38	0.00	31.35	0.00
188.67	188.69	21/1/117-119	0.00	0.00	3.24	0.00	0.00	0.00	3.24	0.00	0.00	22.04	0.16	0.00	0.00	0.00	8.75	0.00	30.96	0.00
189.08	189.10	21/2/8-10	0.00	0.00	4.38	0.00	0.00	0.00	4.38	0.00	0.00	19.35	0.00	0.00	0.00	0.23	9.68	0.00	29.26	0.00
189.46	189.48	21/2/46-48	0.00	0.00	1.82	0.00	0.00	0.00	1.82	0.00	0.00	19.01	0.33	0.00	0.00	0.00	13.39	0.00	32.73	0.00
189.93	189.96	21/2/93-96	0.00	0.00	2.65	0.00	0.00	0.00	2.65	0.00	0.00	22.93	0.16	0.00	0.00	0.00	12.48	0.00	35.57	0.00
190.42	190.44	21/2/142-144	0.00	0.00	4.58	0.00	0.00	0.00	4.58	0.00	0.00	19.32	0.17	0.00	0.00	0.17	11.69	0.00	31.36	0.00
190.66	190.68	21/3/16-18	0.00	0.00	1.74	0.00	0.00	0.00	1.74	0.00	0.17	21.43	0.17	0.00	0.00	0.00	10.45	0.00	32.23	0.00
191.12	191.14	21/3/62-64	0.00	0.00	2.63	0.00	0.00	0.00	2.63	0.00	0.00	18.56	0.00	0.18	0.18	0.00	10.51	0.00	29.42	0.00
191.52	191.54	21/3/102-104	0.00	0.00	11.64	0.00	0.00	0.00	11.64	0.00	0.00	17.85	0.00	0.00	0.13	0.00	9.83	0.00	27.81	0.00
191.86	191.89	21/3/136-139	0.00	0.00	2.19	0.00	0.00	0.00	2.19	0.00	0.00	19.69	0.00	0.00	0.00	0.22	7.44	0.00	27.35	0.00
192.36	192.38	21/4/36-38	0.00	0.00	1.19	0.00	0.00	0.00	1.19	0.00	0.00	23.97	0.00	0.00	0.00	0.00	7.68	0.00	31.66	0.00
192.73	192.75	21/4/73-75	0.00	0.00	2.90	0.00	0.00	0.00	2.90	0.00	0.00	15.91	0.13	0.00	0.00	0.13	11.49	0.00	27.65	0.00
193.12	193.14	21/4/112-114	0.00	0.00	2.08	0.00	0.00	0.17	2.25	0.00	0.00	18.54	0.35	0.00	0.00	0.17	11.44	0.00	30.50	0.00
193.50	193.52	21/5/0-2	0.00	0.00	0.81	0.00	0.00	0.00	0.81	0.00	0.00	16.87	0.00	0.00	0.00	0.00	14.85	0.00	31.72	0.00
193.92	193.94	21/5/42-44	0.00	0.00	0.00	0.00	0.00	0.16	0.16	0.00	0.16	18.10	0.63	0.00	0.00	0.00	14.92	0.00	33.81	0.00
194.34	194.26	21/5/84-86	0.00	0.00	0.22	0.00	0.00	0.00	0.22	0.00	0.00	18.67	0.00	0.00	0.00	0.44	14.67	0.00	33.78	0.00
194.72	194.74	21/5/122-124	0.00	0.00	0.00	0.00	0.00	0.91	0.91	0.11	0.00	24.23	0.11	0.00	0.00	0.11	6.97	0.00	31.54	0.00
195.07	195.09	21/6/7-9	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.00	0.00	22.58	0.28	0.00	0.00	0.00	11.50	0.00	34.35	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Truncorotalia* aff. *crassaformis*	*Truncorotalia crassaformis*	*Truncorotalia juanai*	*Truncorotalia juanai?*	*Truncorotalia praecrassaformis*	*Truncorotalia praecrassaformis?*	***Truncorotalia***	*Zeaglobigerina nepenthes*	*Zeaglobigerina nepenthes?*	*Zeaglobigerina* sp.	*Zeaglobigerina woodi apertura*	*Zeaglobigerina woodi apertura?*	*Zeaglobigerina woodi decoraperta*	*Zeaglobigerina wodi decoraperta?*	*Zeaglobigerina woodi woodi*	*Zeaglobigerina wooodi woodi?*	***Zeaglobigerina***	Misc: unidentified planktics
195.49	195.51	21/6/49-51	0.00	0.00	0.27	0.00	0.00	0.00	0.27	0.00	0.40	21.46	0.00	0.00	0.00	0.00	13.77	0.00	35.63	0.00
195.87	195.89	21/6/87-89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	26.04	0.00	0.00	0.00	0.11	9.01	0.00	35.38	0.00
196.34	196.36	21/6/134-136	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.44	0.00	0.00	0.00	0.19	8.19	0.00	26.82	0.00
196.72	196.74	21/7/22-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.06	0.00	0.00	0.00	0.00	6.46	0.00	30.52	0.00
197.11	197.13	22/1/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.03	0.00	0.00	0.00	0.00	12.39	0.00	31.42	0.00
197.48	197.50	22/1/38-40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	26.64	0.45	0.00	0.00	0.00	13.43	0.00	40.86	0.00
197.94	197.96	22/1/84-86	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.00	0.00	25.60	0.00	0.00	0.00	0.43	8.68	0.00	34.71	0.00
198.32	198.34	22/1/122-124	0.00	0.00	0.00	0.00	0.00	0.13	0.13	0.00	0.00	19.92	0.00	0.00	0.00	0.00	10.34	0.00	30.26	0.00
198.73	198.75	22/2/13-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.03	0.19	0.00	0.00	0.00	9.58	0.00	31.80	0.00
199.14	199.16	22/2/54-56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.03	0.35	0.00	0.00	0.00	9.57	0.00	31.95	0.00
199.53	199.55	22/2/93-95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.11	0.00	0.00	0.00	0.00	16.23	0.00	33.33	0.00
199.93	199.95	22/2/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.51	0.20	0.00	0.00	0.00	11.24	0.00	31.95	0.00
200.25	200.27	22/3/15-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.97	0.26	0.00	0.00	0.00	11.00	0.00	32.23	0.00
200.66	200.68	22/3/56-58	0.00	0.00	0.20	0.00	0.00	0.00	0.20	0.00	0.00	20.25	0.61	0.00	0.00	0.20	10.84	0.00	31.90	0.00
201.05	201.07	22/3/95-97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.33	0.00	0.00	0.00	0.00	6.88	0.00	27.20	0.00
201.42	201.44	22/3/132-134	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.00	0.00	19.96	0.30	0.00	0.00	0.00	12.14	0.00	32.40	0.00
201.93	201.95	22/4/33-35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	22.92	0.15	0.00	0.00	0.00	6.86	0.00	30.36	0.00
202.52	202.55	22/4/92-95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.53	0.35	0.00	0.00	0.00	7.61	0.00	33.49	0.00
202.93	202.95	22/4/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	23.15	0.40	0.00	0.00	0.00	8.07	0.00	31.75	0.00
203.17	203.20	22CC/7-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	27.73	0.12	0.00	0.00	0.00	11.16	0.00	39.25	0.00
206.71	206.73	23/1/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.72	0.26	0.00	0.00	0.00	11.37	0.00	40.35	0.00
207.13	207.15	23/1/43-45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	31.20	0.00	0.00	0.00	0.00	6.27	0.00	37.60	0.00
207.48	207.50	23/1/78-80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.05	0.33	0.00	0.00	0.00	4.46	0.00	32.84	0.00
207.88	207.90	23/1/118-120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30.63	0.00	0.00	0.00	0.13	4.89	0.00	35.65	0.00
208.26	208.28	23/2/6-8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	35.70	0.00	0.00	0.00	0.00	4.25	0.00	40.21	0.00
208.52	208.54	23/2/32-34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	27.02	0.81	0.00	0.00	0.00	12.66	0.00	40.71	0.00
209.06	209.08	23/2/86-88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	30.09	0.26	0.00	0.00	0.00	7.91	0.00	38.39	0.00
209.54	209.56	23/2/134-136	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.23	0.14	0.00	0.00	0.14	6.88	0.00	38.40	0.00
209.85	209.87	23/3/15-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.11	0.00	0.00	0.00	0.00	7.03	0.00	36.15	0.00
210.33	210.35	23/3/63-65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.80	0.15	0.00	0.00	0.15	5.23	0.00	35.32	0.00
210.53	210.55	23/3/83-85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.15	0.31	0.00	0.20	0.00	6.15	0.00	37.81	0.00
210.87	210.89	23/3/117-119	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34.73	0.00	0.00	0.00	0.00	1.55	0.00	36.28	0.00
211.27	211.29	23/4/7-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.90	0.00	0.00	0.00	0.00	2.94	0.00	31.84	0.00
211.72	211.74	23/4/52-54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	30.53	0.37	0.00	0.00	0.12	6.43	0.00	37.58	0.00
212.13	212.15	23/4/93-95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	28.01	0.47	0.00	0.00	0.00	8.23	0.00	36.87	0.00
212.32	212.34	23/4/112-114	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.12	0.60	0.00	0.00	0.00	11.56	0.00	36.28	0.00
212.71	212.73	23/5/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	35.07	0.00	0.00	0.00	0.00	4.31	0.00	39.38	0.00
213.12	213.14	23/5/42-44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.92	0.21	0.00	0.00	0.10	8.92	0.00	38.15	0.00
213.72	213.74	23/5/102-104	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	26.92	0.37	0.00	0.00	0.55	8.42	0.00	36.63	0.00
214.12	214.14	23/5/142-144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	32.19	0.16	0.00	0.00	0.00	7.62	0.00	39.97	0.00
214.51	214.53	23/6/31-33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	21.29	0.26	0.00	0.00	0.09	14.25	0.00	36.05	0.00
215.05	215.07	23/6/85-87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.97	0.19	0.00	0.00	0.00	2.70	0.00	29.87	0.00
215.53	215.55	23/6/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.75	0.28	0.00	0.00	0.00	4.69	0.00	30.73	0.00
215.93	215.95	23/7/23-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.26	0.00	0.00	0.00	0.31	4.40	0.00	30.97	0.00
216.31	216.33	24/1/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	22.40	0.36	0.00	0.00	0.36	9.50	0.00	32.80	0.00
216.57	216.59	24/1/27-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	17.58	1.13	0.00	0.00	0.00	14.98	0.00	33.76	0.00
216.94	216.96	24/1/64-66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	22.35	0.30	0.00	0.00	0.00	6.56	0.00	29.51	0.00
217.34	217.36	24/1/104-106	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.02	0.69	0.00	0.00	0.17	7.04	0.00	30.93	0.00
217.72	217.74	24/1/142-144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.54	0.00	0.00	0.00	0.16	8.37	0.00	31.08	0.00
218.08	218.10	24/2/28-30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	25.49	0.00	0.00	0.00	0.30	4.95	0.00	30.88	0.00
218.52	218.54	24/2/72-74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	20.81	0.53	0.00	0.38	0.00	11.89	0.00	33.84	0.00
218.87	218.89	24/2/107-109	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	27.09	0.46	0.00	0.00	0.00	3.66	0.00	31.54	0.00
219.31	219.33	24/3/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.13	2.18	0.00	0.00	0.33	0.00	8.93	0.00	32.57
219.72	219.74	24/3/42-44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.79	0.26	0.00	0.26	0.00	5.37	0.00	25.69	0.00
220.12	220.14	24/3/82-84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.24	0.60	0.00	0.00	0.00	7.76	0.00	29.59	0.00
220.46	220.48	24/3/116-118	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.98	1.29	0.00	0.00	0.00	8.17	0.00	33.44	0.00
220.87	220.89	24/4/7-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.97	0.93	0.00	0.78	0.00	8.40	0.00	29.08	0.00
221.27	221.29	24/4/47-49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.53	1.48	0.00	0.11	0.00	8.57	0.00	30.69	0.00
221.66	221.68	24/4/86-88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.82	1.22	0.00	0.12	0.00	7.78	0.00	32.93	0.00
222.13	222.15	24/4/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	23.99	1.23	0.00	0.25	0.00	8.61	0.00	34.19	0.00
222.45	222.47	24/5/15-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.58	1.91	0.00	0.21	0.00	10.91	0.00	37.61	0.00
222.93	222.95	24/5/63-65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.55	1.58	0.00	0.66	0.00	12.61	0.00	36.40	0.00
223.33	223.35	24/5/103-105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63	0.00	21.32	1.72	0.00	0.31	0.00	10.03	0.00	34.01	0.00
223.72	223.74	24/5/142-144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	20.45	0.98	0.00	0.28	0.00	9.52	0.00	31.51	0.00
224.07	224.09	24/6/27-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.00	17.22	2.78	0.00	0.35	0.00	9.57	0.00	30.61	0.00
224.47	224.49	24/6/67-69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.22	2.62	0.00	0.29	0.00	9.51	0.00	31.65	0.00
224.87	224.89	24/6/107-109	0.00	0.00	0.21	0.00	0.00	0.00	0.21	0.00	0.00	20.66	1.86	0.00	0.00	0.00	11.98	0.00	34.50	0.00
225.36	225.38	24CC/9-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	16.69	1.50	0.00	0.00	0.00	14.02	0.00	32.39	0.00
226.13	226.15	25/1/23-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.23	0.00	19.02	0.31	0.00	0.15	0.00	13.04	0.00	33.74	0.00
226.53	226.55	25/1/63-65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.98	2.27	0.00	0.97	0.00	11.03	0.00	33.25	0.00
226.93	226.95	25/1/103-105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.00	17.89	1.05	0.00	0.53	0.00	11.58	0.00	31.75	0.00
227.34	227.36	25/1/144-146	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	17.03	2.52	0.00	0.63	0.00	14.98	0.00	36.12	0.16
227.72	227.74	25/2/-32-34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.35	1.88	0.00	1.13	0.00	14.29	0.00	33.65	0.00
228.12	228.14	25/2/72-74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	19.51	1.11	0.00	0.62	0.00	10.86	0.00	32.35	0.12
228.52	228.54	25/2/112-114	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	16.80	3.48	0.00	1.23	0.00	13.83	0.00	35.66	0.00
228.90	228.92	25/3/0-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	19.19	2.52	0.00	1.16	0.00	10.66	0.00	33.72	0.00
229.33	229.35	25/3/43-45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.19	2.24	0.00	0.82	0.00	15.08	0.00	33.33	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Truncorotalia* aff. *crassaformis*	*Truncorotalia crassaformis*	*Truncorotalia juanai*	*Truncorotalia juanai?*	*Truncorotalia praecrassaformis*	*Truncorotalia praecrassaformis?*	***Truncorotalia***	*Zeaglobigerina nepenthes*	*Zeaglobigerina nepenthes?*	*Zeaglobigerina* sp.	*Zeaglobigerina woodi apertura*	*Zeaglobigerina woodi apertura?*	*Zeaglobigerina woodi decoraperta*	*Zeaglobigerina wodi decoraperta?*	*Zeaglobigerina woodi woodi*	*Zeaglobigerina wooodi woodi?*	***Zeaglobigerina***	Misc: unidentified planktics
229.85	229.87	25/3/95-97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.96	0.00	16.46	2.19	0.00	0.27	0.00	12.76	0.00	32.65	0.00
230.27	230.29	25/3/137-139	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.10	0.00	10.64	2.94	0.00	0.18	0.00	17.98	0.00	32.84	0.00
230.47	230.49	25/4/7-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.55	1.33	0.00	0.00	0.27	12.23	0.00	31.38	0.00
230.93	230.95	25/4/53-55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	15.43	1.27	0.00	0.00	0.00	13.61	0.00	30.49	0.18
231.33	231.35	25/4/93-95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.67	2.21	0.00	0.49	0.00	10.29	0.00	29.66	0.00
231.73	231.75	25/4/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	13.64	1.89	0.00	0.29	0.00	11.03	0.00	27.00	0.29
232.06	232.08	25/5/16-18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.81	0.00	14.86	2.75	0.00	0.16	0.00	14.38	0.00	32.96	0.48
232.52	232.54	25/5/62-64	0.00	0.00	0.00	0.00	0.00	0.89	0.89	0.00	0.45	13.49	3.12	0.00	0.00	0.11	14.60	0.00	31.77	0.00
232.92	232.94	25/5/102-104	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	17.39	1.86	0.00	0.00	0.00	11.18	0.00	30.64	0.00
233.27	233.29	25/5137-139	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.65	0.00	20.88	0.71	0.00	0.35	0.00	6.19	0.00	30.80	0.00
233.67	233.69	25/6/27-29	0.00	0.00	0.00	0.13	0.00	0.00	0.13	0.00	0.67	20.78	1.21	0.00	1.07	0.00	12.73	0.00	36.46	0.27
234.15	234.17	25/6/75-77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.00	20.07	1.46	0.00	0.00	0.00	8.76	0.00	30.90	0.00
234.52	234.54	25/6/112-114	0.00	0.00	0.00	0.00	0.00	0.64	0.64	0.32	0.00	19.89	1.60	0.00	0.00	0.00	6.31	0.00	28.13	0.00
234.91	234.93	25/7/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	21.51	0.85	0.00	0.85	0.00	9.54	0.00	33.76	0.00
235.26	235.28	25CC/10-22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.00	17.75	0.81	0.00	0.00	0.00	11.56	0.00	30.62	0.00
235.73	235.75	26/1/23-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.93	0.00	15.28	0.93	0.00	0.69	0.00	12.04	0.00	29.86	0.00
236.08	236.10	26/1/58-60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.93	0.00	17.20	1.29	0.00	0.16	0.00	10.13	0.00	30.71	0.00
236.52	236.54	26/1/102-104	0.00	0.00	0.00	0.00	0.00	0.59	0.59	1.03	0.00	17.16	1.61	0.00	0.15	0.00	11.29	0.00	31.23	0.00
236.92	236.94	26/1/142-144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.21	0.00	18.12	0.72	0.00	0.00	0.00	9.66	0.00	29.71	0.00
237.32	237.34	26/2/32-34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.45	0.71	0.00	0.00	0.00	9.23	0.00	30.40	0.00
237.93	237.95	26/2/93-95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	18.03	0.61	0.00	0.20	0.00	8.61	0.00	27.66	0.00
238.33	238.35	26/2/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.41	0.56	0.00	0.19	0.00	5.84	0.00	29.00	0.00
238.51	238.53	26/3/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	21.86	1.05	0.00	0.00	0.00	9.42	0.00	32.56	0.00
238.93	238.95	26/3/43-45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.72	0.00	24.32	0.72	0.00	0.00	0.00	8.20	0.00	33.96	0.00
239.32	239.34	26/3/82-84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00	18.80	1.09	0.00	0.00	0.00	9.67	0.00	29.97	0.00
239.67	239.69	26/3/117-119	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.22	0.00	22.30	1.39	0.00	0.00	0.00	8.89	0.00	33.80	0.00
240.07	240.09	26/4/7-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	18.92	0.46	0.00	0.00	0.00	8.62	0.00	28.31	0.15
240.52	240.54	26/4/52-54	0.00	0.00	0.00	0.00	0.00	0.97	0.97	0.39	0.00	16.02	2.12	0.00	0.00	0.00	17.37	0.00	35.91	0.00
240.92	240.94	26/4/92-94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	24.89	0.99	0.00	0.00	0.00	9.76	0.00	35.75	0.00
241.32	241.34	26/4/132-134	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.58	0.91	0.00	0.00	0.00	10.17	0.00	30.65	0.00
241.65	241.67	26/5/15-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.59	0.00	20.33	0.59	0.00	0.00	0.00	9.05	0.00	30.56	0.00
242.13	242.15	26/5/63-65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	0.00	17.83	1.09	0.00	0.00	0.00	12.17	0.00	31.30	0.00
242.52	242.54	26/5/102-104	0.00	0.00	0.00	0.00	0.00	0.18	0.18	0.00	0.00	14.34	2.54	0.00	0.00	0.00	10.53	0.00	27.40	0.00
242.92	242.94	26/5/142-144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.05	15.99	0.75	0.00	0.00	0.00	6.73	0.00	24.51	0.00
243.26	243.28	26/6/26-28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	19.81	0.96	0.00	0.00	0.00	4.42	0.00	25.38	0.00
243.63	243.65	26/6/63-65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.79	1.14	0.00	0.00	0.00	8.68	0.00	22.60	0.00
243.86	243.88	26CC/13-15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.13	4.97	0.00	0.00	0.00	13.81	0.00	28.91	0.00
245.11	245.13	27/1/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	13.54	2.31	0.00	0.31	0.00	11.69	0.00	28.00	0.00
245.53	245.55	27/1/43-45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.95	0.00	17.02	1.97	0.00	0.00	0.00	13.50	0.00	35.44	0.00
245.91	245.93	27/1/81-83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.76	0.00	18.26	0.64	0.00	0.00	0.21	9.77	0.00	31.63	0.00
246.27	246.29	27/1/117-119	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.01	0.00	21.42	0.29	0.00	0.14	0.00	13.17	0.00	36.03	0.00
246.52	246.54	27/1/142-144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.16	2.82	0.00	0.00	0.21	14.81	0.00	33.99	0.10
246.87	246.89	27/2/27-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.00	18.64	0.36	0.00	0.24	0.00	14.04	0.00	34.14	0.00
247.33	247.35	27/2/73-76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.49	0.00	22.68	0.56	0.00	0.00	0.00	7.25	0.00	31.97	0.00
247.67	247.69	27/2/107-109	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.09	0.00	24.43	0.97	0.00	0.12	0.00	9.43	0.00	36.03	0.00
248.11	248.13	27/3/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	22.47	0.75	0.00	0.00	0.00	10.67	0.00	34.46	0.00
248.47	248.49	27/3/37-39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.38	2.13	0.00	0.11	0.00	17.02	0.00	35.64	0.00
248.93	248.95	27/3/83-85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.82	0.24	0.00	0.00	0.00	8.43	0.00	33.49	0.00
249.27	249.27	27/3/117-119	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	20.79	1.09	0.00	0.00	0.00	13.45	0.00	35.60	0.00
249.67	249.69	27/4/7-9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	19.98	1.12	0.00	0.00	0.00	10.55	0.00	32.10	0.22
250.12	250.14	27/4/52-54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	22.82	0.42	0.00	0.00	0.14	10.99	0.00	34.65	0.00
250.46	250.48	27/4/86-88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	2.96	0.00	0.00	0.00	18.38	0.00	35.38	0.00
250.92	250.94	27/4/132-134	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	19.00	2.06	0.00	0.00	0.00	10.01	0.00	31.22	0.00
251.33	251.36	27/5/23-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	21.64	0.95	0.00	0.00	0.00	6.64	0.00	29.38	0.00
251.67	251.69	27/5/57-59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.30	0.18	0.00	0.18	0.00	10.38	0.00	26.05	0.00
252.13	252.15	27/5/103-105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00	18.20	0.87	0.00	0.00	0.00	10.48	0.00	30.13	0.00
252.53	252.55	27/5/143-145	0.00	0.00	0.00	0.00	0.00	0.33	0.33	0.00	0.00	15.63	4.93	0.00	0.00	0.00	13.98	0.00	34.54	0.00
252.92	252.94	27/6/32-34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.97	1.33	0.00	0.00	0.00	11.15	0.00	30.45	0.00
253.33	253.35	27/6/73-75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.33	0.84	0.00	0.00	0.28	9.83	0.00	25.28	0.00
253.67	253.69	27/6/107-109	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.40	2.74	0.00	0.00	0.00	10.96	0.00	31.10	0.00
254.10	254.12	27/7/0-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.21	1.11	0.00	0.32	0.00	11.43	0.00	32.06	0.00
254.49	254.51	27CC/10-12	0.00	0.00	0.00	0.00	0.00	0.12	0.12	0.00	0.00	13.16	1.93	0.00	0.12	0.00	14.49	0.00	29.71	0.00
254.93	254.95	28/1/23-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00	17.38	0.46	0.00	0.00	0.00	11.69	0.00	30.00	0.00
255.28	255.30	28/1/58-60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	16.52	1.21	0.00	0.00	0.15	11.52	0.00	29.70	0.00
255.73	255.75	28/1/103-105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	15.63	0.75	0.00	0.00	0.00	8.85	0.00	25.80	0.00
256.11	256.13	28/1/141-143	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.47	0.00	16.05	1.40	0.00	0.00	0.00	13.26	0.00	31.16	0.00
256.53	256.55	28/2/33-35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.56	1.56	0.00	0.17	0.00	18.37	0.00	34.66	0.00
257.03	257.05	28/2/83-85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30	0.00	23.48	0.65	0.00	0.00	0.00	10.43	0.00	35.87	0.00
257.33	257.35	28/2/113-115	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.39	0.00	17.13	2.08	0.00	0.00	0.00	14.35	0.00	34.95	0.00
257.71	257.73	28/3/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.67	0.00	20.00	1.67	0.00	0.42	0.00	11.04	0.00	34.79	0.00
258.12	258.14	28/3/42-44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	17.25	1.17	0.00	0.17	0.00	16.25	0.00	35.01	0.00
258.54	258.56	28/3/84-86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.05	0.00	19.37	1.57	0.00	0.26	0.00	10.21	0.00	32.46	0.00
259.07	259.09	28/3/137-139	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.77	0.00	17.39	0.77	0.00	0.51	0.00	10.49	0.00	29.92	0.00
259.53	259.55	28/4/33-35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	16.15	0.65	0.00	0.33	0.00	11.75	0.00	29.04	0.00
259.86	259.88	28/4/66-68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	16.50	1.53	0.00	0.13	0.00	13.17	0.00	31.46	0.00
260.28	260.30	28/4/108-110	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	0.00	17.88	1.24	0.00	0.00	0.00	10.11	0.00	29.55	0.00
260.54	260.56	28/4/134-136	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.90	3.09	0.00	0.00	0.00	21.21	0.00	35.20	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Truncorotalia* aff. *crassaformis*	*Truncorotalia crassaformis*	*Truncorotalia juanai*	*Truncorotalia juanai?*	*Truncorotalia praecrassaformis*	*Truncorotalia praecrassaformis?*	***Truncorotalia***	*Zeaglobigerina nepenthes*	*Zeaglobigerina nepenthes?*	*Zeaglobigerina* sp.	*Zeaglobigerina woodi apertura*	*Zeaglobigerina woodi apertura?*	*Zeaglobigerina woodi decoraperta*	*Zeaglobigerina wodi decoraperta?*	*Zeaglobigerina woodi woodi*	*Zeaglobigerina wooodi woodi?*	***Zeaglobigerina***	Misc: unidentified planktics
260.86	260.88	28/5/16-18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	17.34	1.07	0.00	0.00	0.00	13.70	0.00	32.33	0.00
261.31	261.33	28/5/61-63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.63	0.91	0.00	0.61	0.00	6.71	0.00	31.86	0.00
261.72	261.74	28/5/102-104	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.78	1.95	0.00	0.13	0.00	14.04	0.00	32.90	0.00
262.11	262.13	28/5/141-143	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	19.19	1.73	0.00	0.38	0.00	14.01	0.00	35.51	0.00
262.45	262.47	28CC/8-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.00	17.15	3.51	0.00	0.11	0.00	15.97	0.00	37.27	0.00
264.30	264.32	29/1/0-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.55	0.00	21.13	0.77	0.00	0.77	0.00	11.34	0.00	35.57	0.00
264.64	264.66	29/1/34-36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.60	3.25	0.00	0.46	0.00	14.99	0.00	32.30	0.00
264.88	264.90	29/1/58-60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	20.51	0.48	0.00	0.48	0.00	11.22	0.00	32.85	0.00
265.26	265.28	29/1/96-98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.09	0.33	0.00	0.33	0.00	9.54	0.00	28.29	0.00
265.72	265.74	29/1/142-144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.90	0.39	0.00	0.19	0.00	5.84	0.00	24.32	0.00
266.12	266.14	29/2/32-34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.40	0.00	0.00	0.43	0.00	2.81	0.00	21.65	0.00
266.44	266.46	29/2/64-66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.45	0.89	0.00	0.00	0.00	10.07	0.00	28.41	0.00
266.87	266.89	29/2/107-109	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.95	0.00	0.00	0.49	0.00	7.88	0.00	28.33	0.00
267.31	267.33	29/3/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.88	0.00	0.00	0.00	0.00	4.08	0.00	22.96	0.00
267.53	267.55	29/3/23-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.28	0.53	0.00	0.00	0.00	8.11	0.00	31.92	0.00
267.72	267.74	29/3/42-44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.71	0.71	0.00	0.00	0.00	10.64	0.00	32.06	0.00
267.87	267.89	29/3/57-59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.54	0.70	0.00	0.18	0.00	7.53	0.00	29.95	0.00
268.14	268.16	29/3/84-86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	19.93	0.37	0.00	0.00	0.00	10.42	0.00	30.90	0.00
268.34	268.36	29/3/104-106	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.24	1.09	0.00	0.00	0.00	8.71	0.00	27.04	0.00
268.47	268.49	29/3/117-119	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	13.79	3.82	0.00	0.00	0.00	8.91	5.30	32.03	0.00
268.68	268.70	29/3/138-140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	21.82	0.52	0.00	0.00	0.00	8.31	0.00	30.91	0.00
268.86	268.88	29/4/6-8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.87	0.00	17.20	0.87	0.00	0.00	0.00	11.66	0.00	30.61	0.00
269.28	269.30	29/4/48-50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.70	0.00	12.22	1.42	0.00	0.00	0.00	16.76	0.00	32.10	0.00
269.52	269.54	29/4/72-74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20	0.00	13.73	2.89	0.00	0.72	0.00	11.57	0.00	30.12	0.00
269.75	269.77	29/4/95-97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.00	12.27	1.65	0.00	0.18	0.00	12.09	0.00	26.92	0.00
269.87	269.89	29/4/107-109	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	13.37	1.44	0.00	1.03	0.00	11.11	0.00	27.16	0.00
270.15	270.17	29/4/135-137	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.35	0.00	18.61	2.20	0.00	0.17	0.00	9.31	0.00	31.64	0.00
270.31	270.33	29/5/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.78	0.00	14.26	2.33	0.00	0.44	0.00	12.52	0.00	33.33	0.00
270.45	270.47	29/5/15-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.35	0.00	14.86	1.80	0.00	0.00	0.00	11.49	4.05	33.56	0.00
270.72	270.74	29/5/42-44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.35	0.00	13.77	1.58	0.00	0.23	0.00	12.64	0.00	29.57	0.00
270.91	270.93	29/5/61-63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.87	0.00	20.07	0.54	0.00	0.18	0.00	6.27	0.00	29.93	0.00
271.15	271.17	29/5/85-87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.68	0.00	10.68	1.84	0.00	0.18	0.00	11.23	0.00	27.62	0.00
271.34	271.36	29/5/104-106	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00	15.20	0.80	0.00	1.20	0.00	9.40	0.00	27.40	0.00
271.48	271.50	29/5/118-120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.98	0.00	16.93	0.20	0.00	0.98	0.00	6.30	0.00	25.39	0.00
271.72	271.74	29/5/142-144	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	16.10	1.82	0.00	0.26	0.00	15.84	0.00	34.29	0.00
271.94	271.96	29/6/14-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.66	0.00	15.34	2.40	0.00	0.18	0.00	13.49	0.00	33.09	0.00
272.19	272.21	29CC/17-19	0.00	0.00	0.00	0.00	0.00	0.11	0.11	4.77	0.00	14.42	2.97	0.00	0.32	0.00	9.12	3.39	34.99	0.00
273.91	273.93	30/1/1-A7303	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.97	0.00	19.47	0.99	0.00	0.33	0.00	11.72	0.00	35.48	0.00
274.04	274.06	30/1/14-16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.45	0.00	11.88	2.47	0.00	0.22	0.00	13.00	0.00	28.03	0.00
274.32	274.34	30/1/42-44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.87	0.00	14.93	3.30	0.00	0.69	0.00	7.29	0.00	27.08	0.00
274.48	274.50	30/1/58-60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.00	9.39	2.45	0.00	0.00	0.00	14.49	4.49	31.84	0.00
274.72	274.74	30/1/82-84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.53	0.00	15.12	1.25	0.00	0.28	0.00	14.70	0.00	32.87	0.00
274.93	274.95	30/1/103-105	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.00	16.05	1.94	0.00	0.00	0.00	9.72	0.00	28.04	0.00
275.12	275.14	30/1/122-124	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00	14.32	1.20	0.00	0.54	0.00	15.26	0.00	32.13	0.00
275.31	275.33	30/1/141-143	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	20.68	1.49	0.00	0.27	0.00	13.11	0.00	35.68	0.00
275.45	275.47	30/2/5-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	17.87	1.99	0.00	0.36	0.00	10.29	0.00	30.69	0.00
275.93	275.95	30/2/53-55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.31	0.00	16.39	1.80	0.00	0.49	0.00	16.39	0.00	36.39	0.00
276.52	276.54	30/2/112-114	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.16	4.58	0.00	0.48	0.00	19.45	0.00	37.65	0.00
276.91	276.93	30/3/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.57	1.02	0.00	0.17	0.00	15.50	0.00	35.26	0.00
277.33	277.35	30/3/43-45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.22	0.00	16.82	0.76	0.00	0.46	0.00	11.16	0.00	30.43	0.00
277.74	277.76	30/3/84-86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.78	0.00	16.09	1.09	0.00	0.63	0.00	11.25	0.00	29.84	0.00
278.07	278.09	30/3/117-119	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	20.77	0.93	0.00	0.26	0.00	12.70	0.00	35.05	0.00
278.49	278.51	30/4/9-11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.23	0.00	11.26	4.68	0.00	0.33	0.00	18.39	0.00	35.90	0.00
278.88	278.90	30/4/48-50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.00	18.08	0.49	0.00	0.49	0.00	11.56	0.00	30.94	0.00
279.33	279.35	30/4/93-95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.29	2.43	0.00	0.19	0.00	15.73	0.00	34.64	0.00
279.75	279.77	30/4/135-137	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.52	0.86	0.00	0.35	0.00	14.85	0.00	35.58	0.00
280.05	280.07	30/5/15-17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	0.00	18.43	1.47	0.00	1.11	0.00	17.57	0.00	39.07	0.00
280.25	280.27	30/5/35-37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	0.00	10.59	6.25	0.00	1.27	0.00	17.37	0.00	36.02	0.00
280.92	280.94	30/5/102-104	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	15.71	1.96	0.00	0.00	0.00	10.36	0.00	28.39	0.00
283.51	283.53	31/1/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.00	13.47	3.95	0.00	0.29	0.00	14.06	0.00	32.06	0.00
283.94	283.96	31/1/44-46	0.00	0.00	0.00	0.15	0.00	0.00	0.15	0.15	0.00	18.41	0.30	0.00	0.00	0.00	12.43	0.00	31.29	0.00
284.33	284.35	31/1/83-85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.63	0.61	0.00	0.15	0.00	13.34	0.00	33.74	0.00
284.55	284.57	31/1/105-107	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.28	3.20	0.00	0.12	0.00	9.23	11.60	32.43	0.00
284.88	284.90	31/1/138-140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.55	2.02	0.00	0.00	0.00	15.34	0.00	33.92	0.00
285.29	285.31	31/2/29-31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63	0.00	16.41	2.03	0.00	0.47	0.00	16.25	0.00	35.78	0.00
285.73	285.75	31/2/73-75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.23	1.86	0.00	0.34	0.00	15.57	0.00	32.99	0.00
286.10	286.12	31/2/110-112	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	16.71	1.29	0.00	0.86	0.00	15.00	0.00	34.00	0.00
286.51	286.53	31/3/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.49	0.00	12.21	2.65	0.00	1.59	0.00	10.93	6.90	35.77	0.00
286.88	286.90	31/3/38-40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.13	1.43	0.00	0.54	0.00	16.67	0.00	34.77	0.00
287.32	287.34	31/3/82-84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.56	0.53	0.00	0.53	0.00	6.71	0.00	35.34	0.00
287.67	287.69	31/3/117-119	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	25.09	1.19	0.00	0.00	0.59	4.04	0.00	31.03	0.00
288.08	288.10	31/4/8-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	27.15	1.47	0.00	1.26	0.00	6.81	0.00	36.79	0.00
288.55	288.57	31/4/55-57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.24	0.00	15.50	3.00	0.00	0.41	0.00	16.53	0.00	36.67	0.00
288.89	288.91	31/4/89-91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.96	0.00	14.29	0.81	0.00	1.35	0.00	4.58	0.00	23.99	0.00
289.34	289.36	31/4/134-136	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	16.39	0.96	0.00	0.00	0.00	11.24	0.00	28.95	0.00
289.73	289.75	31/5/23-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	13.73	0.75	0.00	0.00	0.00	8.66	0.00	23.43	0.00
290.12	290.14	31/5/62-64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.16	1.62	0.00	0.97	0.00	17.67	0.00	32.41	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Truncorotalia* aff. *crassaformis*	*Truncorotalia crassaformis*	*Truncorotalia juanai*	*Truncorotalia juanai?*	*Truncorotalia praecrassaformis*	*Truncorotalia praecrassaformis?*	***Truncorotalia***	*Zeaglobigerina nepenthes*	*Zeaglobigerina nepenthes?*	*Zeaglobigerina* sp.	*Zeaglobigerina woodi apertura*	*Zeaglobigerina woodi apertura?*	*Zeaglobigerina woodi decoraperta*	*Zeaglobigerina wodi decoraperta?*	*Zeaglobigerina woodi woodi*	*Zeaglobigerina wooodi woodi?*	***Zeaglobigerina***	Misc: unidentified planktics
290.51	290.53	31/5/101-103	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	12.36	4.57	0.00	0.25	0.00	16.56	0.00	33.87	0.00
290.74	290.76	31CC/0-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	17.41	0.76	0.00	0.13	0.00	11.05	0.00	29.61	0.00
293.11	293.13	32/1/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.45	1.30	0.00	0.00	0.00	14.61	0.00	30.36	0.00
293.33	293.35	32/1/23-25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.62	0.00	12.19	1.62	0.00	0.15	0.00	9.40	0.00	24.96	0.00
293.71	293.73	32/1/61-63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	15.42	1.33	0.00	0.00	0.00	9.78	0.00	26.70	0.00
294.12	294.14	32/1/102-104	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.00	13.66	0.88	0.00	0.18	0.00	12.08	0.00	27.15	0.00
294.51	294.53	32/1/141-143	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	15.01	2.62	0.00	0.24	0.00	16.60	0.00	34.55	0.00
294.90	294.92	32/2/30-32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.78	0.86	0.00	0.12	0.00	14.15	0.00	28.91	0.00
295.33	295.35	32/2/73-75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	16.28	1.36	0.00	0.41	0.00	13.70	0.00	32.70	0.00
295.73	295.75	32/2/113-115	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.59	0.85	0.00	0.00	0.00	15.84	0.00	36.29	0.00
295.93	295.95	32/2/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.83	1.20	0.00	0.00	0.00	16.83	0.00	33.87	0.00
296.50	296.52	32/3/40-42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.00	12.74	1.91	0.00	0.16	0.00	20.22	0.00	35.51	0.00
296.93	296.95	32/3/83-85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.32	1.52	0.00	0.00	0.00	12.98	0.00	27.82	0.00
297.33	297.35	32/3/123-125	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.57	0.29	0.00	0.00	0.00	14.57	0.00	29.43	0.00
297.70	297.72	32/4/10-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	17.54	1.27	0.00	0.00	0.00	14.57	0.00	33.52	0.00
298.08	298.10	32/4/48-50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00	14.85	1.31	0.00	0.00	0.00	15.50	0.00	32.30	0.00
298.52	298.54	32/4/92-94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.00	14.38	2.91	0.00	0.00	2.23	15.75	0.00	35.79	0.00
298.93	298.95	32/4/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.06	2.10	0.00	0.48	0.00	11.94	0.00	27.58	0.00
299.38	299.40	32/5/28-30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.08	0.00	14.83	0.98	0.00	0.56	0.00	13.29	0.00	32.73	0.00
299.67	299.69	32CC/2-4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.08	0.00	12.75	1.88	0.00	1.15	0.00	14.73	0.00	34.59	0.00
302.71	302.73	33/1/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.41	0.00	14.61	1.79	0.00	0.65	0.00	15.42	0.00	35.88	0.00
302.97	302.99	33/1/27-29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.97	0.00	13.62	0.90	0.00	3.05	0.00	11.47	0.00	31.00	0.00
303.29	303.31	33/1/59-61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.28	0.00	12.66	0.80	0.00	4.81	0.00	9.62	0.00	29.17	0.00
303.77	303.79	33/1/107-109	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.83	0.00	17.47	0.33	0.00	1.00	0.00	11.48	0.00	31.11	0.00
304.13	304.15	33/1/143-145	0.00	0.00	0.00	1.17	0.00	0.00	1.17	0.97	0.00	16.37	0.19	0.00	1.36	0.00	8.58	0.00	27.49	0.00
304.29	304.31	33/2/9-11	0.00	0.00	0.00	1.78	0.00	0.00	1.78	0.00	0.00	19.18	1.42	0.00	0.36	0.00	9.41	0.00	30.37	0.00
304.47	304.49	33/2/27-29	0.00	0.00	0.00	2.08	0.00	0.00	2.08	1.97	0.00	16.30	1.04	0.00	0.83	0.00	12.05	0.00	32.19	0.00
304.66	304.68	33/2/46-48	0.00	0.00	0.00	5.31	0.00	0.00	5.31	0.53	0.00	15.93	1.77	0.00	0.00	0.00	6.73	0.00	24.96	0.00
305.02	305.04	33/2/82-84	0.00	0.00	0.00	5.51	0.00	0.00	5.51	0.32	0.00	17.34	0.65	0.00	1.46	0.00	8.91	0.00	28.69	0.00
305.15	305.17	33/2/95-97	0.00	0.00	0.00	7.11	0.00	0.00	7.11	1.08	0.00	18.10	0.00	0.00	0.86	0.00	9.70	0.00	29.74	0.00
305.34	305.36	33/2/114-116	0.00	0.00	0.00	1.87	0.00	0.00	1.87	1.66	0.00	16.80	0.00	0.00	1.45	0.00	9.75	0.00	29.67	0.00
305.55	305.57	33/2/135-137	0.00	0.00	0.00	4.81	0.00	0.00	4.81	0.18	0.00	16.93	0.53	0.00	0.18	0.00	11.23	0.00	29.06	0.00
305.71	305.73	33/3/1-3	0.00	0.00	0.00	1.46	0.00	0.00	1.46	0.83	0.00	15.42	0.83	0.00	0.42	0.00	7.29	0.00	24.79	0.00
305.93	305.95	33/3/23-25	0.00	0.00	0.00	4.04	0.00	0.00	4.04	0.22	0.00	15.47	0.22	0.00	0.00	0.00	11.21	0.00	27.13	0.00
306.11	306.13	33/3/41-43	0.00	0.00	0.00	1.19	0.00	0.00	1.19	0.59	0.00	14.62	0.99	0.00	1.38	0.00	11.46	0.00	29.05	0.00
306.27	306.29	33/3/57-59	0.00	0.00	0.00	2.44	0.00	0.00	2.44	0.57	0.00	20.40	0.00	0.00	0.29	0.00	9.91	0.00	31.18	0.00
306.54	306.56	33/3/84-86	0.00	0.00	0.00	4.72	0.00	0.00	4.72	0.00	0.00	19.48	0.76	0.00	0.00	0.00	16.44	0.00	36.68	0.00
306.75	306.77	33/3/105-107	0.00	0.00	0.00	4.35	0.00	0.00	4.35	0.33	0.00	14.69	0.54	0.00	0.00	0.00	13.82	0.00	29.38	0.00
306.86	306.88	33/3/116-118	0.00	0.00	0.00	2.62	0.00	0.00	2.62	0.44	0.00	16.81	0.22	0.00	0.44	0.00	6.99	0.00	24.89	0.00
307.08	307.10	33/3/138-140	0.00	0.00	0.00	3.07	0.00	0.00	3.07	0.00	0.61	14.96	0.61	0.00	0.20	0.00	12.50	0.00	28.89	0.00
307.30	307.32	33/4/10-12	0.00	0.00	0.00	2.84	0.00	0.00	2.84	0.00	0.52	8.76	0.52	0.00	0.52	0.00	6.44	0.00	16.75	0.00
307.49	307.51	33/4/29-31	0.00	0.00	0.00	1.79	0.00	0.00	1.79	0.00	0.00	19.05	0.00	0.00	0.60	0.00	7.14	0.00	26.79	0.00
307.70	307.72	33/4/50-52	0.00	0.00	0.00	3.01	0.00	0.00	3.01	0.00	1.00	16.54	0.50	0.00	1.75	0.00	4.26	0.00	24.06	0.00
307.93	307.95	33/4/73-75	0.00	0.00	0.00	1.95	0.00	0.00	1.95	0.00	0.00	14.01	0.19	0.00	0.00	0.00	7.20	0.00	21.40	0.00
308.14	308.16	33/4/94-96	0.00	0.00	0.00	4.21	0.00	0.00	4.21	0.00	0.32	15.53	0.65	0.00	0.97	0.00	8.25	0.00	25.73	0.00
308.30	308.32	33/4/110-112	0.00	0.00	0.00	3.15	0.00	0.00	3.15	0.23	0.00	13.06	0.00	0.00	0.00	0.00	7.21	0.00	20.50	0.00
308.53	308.55	33/4/133-135	0.00	0.00	0.00	2.43	0.00	0.00	2.43	0.00	0.17	12.13	0.52	0.00	0.35	0.00	12.31	0.00	25.48	0.00
308.71	308.73	33/5/1-3	0.00	0.00	0.00	0.61	0.00	0.00	0.61	0.00	0.00	15.57	0.61	0.00	0.31	0.00	14.20	0.00	30.69	0.00
308.99	309.01	33/5/29-31	0.00	0.00	0.00	1.92	0.00	0.00	1.92	0.00	0.64	15.78	0.85	0.00	0.64	0.00	7.68	0.00	25.59	0.00
309.11	309.13	33/5/41-43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	13.09	0.00	0.00	0.41	0.00	13.70	0.00	27.61	0.00
309.28	309.30	33/5/58-60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	13.94	0.46	0.00	0.00	0.00	15.01	0.00	29.56	0.00
309.54	309.56	33/5/84-86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.11	0.00	15.87	1.60	0.00	0.00	0.00	15.87	0.00	34.44	0.00
309.74	309.76	33/5/104-106	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	21.49	0.66	0.00	0.13	0.00	9.95	0.00	32.36	0.00
312.31	312.33	34/1/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	15.41	0.54	0.00	0.36	0.00	14.87	0.00	31.72	0.00
312.54	312.56	34/1/24-26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	14.82	0.59	0.00	0.20	0.00	14.23	0.00	30.04	0.00
312.67	312.69	34/1/37-39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.48	23.00	0.21	0.00	0.63	0.00	6.96	0.00	32.28	0.00
312.87	312.89	34/1/57-59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.23	0.45	0.00	0.45	0.00	12.05	0.00	33.18	0.00
313.07	313.09	34/1/77-79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.79	15.02	0.00	0.00	0.64	0.00	4.94	0.00	23.39	0.00
313.31	313.33	34/1/101-103	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41	16.33	0.82	0.00	1.43	0.00	14.08	0.00	33.06	0.00
313.53	313.55	34/1/123-125	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.02	20.20	0.51	0.00	0.34	0.00	8.83	0.00	30.90	0.00
313.71	313.73	34/1/141-143	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.67	14.29	0.63	0.00	0.31	0.00	13.19	0.00	31.08	0.00
313.90	313.92	34/2/10-12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.58	15.90	0.20	0.00	0.00	1.39	5.37	0.00	26.44	0.00
314.09	314.11	34/2/29-31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.86	10.08	0.00	0.00	1.86	0.00	9.55	0.00	23.34	0.00
314.29	314.31	34/2/49-51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	18.41	0.00	0.00	0.75	0.00	7.71	0.00	27.86	0.00
314.45	314.47	34/2/65-67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.36	11.95	0.00	0.00	1.77	0.00	7.52	0.00	23.60	0.00
314.69	314.71	34/2/89-91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.46	14.89	0.13	0.00	1.60	0.00	7.71	0.00	27.79	0.00
314.90	314.92	34/2/110-112	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.11	0.21	0.00	11.06	0.00	7.31	0.00	30.69	0.00
315.13	315.15	34/2/133-135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	19.66	0.14	0.00	0.00	1.00	7.89	0.00	28.98	0.00
315.30	315.32	34/3/0-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.44	0.00	0.00	1.40	0.00	7.54	0.00	27.37	0.00
315.52	315.54	34/3/22-24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.04	18.50	0.00	0.00	0.00	3.33	4.16	0.00	27.03	0.00
315.71	315.73	34/3/41-43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.77	0.43	0.00	4.97	0.00	9.29	0.00	30.45	0.00
316.06	316.08	34/3/76-78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	22.70	0.29	0.00	0.00	1.01	7.18	0.00	31.75	0.00
316.27	316.29	34/3/97-99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.72	0.00	18.29	1.23	0.00	0.41	0.00	12.54	0.00	33.20	0.00
316.48	316.50	34/3/118-120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.76	13.61	0.19	0.00	2.84	0.00	10.59	0.00	27.98	0.00
316.67	316.69	34/3/137-139	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.04	0.00	21.04	0.00	0.00	0.00	0.23	0.23	0.00	23.53	0.00
317.10	317.12	34/4/30-32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.77	13.41	0.00	0.00	1.30	0.00	6.33	0.00	26.82	0.00
317.50	317.52	34/4/70-72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	12.53	0.24	0.00	0.00	0.24	5.78	0.00	19.28	0.00

Data Appendix 1.2

Planktic foraminiferal distribution and abundance (percentage), DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top Depth (mbsf)	Bottom Depth (mbsf)	Core/Section /Interval	*Truncorotalia* aff. *crassaformis*	*Truncorotalia crassaformis*	*Truncorotalia juanai*	*Truncorotalia juanai?*	*Truncorotalia praecrassaformis*	*Truncorotalia praecrassaformis?*	***Truncorotalia***	*Zeaglobigerina nepenthes*	*Zeaglobigerina nepenthes?*	*Zeaglobigerina* sp.	*Zeaglobigerina woodi apertura*	*Zeaglobigerina woodi apertura?*	*Zeaglobigerina woodi decoraperta*	*Zeaglobigerina wodi decoraperta?*	*Zeaglobigerina woodi woodi*	*Zeaglobigerina wooodi woodi?*	***Zeaglobigerina***	Misc: unidentified planktics
317.90	317.92	34/4/110-112	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.56	0.25	0.00	0.00	0.00	8.66	0.00	27.48	0.00
318.35	318.37	34/5/5-7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.75	0.00	0.00	0.00	7.98	3.27	0.00	26.99	0.00
318.60	318.62	34/5/30-32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.98	0.97	0.00	0.24	0.00	13.49	0.00	32.69	0.00
321.91	321.93	35/1/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.62	0.64	0.00	0.16	0.00	10.79	0.00	27.21	0.00
322.33	322.35	35/1/43-45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.73	16.29	0.00	0.00	0.00	3.07	0.41	0.00	29.51	0.00
322.72	322.74	35/1/82-84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	18.20	0.40	0.00	0.00	1.40	7.20	0.00	28.00	0.00
323.09	323.11	35/1/119-121	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95	20.91	0.00	0.00	0.00	2.28	6.65	0.00	30.80	0.00
323.48	323.50	35/2/8-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.97	9.97	0.00	0.00	0.00	0.27	1.89	0.00	22.10	0.00
323.91	323.93	35/2/51-53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	11.73	0.32	0.00	0.86	0.00	4.52	0.00	17.87	0.00
324.50	324.52	35/2/110-112	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.15	11.94	0.00	0.00	0.00	0.70	3.75	0.00	21.55	0.00
324.91	324.93	35/3/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.77	15.63	0.00	0.00	0.00	0.00	5.60	0.00	23.01	0.00
325.33	325.35	35/3/43-45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.54	0.16	0.00	0.00	0.00	6.20	0.00	19.90	0.00
325.71	325.73	35/3/81-83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.47	0.00	16.09	0.00	0.00	0.00	0.00	10.05	0.00	27.61	0.00
325.94	325.96	35/3/104-106	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.87	0.00	8.32	0.55	0.00	0.00	0.00	5.73	0.00	20.46	0.00
326.28	326.30	35/3/138-140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	11.06	0.00	0.00	0.00	0.00	4.84	0.00	16.36	0.00
326.70	326.72	35/4/30-32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	19.46	0.00	0.00	0.00	0.36	7.50	0.00	27.68	0.00
327.09	327.11	35/4/69-71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.77	16.60	0.00	0.00	0.00	0.39	4.25	0.00	22.01	0.00
327.50	327.52	35/4/110-112	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	15.04	0.00	0.00	0.00	0.00	6.02	0.00	21.20	0.00
327.91	327.93	35/5/1-3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	12.96	0.51	0.00	0.00	0.00	8.42	0.00	22.22	0.00
328.27	328.29	35/5/37-39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.36	0.00	0.00	0.00	0.14	6.46	0.00	18.96	0.00
328.72	328.74	35/5/82-84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	9.52	0.54	0.00	0.00	0.00	6.71	0.00	16.99	0.00
331.69	331.71	36/1/19-21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	12.67	0.00	0.00	0.29	0.00	8.69	0.00	21.94	0.00
332.11	332.13	36/1/61-63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	15.56	0.00	0.38	0.00	0.38	8.92	0.00	25.81	0.00
332.68	332.70	36/1/118-120	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22	15.91	0.00	0.00	0.22	0.00	9.68	0.00	26.02	0.00
332.98	333.00	36/1/148-150	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.56	0.00	0.00	0.44	0.00	7.93	0.00	20.93	0.00
333.40	333.42	36/2/40-42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.75	0.00	0.00	0.18	0.00	4.26	0.00	11.19	0.00
334.00	334.02	36/2/100-102	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.35	7.83	0.00	0.00	0.98	0.00	4.50	0.00	15.66	0.00
334.36	334.38	36/2/136-138	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.30	8.97	0.00	0.00	0.23	0.00	6.67	0.00	18.16	0.00
334.87	334.89	36/3/37-39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.42	0.00	16.21	0.48	0.00	0.00	0.00	13.80	0.00	36.92	0.00
335.47	335.49	36/3/97-99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.46	0.00	16.21	0.00	0.00	0.36	0.00	9.84	0.00	29.87	0.00
335.88	335.90	36/3/138-140	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.86	0.00	19.29	0.68	0.00	1.02	0.00	13.37	0.00	36.21	0.00
336.20	336.22	36/4/20-22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.33	0.00	17.77	0.33	0.00	0.66	0.00	6.81	0.00	27.91	0.00
336.60	336.62	36/4/60-62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.65	21.44	0.00	0.00	0.45	0.00	7.95	0.00	31.48	0.00

Data Appendix 1.3

Globoconellid coiling data, DSDP Site 593-14X to 37X (120.30–347.50 mbsf)

Top depth (mbsf)	Core/Section/Interval	NZ Stage	Species	*Globoconella miotumida* bioseries (excludes *Gc. mons and Gc. pliozea*)												
				Supplementary (Sin)	Supplementary (Dex)	Ontogeny count (Sin)	Ontogeny count (Dex)	Census (Sin)	Census (Dex)	GHS data (Sin)	GHS data (Dex)	Total (Dextral)	Total (Sinistral)	Dextral perecentage	Gm/Gc-Interval	Coiling Zone
120.30	14/1/0-3	lower Wo	*Gc. puncticulata*					101	3			101	3	2.9		
120.51	14/1/21-24	lower Wo	*Gc. puncticulata*					114	3			114	3	2.6		
120.69	14/1/39-42	lower Wo	*Gc. puncticulata*					73	1			73	1	1.4		
120.90	14/1/60-63	lower Wo	*Gc. puncticulata*					43	2			43	2	4.4		
121.11	14/1/81-84	lower Wo	*Gc. puncticulata*					55	1			55	1	1.8		
121.26	14/1/96-99	lower Wo	*Gc. puncticulata*					50	0			50	0	0.0		
121.49	14/1/119-122	lower Wo	*Gc. puncticulata*					58	0			58	0	0.0		
121.69	14/1/139-142	lower Wo	*Gc. puncticulata*					102	2			102	2	1.9		
121.90	14/2/10-13	lower Wo	*Gc. puncticulata*					133	2			133	2	1.5		
122.09	14/2/29-32	lower Wo	*Gc. puncticulata*					139	3			139	3	2.1		
122.26	14/2/46-49	lower Wo	*Gc. puncticulata*					145	8			145	8	5.2		
122.51	14/2/71-75	lower Wo	*Gc. puncticulata*					87	2			87	2	2.2		
122.71	14/2/91-94	lower Wo	*Gc. puncticulata*					158	5			158	5	3.1		
122.92	14/2/112-115	lower Wo	*Gc. puncticulata*					134	1			134	1	0.7		
123.10	14/2/130-133	upper Tk	*Gc. sphericomiozea*					110	3			110	3	2.7		
123.30	14/3/0-3	upper Tk	*Gc. sphericomiozea*					93	1			93	1	1.1		
123.53	14/3/23-26	upper Tk	*Gc. sphericomiozea*					110	0			110	0	0.0		
123.69	14/3/39-42	upper Tk	*Gc. sphericomiozea*					79	2			79	2	2.5		
123.88	14/3/58-61	upper Tk	*Gc. sphericomiozea*					72	4			72	4	5.3		
124.11	14/3/81-84	upper Tk	*Gc. sphericomiozea*					83	3			83	3	3.5		
124.30	14/3/100-103	upper Tk	*Gc. sphericomiozea*					162	3			162	3	1.8		
124.50	14/3/120-123	upper Tk	*Gc. sphericomiozea*					109	6			109	6	5.2		
124.68	14/3/138-141	upper Tk	*Gc. sphericomiozea*					103	1			103	1	1.0		
124.90	14/4/10-13	upper Tk	*Gc. sphericomiozea*					112	5			112	5	4.3		
125.10	14/4/30-33	upper Tk	*Gc. sphericomiozea*					126	1			126	1	0.8		
125.30	14/4/50-53	upper Tk	*Gc. sphericomiozea*					78	2			78	2	2.5		
125.48	14/4/68-71	upper Tk	*Gc. sphericomiozea*					66	1			66	1	1.5		
125.71	14/4/91-94	upper Tk	*Gc. sphericomiozea*					49	3			49	3	5.8		
125.91	14/4/111-114	upper Tk	*Gc. sphericomiozea*					117	2			117	2	1.7		
126.10	14/4/130-133	upper Tk	*Gc. sphericomiozea*					68	5			68	5	6.8		
126.30	14/5/0-3	upper Tk	*Gc. sphericomiozea*					65	7			65	7	9.7		
126.56	14/5/26-29	upper Tk	*Gc. sphericomiozea*					82	7			82	7	7.9		
126.70	14/5/40-43	upper Tk	*Gc. sphericomiozea*					68	4			68	4	5.6		
126.90	14/5/60-63	upper Tk	*Gc. sphericomiozea*					68	3			68	3	4.2		
127.12	14/5/82-85	upper Tk	*Gc. sphericomiozea*					106	4			106	4	3.6		
127.30	14/5/100-103	upper Tk	*Gc. sphericomiozea*					94	6			94	6	6.0		
127.51	14/5/121-124	upper Tk	*Gc. sphericomiozea*					70	0			70	0	0.0		
127.70	14/5/140-143	upper Tk	*Gc. sphericomiozea*					77	4			77	4	4.9		
127.90	14/6/10-13	upper Tk	*Gc. sphericomiozea*					46	1			46	1	2.1		
128.29	14/6/49-52	upper Tk	*Gc. sphericomiozea*					61	5			61	5	7.6		
128.72	14/6/92-95	upper Tk	*Gc. sphericomiozea*					96	3			96	3	3.0		
129.10	14/6/130-133	upper Tk	*Gc. sphericomiozea*					86	5			86	5	5.5		
129.50	14/7/20-23	upper Tk	*Gc. sphericomiozea*					142	8			142	8	5.3		
129.90	15/1/0-3	upper Tk	*Gc. sphericomiozea*					56	0			56	0	0.0		
130.29	15/1/39-42	upper Tk	*Gc. sphericomiozea*					68	1			68	1	1.4		
130.69	15/1/79-82	upper Tk	*Gc. sphericomiozea*					70	2			70	2	2.8		
131.10	15/1/120-123	upper Tk	*Gc. sphericomiozea*					46	1			46	1	2.1		
131.51	15/2/11-14	upper Tk	*Gc. sphericomiozea*					47	1			47	1	2.1		
131.91	15/2/51-53	upper Tk	*Gc. sphericomiozea*					97	3			97	3	3.0		
132.33	15/2/93-96	upper Tk	*Gc. sphericomiozea*					38	0			38	0	0.0		
132.74	15/2/134-136	upper Tk	*Gc. sphericomiozea*					51	4			51	4	7.3		
133.07	15/3/17-20	upper Tk	*Gc. sphericomiozea*					88	3			88	3	3.3		
133.46	15/3/56-59	upper Tk	*Gc. sphericomiozea*					124	5			124	5	3.9		
133.89	15/3/99-102	upper Tk	*Gc. sphericomiozea*					85	0			85	0	0.0		
134.30	15/3/140-143	upper Tk	*Gc. sphericomiozea*					113	2			113	2	1.7		
134.70	15/4/30-33	upper Tk	*Gc. sphericomiozea*					78	0			78	0	0.0		
135.10	15/4/70-73	upper Tk	*Gc. sphericomiozea*					146	5			146	5	3.3		
135.30	15/4/90-93	upper Tk	*Gc. sphericomiozea*					185	4			185	4	2.1		
135.50	15/4/110-113	upper Tk	*Gc. sphericomiozea*					158	6			158	6	3.7		
135.70	15/4/130-133	upper Tk	*Gc. sphericomiozea*					148	6			148	6	3.9		
135.90	15/5/0-3	upper Tk	*Gc. sphericomiozea*					144	2			144	2	1.4		
136.06	15/5/16-19	upper Tk	*Gc. sphericomiozea*					99	3			99	3	2.9		
136.32	15/5/42-45	upper Tk	*Gc. sphericomiozea*					129	2			129	2	1.5		
136.51	15/5/61-63	upper Tk	*Gc. sphericomiozea*					139	4			139	4	2.8		
136.92	15/5/102-105	upper Tk	*Gc. sphericomiozea*					146	3			146	3	2.0		
137.13	15/5/123-126	upper Tk	*Gc. sphericomiozea*					116	1			116	1	0.9		
137.52	15/6/12-15	upper Tk	*Gc. sphericomiozea*					172	6			172	6	3.4		
137.91	15/6/51-54	upper Tk	*Gc. sphericomiozea*					113	7			113	7	5.8		
138.27	15/6/87-90	upper Tk	*Gc. sphericomiozea*					113	4			113	4	3.4		
138.66	15/6/126-129	upper Tk	*Gc. sphericomiozea*					134	1			134	1	0.7		
139.07	15/7/17-20	upper Tk	*Gc. sphericomiozea*					124	2			124	2	1.6		
139.50	16/1/0-3	lower Tk	*Gc. conomiozea*	99	1			92	1			191	2	1.0		
139.75	16/1/25-28	lower Tk	*Gc. conomiozea*	98	2							98	2	2.0		
139.93	16/1/43-46	lower Tk	*Gc. conomiozea*	96	4			150	6			150	6	3.8		

Data Appendix 1.3

Globoconellid coiling data, DSDP Site 593-14X to 37X (120.30–347.50 mbsf)

Top depth (mbsf)	Core/Section/Interval	NZ Stage	Species	*Globoconella miotumida* bioseries (excludes *Gc. mons* and *Gc. pliozea*)												
				Supplementary (Sin)	Supplementary (Dex)	Ontogeny count (Sin)	Ontogeny count (Dex)	Census (Sin)	Census (Dex)	GHS data (Sin)	GHS data (Dex)	Total (Dextral)	Total (Sinistral)	Dextral percentage	Gm/Gc-Interval	Coiling Zone
140.17	16/1/67-70	lower Tk	*Gc. conomiozea*	97	3							97	3	3.0		
140.34	16/1/84-87	lower Tk	*Gc. conomiozea*	98	2			146	3			146	3	2.0		
140.54	16/1/104-107	lower Tk	*Gc. conomiozea*	99	1							99	1	1.0		
140.73	16/1123-126	lower Tk	*Gc. conomiozea*	97	3			107	5			107	5	4.5		
140.92	16/1/142-145	lower Tk	*Gc. conomiozea*	96	4							96	4	4.0		
141.13	16/2/13-16	lower Tk	*Gc. conomiozea*	96	4			20	2			116	6	4.9		
141.36	16/2/36-39	lower Tk	*Gc. conomiozea*	96	4							96	4	4.0		
141.54	16/2/54-57	lower Tk	*Gc. conomiozea*	0	0			55	2			55	2	3.5		
141.79	16/2/79-82	lower Tk	*Gc. conomiozea*	99	1							99	1	1.0		
141.92	16/2/92-95	lower Tk	*Gc. conomiozea*	99	1			24	0			123	1	0.8		
142.12	16/2/112-114	lower Tk	*Gc. conomiozea*	99	1							99	1	1.0		
142.32	16/2/132-135	lower Tk	*Gc. conomiozea*	97	3			34	1			131	4	3.0		
142.50	16/3/10-3	lower Tk	*Gc. conomiozea*	99	1							99	1	1.0		
142.75	16/3/25-28	lower Tk	*Gc. conomiozea*	100	0			36	1			136	1	0.7		
142.93	16/3/43-46	lower Tk	*Gc. conomiozea*	97	3							97	3	3.0		
143.15	16/3/65-68	lower Tk	*Gc. conomiozea*	97	3			26	0			123	3	2.4		
143.32	16/3/82-85	lower Tk	*Gc. conomiozea*	97	3							97	3	3.0		
143.53	16/3/103-106	lower Tk	*Gc. conomiozea*	95	5			52	2			147	7	4.5		
143.74	16/3/124-127	lower Tk	*Gc. conomiozea*	99	1							99	1	1.0		
143.84	16/3/134-137	lower Tk	*Gc. conomiozea*	99	1			92	2			191	3	1.5		
144.07	16/4/7-10	lower Tk	*Gc. conomiozea*	98	2							98	2	2.0		
144.26	16/4/26-29	lower Tk	*Gc. conomiozea*	96	4			110	2			206	6	2.8		
144.46	16/4/46-49	lower Tk	*Gc. conomiozea*	99	1							99	1	1.0		
144.67	16/4/67-70	lower Tk	*Gc. conomiozea*	100	0			86	4			186	4	2.1		
144.93	16/4/93-96	lower Tk	*Gc. conomiozea*	99	1							99	1	1.0		
145.13	16/4/113-116	lower Tk	*Gc. conomiozea*	99	1			110	1			209	2	0.9		
145.32	16/4/132-135	lower Tk	*Gc. conomiozea*	98	2							98	2	2.0		
145.50	16/5/0-3	lower Tk	*Gc. conomiozea*	0	0			138	3			138	3	2.1		
145.64	16/5/14-17	lower Tk	*Gc. conomiozea*	99	1							99	1	1.0		
145.93	16/5/43-46	lower Tk	*Gc. conomiozea*	100	0			112	6			212	6	2.8		
146.13	16/5/63-66	lower Tk	*Gc. conomiozea*	98	2							98	2	2.0		
146.36	16/5/86-88	lower Tk	*Gc. conomiozea*	100	0			108	4			208	4	1.9		
146.52	16/5/102-105	lower Tk	*Gc. conomiozea*	97	3							97	3	3.0		
146.71	16/5/121-124	lower Tk	*Gc. conomiozea*	99	1			70	0			169	1	0.6		
146.92	16/5/142-145	lower Tk	*Gc. conomiozea*	95	5							95	5	5.0		
147.06	16/6/6-9	lower Tk	*Gc. conomiozea*	100	0			97	0			197	0	0.0		
147.26	16/6/26-29	lower Tk	*Gc. conomiozea*	98	2							98	2	2.0		
147.47	16/6/47-50	lower Tk	*Gc. conomiozea*	0	0			167	2			167	2	1.2		
147.64	16/6/64-66	lower Tk	*Gc. conomiozea*	97	3							97	3	3.0		
147.93	16/6/93-96	lower Tk	*Gc. conomiozea*	98	2			98	1			196	3	1.5		
148.15	16/6/115-117	lower Tk	*Gc. conomiozea*	100	0							100	0	0.0		
148.33	16/6/133-136	lower Tk	*Gc. conomiozea*	98	2			82	4			180	6	3.2		
148.50	16/7/0-3	lower Tk	*Gc. conomiozea*	96	4							96	4	4.0		
148.67	16/7/17-19	lower Tk	*Gc. conomiozea*	98	2			74	1			172	3	1.7		
148.77	16CC/8-11	lower Tk	*Gc. conomiozea*	99	1							99	1	1.0		
149.10	17/1/0-3	lower Tk	*Gc. conomiozea*	97	3			140	3			237	6	2.5		
149.36	17/1/26-28	lower Tk	*Gc. conomiozea*	98	2							98	2	2.0		
149.52	17/1/42-45	lower Tk	*Gc. conomiozea*	0	0			128	0			128	0	0.0		
149.92	17/1/82-85	lower Tk	*Gc. conomiozea*	98	2							98	2	2.0		
150.11	17/1/101-104	lower Tk	*Gc. conomiozea*	94	6			100	2			194	8	4.0		
150.31	17/1/121-124	lower Tk	*Gc. conomiozea*	98	2							98	2	2.0		
150.51	17/1/141-144	lower Tk	*Gc. conomiozea*	97	3			93	2			190	5	2.6		
150.67	17/2/7-10	lower Tk	*Gc. conomiozea*	97	3							97	3	3.0		
150.87	17/2/27-30	lower Tk	*Gc. conomiozea*	99	1			138	3			237	4	1.7		
151.07	17/2/47-50	lower Tk	*Gc. conomiozea*	99	1			100	0			199	1	0.5		
151.33	17/2/73-76	lower Tk	*Gc. conomiozea*	96	4							96	4	4.0		
151.52	17/2/92-95	lower Tk	*Gc. conomiozea*	0	0			141	5			141	5	3.4		
151.75	17/2/115-118	lower Tk	*Gc. conomiozea*	96	4							96	4	4.0		
151.96	17/2/136-138	lower Tk	*Gc. conomiozea*	99	1			101	4			200	5	2.4		
152.10	17/3/0-3	lower Tk	*Gc. conomiozea*	98	2			117	6			215	8	3.6		
152.25	17/3/15-18	lower Tk	*Gc. conomiozea*	99	1			112	4			211	5	2.3		
152.47	17/3/37-40	lower Tk	*Gc. conomiozea*	96	4			78	0			174	4	2.2		
152.75	17/3/65-67	lower Tk	*Gc. conomiozea*	99	1			122	4			221	5	2.2		
152.91	17/3/81-84	lower Tk	*Gc. conomiozea*	96	4	595	5	114	3			805	12	1.5		
153.12	17/3/102-105	lower Tk	*Gc. conomiozea*	96	4	581	19	117	4			794	27	3.3		
153.26	17/3/116-119	lower Tk	*Gc. conomiozea*	97	3	584	16	137	3			818	22	2.6		
153.45	17/3/135-138	lower Tk	*Gc. conomiozea*	0	0	583	17	131	3			714	20	2.7		
153.66	17/4/6-9	lower Tk	*Gc. conomiozea*	91	9	544	56	66	9			701	74	9.5		
153.97	17/4/37-39	lower Tk	*Gc. conomiozea*	41	59	256	344	32	68			329	471	58.9	*Gc*-593/D3	Palliser (PCZ)
154.13	17/4/53-56	lower Tk	*Gc. conomiozea*	51	49	313	287	70	46			434	382	46.8	*Gc*-593/D3	Palliser (PCZ)
154.32	17/4/72-75	lower Tk	*Gc. conomiozea*	96	4	558	42	124	10			778	56	6.7		Palliser (PCZ)
154.54	17/4/94-97	lower Tk	*Gc. conomiozea*	97	3	586	14	122	3			805	20	2.4		Palliser (PCZ)
154.77	17/4/117-119	lower Tk	*Gc. conomiozea*	99	1	582	18	110	4			791	23	2.8		Palliser (PCZ)
154.95	17/4/135-138	lower Tk	*Gc. conomiozea*	98	2	586	14	122	4			806	20	2.4		Palliser (PCZ)

Data Appendix 1.3

Globoconellid coiling data, DSDP Site 593-14X to 37X (120.30–347.50 mbsf)

Top depth (mbsf)	Core/Section/Interval	NZ Stage	Species	*Globoconella miotumida* bioseries (excludes *Gc. mons* and *Gc. pliozea*)												
				Supplementary (Sin)	Supplementary (Dex)	Ontogeny count (Sin)	Ontogeny count (Dex)	Census (Sin)	Census (Dex)	GHS data (Sin)	GHS data (Dex)	Total (Dextral)	Total (Sinistral)	Dextral perecentage	Gm/Gc-Interval	Coiling Zone
155.10	17/5/0-3	lower Tk	*Gc. conomiozea*	96	4	568	32	114	4			778	40	4.9		Palliser (PCZ)
155.24	17/5/14-17	lower Tk	*Gc. conomiozea*	77	23	405	195	59	23			541	241	30.8	*Gc*-593/D2	Palliser (PCZ)
155.48	17/5/38-40	lower Tk	*Gc. conomiozea*	0	0	551	49	159	15			710	64	8.3	*Gc*-593/D2	Palliser (PCZ)
155.67	17/5/57-60	lower Tk	*Gc. conomiozea*	82	18	520	80	87	15			689	113	14.1	*Gc*-593/D2	Palliser (PCZ)
155.94	17/5/84-87	lower Tk	*Gc. conomiozea*	63	37	399	201	75	44			537	282	34.4	*Gc*-593/D2	Palliser (PCZ)
156.13	17/5/103-106	lower Tk	*Gc. conomiozea*	96	4	572	28	100	6			768	38	4.7		Palliser (PCZ)
156.27	17/5/117-120	lower Tk	*Gc. conomiozea*	97	3	580	20	113	4			790	27	3.3		Palliser (PCZ)
156.47	17/5/137-140	lower Tk	*Gc. conomiozea*	95	5	562	38	118	5			775	48	5.8		Palliser (PCZ)
156.71	17/6/11-14	lower Tk	*Gc. conomiozea*	97	3	571	29	116	2			784	34	4.2		Palliser (PCZ)
156.95	17/6/35-38	lower Tk	*Gc. conomiozea*	97	3	591	9	78	1			766	13	1.7		Palliser (PCZ)
157.12	17/6/52-55	lower Tk	*Gc. conomiozea*	97	3	586	14	108	3			791	20	2.5		Palliser (PCZ)
157.37	17/6/77-79	lower Tk	*Gc. conomiozea*	98	2	582	18	105	6			785	26	3.2		Palliser (PCZ)
157.52	17/6/92-95	lower Tk	*Gc. conomiozea*	0	0	581	19	135	5			716	24	3.2		Palliser (PCZ)
157.76	17/6/116-119	lower Tk	*Gc. conomiozea*	91	9	553	47	114	6			758	62	7.6		Palliser (PCZ)
157.93	17/6/133-136	lower Tk	*Gc. conomiozea*	37	63	274	326	41	48			352	437	55.4	*Gc*-593/D1	Palliser (PCZ)
158.10	17/7/0-3	lower Tk	*Gc. conomiozea*	54	46	366	234	67	29			487	309	38.8	*Gc*-593/D1	Palliser (PCZ)
158.27	17/7/17-20	lower Tk	*Gc. conomiozea*	93	7	555	45	127	10			775	62	7.4		
158.52	17CC/6-9	lower Tk	*Gc. conomiozea*	97	3	579	21	99	0			775	24	3.0		
158.70	18/1/0-3	lower Tk	*Gc. conomiozea*	99	1	585	15	107	2			791	18	2.2		
158.95	18/1/25-28	lower Tk	*Gc. conomiozea*	99	1	586	14	144	1			829	16	1.9		
159.13	18/1/43-46	lower Tk	*Gc. conomiozea*	98	2	579	21	102	3			779	26	3.2		
159.35	18/1/65-68	lower Tk	*Gc. conomiozea*	97	3			155	3			252	6	2.3		
159.49	18/1/79-82	lower Tk	*Gc. conomiozea*	0	0			183	4			183	4	2.1		
159.72	18/1/102-105	lower Tk	*Gc. conomiozea*	97	3			118	3			215	6	2.7		
159.86	18/1/116-119	lower Tk	*Gc. conomiozea*	99	1			118	1			217	2	0.9		
160.11	18/1/141-144	lower Tk	*Gc. conomiozea*	97	3			116	4			213	7	3.2		
160.33	18/2/13-16	lower Tk	*Gc. conomiozea*	96	4			103	1			199	5	2.5		
160.54	18/2/34-37	lower Tk	*Gc. conomiozea*	100	0							100	0	0.0		
160.73	18/2/53-56	lower Tk	*Gc. conomiozea*	96	4			86	1			182	5	2.7		
160.99	18/2/79-82	lower Tk	*Gc. conomiozea*	98	2							98	2	2.0		
161.16	18/2/96-99	lower Tk	*Gc. conomiozea*	98	2			146	6			244	8	3.2		
161.32	18/2/112-114	lower Tk	*Gc. conomiozea*	97	3							97	3	3.0		
161.53	18/2/133-136	lower Tk	*Gc. conomiozea*	0	0			126	5			126	5	3.8		
161.70	18/3/0-3	lower Tk	*Gc. conomiozea*	96	4							96	4	4.0		
161.84	18/3/14-17	lower Tk	*Gc. conomiozea*	98	2			120	1			218	3	1.4		
162.12	18/3/42-45	lower Tk	*Gc. conomiozea*	98	2							98	2	2.0		
162.26	18/3/56-59	lower Tk	*Gc. conomiozea*	98	2			119	3			217	5	2.3		
162.55	18/3/85-88	lower Tk	*Gc. conomiozea*	99	1							99	1	1.0		
162.87	18/3/117-120	lower Tk	*Gc. conomiozea*	100	0			146	0			246	0	0.0		
163.05	18/3/135-137	lower Tk	*Gc. conomiozea*	99	1							99	1	1.0		
163.33	18/4/13-16	lower Tk	*Gc. conomiozea*	98	2			111	1			209	3	1.4		
163.56	18/4/36-39	lower Tk	*Gc. conomiozea*	0	0			171	5			171	5	2.8		
163.73	18/4/53-56	lower Tk	*Gc. conomiozea*	97	3							97	3	3.0		
163.93	18/4/73-76	lower Tk	*Gc. conomiozea*	98	2			104	1			202	3	1.5		
164.13	18/4/93-96	lower Tk	*Gc. conomiozea*	97	3							97	3	3.0		
164.31	18/4/111-113	lower Tk	*Gc. conomiozea*	98	2			132	5			230	7	3.0		
164.52	18/4/132-135	lower Tk	*Gc. conomiozea*	100	0							100	0	0.0		
164.70	18/5/0-3	lower Tk	*Gc. conomiozea*	98	2			152	4			250	6	2.3		
164.96	18/5/26-29	lower Tk	*Gc. conomiozea*	100	0							100	0	0.0		
165.13	18/5/43-46	lower Tk	*Gc. conomiozea*	98	2			128	3			226	5	2.2		
165.35	18/5/65-67	lower Tk	*Gc. conomiozea*	95	5							95	5	5.0		
165.50	18/5/80-83	lower Tk	*Gc. conomiozea*	0	0			186	6			186	6	3.1		
165.74	18/5/104-106	lower Tk	*Gc. conomiozea*	99	1							99	1	1.0		
165.95	18/5/125-127	lower Tk	*Gc. conomiozea*	96	4			111	5			207	9	4.2		
166.11	18/5/141-144	lower Tk	*Gc. conomiozea*	95	5							95	5	5.0		
166.26	18/6/6-9	lower Tk	*Gc. conomiozea*	98	2			97	2			195	4	2.0		
166.46	18/6/26-29	lower Tk	*Gc. conomiozea*	98	2							98	2	2.0		
166.66	18/6/46-49	lower Tk	*Gc. conomiozea*	100	0			98	4			198	4	2.0		
166.86	18/6/66-68	lower Tk	*Gc. conomiozea*	98	2							98	2	2.0		
167.06	18/6/86-89	lower Tk	*Gc. conomiozea*	98	2			97	2			195	4	2.0		
167.24	18/6/104-106	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
167.44	18/6/124-127	upper Tt	*Gc. miotumida*	0	0			135	3			135	3	2.2		
167.57	18CC/7-10	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
168.30	19/1/0-3	upper Tt	*Gc. miotumida*	94	6			92	3			186	9	4.6		
168.52	19/1/22-24	upper Tt	*Gc. miotumida*	94	6							94	6	6.0		
168.71	19/1/41-44	upper Tt	*Gc. miotumida*	97	3			122	4			219	7	3.1		
168.92	19/1/62-65	upper Tt	*Gc. miotumida*	95	5							95	5	5.0		
169.13	19/1/83-85	upper Tt	*Gc. miotumida*	99	1			81	2			180	3	1.6		
169.34	19/1/104-107	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
169.51	19/1/121-124	upper Tt	*Gc. miotumida*	97	3			79	1			176	4	2.2		
169.72	19/1/142-145	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
169.85	19/2/5-8	upper Tt	*Gc. miotumida*	99	1			89	5			188	6	3.1		
170.06	19/2/26-28	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
170.32	19/2/52-55	upper Tt	*Gc. miotumida*	98	2			138	4			236	6	2.5		

Data Appendix 1.3

Globoconellid coiling data, DSDP Site 593-14X to 37X (120.30–347.50 mbsf)

Top depth (mbsf)	Core/Section/Interval	NZ Stage	Species	*Globoconella miotumida* bioseries (excludes *Gc. mons* and *Gc. pliozea*)												
				Supplementary (Sin)	Supplementary (Dex)	Ontogeny count (Sin)	Ontogeny count (Dex)	Census (Sin)	Census (Dex)	GHS data (Sin)	GHS data (Dex)	Total (Dextral)	Total (Sinistral)	Dextral perecentage	Gm/Gc-Interval	Coiling Zone
170.52	19/2/72-74	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
170.73	19/2/93-96	upper Tt	*Gc. miotumida*	99	1			120	2			219	3	1.4		
170.94	19/2/114-117	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
171.15	19/2/135-138	upper Tt	*Gc. miotumida*	99	1			140	7			239	8	3.2		
171.30	19/3/0-3	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
171.57	19/3/27-29	upper Tt	*Gc. miotumida*	0	0			103	1			103	1	1.0		
171.72	19/3/42-45	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
171.92	19/3/62-64	upper Tt	*Gc. miotumida*	99	1			89	4			188	5	2.6		
172.13	19/3/83-86	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
172.32	19/3/102-105	upper Tt	*Gc. miotumida*	97	3			108	5			205	8	3.8		
172.47	19/3/117-120	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
172.66	19/3/136-138	upper Tt	*Gc. miotumida*	97	3			94	1			191	4	2.1		
172.86	19/4/6-9	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
173.07	19/4/27-29	upper Tt	*Gc. miotumida*	96	4			95	2			191	6	3.0		
173.27	19/4/47-50	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
173.52	19/4/72-74	upper Tt	*Gc. miotumida*	0	0			99	1			99	1	1.0		
173.72	19/4/92-95	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
173.93	19/4/113-115	upper Tt	*Gc. miotumida*	98	2			126	3			224	5	2.2		
174.14	19/4/134-137	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
174.30	19/5/0-3	upper Tt	*Gc. miotumida*	99	1			123	6			222	7	3.1		
174.54	19/5/24-27	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
174.72	19/5/42-45	upper Tt	*Gc. miotumida*	98	2			130	2			228	4	1.7		
174.86	19/5/56-59	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
175.26	19/5/96-99	upper Tt	*Gc. miotumida*	97	3			98	2			195	5	2.5		
175.47	19/5/117-120	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
175.71	19/5/141-144	upper Tt	*Gc. miotumida*	97	3			78	1			175	4	2.2		
175.86	19/6/6-9	upper Tt	*Gc. miotumida*	95	5							95	5	5.0		
176.06	19/6/26-29	upper Tt	*Gc. miotumida*	99	1			88	1			187	2	1.1		
176.32	19/6/52-55	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
176.47	19/6/67-69	upper Tt	*Gc. miotumida*	100	0			57	0			157	0	0.0		
176.64	19/6/84-87	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
176.92	19/6/112-114	upper Tt	*Gc. miotumida*	96	4			68	2			164	6	3.5		
177.14	19/6/134-137	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
177.30	19/7/0-3	upper Tt	*Gc. miotumida*	99	1			79	1			178	2	1.1		
177.52	19/7/22-25	upper Tt	*Gc. miotumida*	0	0			149	7			149	7	4.5		
177.82	19CC/0-3	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
177.90	20/1/0-3	upper Tt	*Gc. miotumida*	96	4			93	4			189	8	4.1		
178.05	20/1/15-18	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
178.27	20/1/37-40	upper Tt	*Gc. miotumida*	99	1			98	0			197	1	0.5		
178.48	20/1/58-60	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
178.68	20/1/78-80	upper Tt	*Gc. miotumida*	100	0			160	3			260	3	1.1		
178.87	20/1/97-99	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
179.08	20/1/118-120	upper Tt	*Gc. miotumida*	99	1			126	4			225	5	2.2		
179.27	20/1/137-139	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
179.45	20/2/5-7	upper Tt	*Gc. miotumida*	0	0			161	8			161	8	4.7		
179.67	20/2/27-29	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
179.86	20/2/46-48	upper Tt	*Gc. miotumida*	98	2			111	3			209	5	2.3		
180.17	20/2/77-79	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
180.33	20/2/93-95	upper Tt	*Gc. miotumida*	97	3			123	3			220	6	2.7		
180.46	20/2/106-108	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
180.73	20/2/133-135	upper Tt	*Gc. miotumida*	97	3			112	0			209	3	1.4		
180.91	20/3/1-3	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
181.14	20/3/24-26	upper Tt	*Gc. miotumida*	99	1			106	1			205	2	1.0		
181.32	20/3/42-44	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
181.57	20/3/67-69	upper Tt	*Gc. miotumida*	97	3			73	1			170	4	2.3		
181.72	20/3/82-84	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
181.86	20/3/96-98	upper Tt	*Gc. miotumida*	99	1			120	2			219	3	1.4		
182.06	20/3/116-118	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
182.23	20/3/133-135	upper Tt	*Gc. miotumida*	97	3			113	2			210	5	2.3		
182.47	20/4/7-9	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
182.68	20/4/28-30	upper Tt	*Gc. miotumida*	98	2			81	1			179	3	1.6		
182.88	20/4/48-50	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
183.08	20/4/68-70	upper Tt	*Gc. miotumida*	98	2			106	0			204	2	1.0		
183.26	20/4/86-88	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
183.45	20/4/105-107	upper Tt	*Gc. miotumida*	0	0			159	3			159	3	1.9		
183.72	20/4/132-135	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
183.91	20/5/1-3	upper Tt	*Gc. miotumida*	100	0			100	3			200	3	1.5		
184.15	20/5/25-27	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
184.32	20/5/42-44	upper Tt	*Gc. miotumida*	100	0			69	1			169	1	0.6		
184.51	20/5/61-63	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
184.72	20/5/82-84	upper Tt	*Gc. miotumida*	98	2			104	1			202	3	1.5		
184.91	20/5/101-103	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
185.07	20/5/117-119	upper Tt	*Gc. miotumida*	98	2			125	4			223	6	2.6		
185.27	20/5/137-139	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		

Data Appendix 1.3

Globoconellid coiling data, DSDP Site 593-14X to 37X (120.30–347.50 mbsf)

Top depth (mbsf)	Core/Section/Interval	NZ Stage	Species	*Globoconella miotumida* bioseries (excludes *Gc. mons* and *Gc. pliozea*)												
				Supplementary (Sin)	Supplementary (Dex)	Ontogeny count (Sin)	Ontogeny count (Dex)	Census (Sin)	Census (Dex)	GHS data (Sin)	GHS data (Dex)	Total (Dextral)	Total (Sinistral)	Dextral perecentage	Gm/Gc-Interval	Coiling Zone
185.47	20/6/7-9	upper Tt	*Gc. miotumida*	97	3			101	2			198	5	2.5		
185.74	20/6/34-36	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
185.92	20/6/52-54	upper Tt	*Gc. miotumida*	96	4			77	1			173	5	2.8		
186.08	20/6/68-70	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
186.32	20/6/92-94	upper Tt	*Gc. miotumida*	97	3			84	0			181	3	1.6		
186.51	20/6/111-113	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
186.72	20/6/132-134	upper Tt	*Gc. miotumida*	96	4			91	0			187	4	2.1		
186.90	20/7/0-2	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
187.07	20/7/17-19	upper Tt	*Gc. miotumida*	99	1			70	2			169	3	1.7		
187.22	20CC/7-9	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
187.51	21/1/1-3	upper Tt	*Gc. miotumida*	100	0			76	1			176	1	0.6		
187.76	21/1/26-28	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
187.93	21/1/43-45	upper Tt	*Gc. miotumida*	99	1			40	0			139	1	0.7		
188.08	21/1/58-60	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
188.32	21/182-84	upper Tt	*Gc. miotumida*	97	3			53	2			150	5	3.2		
188.52	21/1/102-104	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
188.67	21/1/117-119	upper Tt	*Gc. miotumida*	96	4			68	3			164	7	4.1		
188.92	21/1/142-144	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
189.08	21/2/8-10	upper Tt	*Gc. miotumida*	100	0			53	1			153	1	0.6		
189.33	21/2/33-35	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
189.46	21/2/46-48	upper Tt	*Gc. miotumida*	97	3			88	0			185	3	1.6		
189.75	21/2/75-77	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
189.93	21/2/93-96	upper Tt	*Gc. miotumida*	97	3			65	2			162	5	3.0		
190.17	21/2/117-119	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
190.42	21/2/142-144	upper Tt	*Gc. miotumida*	97	3			58	1			155	4	2.5		
190.51	21/3/1-3	upper Tt	*Gc. miotumida*	95	5							95	5	5.0		
190.66	21/3/16-18	upper Tt	*Gc. miotumida*	99	1			69	0			168	1	0.6		
190.87	21/3/37-39	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
191.12	21/3/62-64	upper Tt	*Gc. miotumida*	96	4			51	2			147	6	3.9		
191.32	21/3/82-84	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
191.52	21/3/102-104	upper Tt	*Gc. miotumida*	0	0			96	4			96	4	4.0		
191.71	21/3/121-123	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
191.86	21/3/136-139	upper Tt	*Gc. miotumida*	97	3			78	1			175	4	2.2		
192.07	21/4/7-9	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
192.36	21/4/36-38	upper Tt	*Gc. miotumida*	98	2			53	3			151	5	3.2		
192.52	21/4/52-54	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
192.73	21/4/73-75	upper Tt	*Gc. miotumida*	99	1			67	5			166	6	3.5		
192.96	21/4/96-98	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
193.12	21/4/112-114	upper Tt	*Gc. miotumida*	99	1			62	3			161	4	2.4		
193.33	21/4/133-135	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
193.50	21/5/0-2	upper Tt	*Gc. miotumida*	98	2			146	3			244	5	2.0		
193.72	21/5/22-24	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
193.92	21/5/42-44	upper Tt	*Gc. miotumida*	98	2			86	2			184	4	2.1		
194.12	21/5/62-64	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
194.34	21/5/84-86	upper Tt	*Gc. miotumida*	99	1			63	3			162	4	2.4		
194.52	21/5/102-104	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
194.72	21/5/122-124	upper Tt	*Gc. miotumida*	99	1			90	3			189	4	2.1		
194.90	21/5/140-142	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
195.07	21/6/7-9	upper Tt	*Gc. miotumida*	99	1			39	1			138	2	1.4		
195.33	21/6/33-35	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
195.49	21/6/49-51	upper Tt	*Gc. miotumida*	99	1			78	3			177	4	2.2		
195.66	21/6/66-68	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
195.87	21/6/87-89	upper Tt	*Gc. miotumida*	100	0			64	1			164	1	0.6		
196.07	21/6/107-109	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
196.34	21/6/134-136	upper Tt	*Gc. miotumida*	97	3			83	3			180	6	3.2		
196.50	21/7/0-2	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
196.72	21/7/22-24	upper Tt	*Gc. miotumida*	100	0			42	0			142	0	0.0		
197.00	21CC/6-8	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
197.11	22/1/1-3	upper Tt	*Gc. miotumida*	100	0			106	2			206	2	1.0		
197.26	22/1/16-18	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
197.48	22/1/38-40	upper Tt	*Gc. miotumida*	99	1			43	0			142	1	0.7		
197.68	22/1/58-60	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
197.94	22/1/84-86	upper Tt	*Gc. miotumida*	98	2			55	3			153	5	3.2		
198.14	22/1/104-106	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
198.32	22/1/122-124	upper Tt	*Gc. miotumida*	98	2			93	1			191	3	1.5		
198.52	22/1/142-144	upper Tt	*Gc. miotumida*	95	5							95	5	5.0		
198.73	22/2/13-15	upper Tt	*Gc. miotumida*	98	2			82	2			180	4	2.2		
198.92	22/2/32-34	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
199.14	22/2/54-56	upper Tt	*Gc. miotumida*	98	2			84	6			182	8	4.2		
199.34	22/2/74-77	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
199.53	22/2/93-95	upper Tt	*Gc. miotumida*	99	1			88	2			187	3	1.6		
199.72	22/2/112-114	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
199.93	22/2/133-135	upper Tt	*Gc. miotumida*	98	2			12	1			110	3	2.7		
200.11	22/3/1-3	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		

Data Appendix 1.3

Globoconellid coiling data, DSDP Site 593-14X to 37X (120.30–347.50 mbsf)

Top depth (mbsf)	Core/Section/Interval	NZ Stage	Species	*Globoconella miotumida* bioseries (excludes *Gc. mons and Gc. pliozea*)												
				Supplementary (Sin)	Supplementary (Dex)	Ontogeny count (Sin)	Ontogeny count (Dex)	Census (Sin)	Census (Dex)	GHS data (Sin)	GHS data (Dex)	Total (Dextral)	Total (Sinistral)	Dextral perecentage	Gm/Gc-Interval	Coiling Zone
200.25	22/3/15-17	upper Tt	*Gc. miotumida*	97	3			55	1			152	4	2.6		
200.52	22/3/42-44	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
200.66	22/3/56-58	upper Tt	*Gc. miotumida*	96	4			77	2			173	6	3.4		
200.92	22/3/82-84	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
201.05	22/3/95-97	upper Tt	*Gc. miotumida*	99	1			56	0			155	1	0.6		
201.27	22/3/117-119	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
201.42	22/3/132-134	upper Tt	*Gc. miotumida*	0	0			154	8			154	8	4.9		
201.67	22/4/7-9	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
201.93	22/4/33-35	upper Tt	*Gc. miotumida*	97	3			69	3			166	6	3.5		
202.33	22/4/73-75	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
202.52	22/4/92-95	upper Tt	*Gc. miotumida*	98	2			64	2			162	4	2.4		
202.73	22/4/113-115	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
202.93	22/4/133-135	upper Tt	*Gc. miotumida*	98	2			93	4			191	6	3.0		
203.17	22CC/7-10	upper Tt	*Gc. miotumida*	95	5			56	1			151	6	3.8		
206.71	23/1/1-3	upper Tt	*Gc. miotumida*	97	3			73	0			170	3	1.7		
206.85	23/1/15-17	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
207.13	23/1/43-45	upper Tt	*Gc. miotumida*	97	3			64	1			161	4	2.4		
207.28	23/1/58-60	upper Tt	*Gc. miotumida*	95	5							95	5	5.0		
207.48	23/1/78-80	upper Tt	*Gc. miotumida*	100	0			73	3			173	3	1.7		
207.73	23/1/103-105	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
207.88	23/1/118-120	upper Tt	*Gc. miotumida*	99	1			56	2			155	3	1.9		
208.12	23/1/142-144	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
208.26	23/2/6-8	upper Tt	*Gc. miotumida*	99	1			51	1			150	2	1.3		
208.52	23/2/32-34	upper Tt	*Gc. miotumida*	97	3			79	5			176	8	4.3		
208.73	23/2/53-55	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
209.06	23/2/86-88	upper Tt	*Gc. miotumida*	99	1			61	1			160	2	1.2		
209.27	23/2/107-109	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
209.54	23/2/134-136	upper Tt	*Gc. miotumida*	98	2			46	1			144	3	2.0		
209.70	23/3/0-2	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
209.85	23/3/15-17	upper Tt	*Gc. miotumida*	96	4			67	0			163	4	2.4		
210.12	23/3/42-44	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
210.33	23/3/63-65	upper Tt	*Gc. miotumida*	99	1			55	0			154	1	0.6		
210.53	23/3/83-85	upper Tt	*Gc. miotumida*	100	0			71	0			171	0	0.0		
210.72	23/3/102-104	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
210.87	23/3/117-119	upper Tt	*Gc. miotumida*	97	3			78	3			175	6	3.3		
211.06	23/3/136-138	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
211.27	23/4/7-9	upper Tt	*Gc. miotumida*	98	2			84	2			182	4	2.2		
211.52	23/4/32-34	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
211.72	23/4/52-54	upper Tt	*Gc. miotumida*	99	1			58	4			157	5	3.1		
211.93	23/4/73-75	upper Tt	*Gc. miotumida*	95	5							95	5	5.0		
212.13	23/4/93-95	upper Tt	*Gc. miotumida*	98	2			66	2			164	4	2.4		
212.32	23/4/112-114	upper Tt	*Gc. miotumida*	0	0			125	4			125	4	3.1		
212.53	23/4/133-135	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
212.71	23/5/1-3	upper Tt	*Gc. miotumida*	97	3			75	3			172	6	3.4		
212.94	23/5/24-26	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
213.12	23/5/42-44	upper Tt	*Gc. miotumida*	96	4			51	1			147	5	3.3		
213.53	23/5/83-85	upper Tt	*Gc. miotumida*	95	5							95	5	5.0		
213.72	23/5/102-104	upper Tt	*Gc. miotumida*	99	1			54	2			153	3	1.9		
213.92	23/5/122-124	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
214.12	23/5/142-144	upper Tt	*Gc. miotumida*	98	2			33	0			131	2	1.5		
214.27	23/6/7-9	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
214.51	23/6/31-33	upper Tt	*Gc. miotumida*	0	0			128	6			128	6	4.5		
214.72	23/6/52-54	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
215.05	23/6/85-87	upper Tt	*Gc. miotumida*	98	2			104	2			202	4	1.9		
215.31	23/6/111-113	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
215.53	23/6/133-135	upper Tt	*Gc. miotumida*	95	5			104	7			199	12	5.7		
215.71	23/7/1-3	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
215.93	23/7/23-25	upper Tt	*Gc. miotumida*	99	1			74	0			173	1	0.6		
216.22	23CC/7-10	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
216.31	24/1/1-3	upper Tt	*Gc. miotumida*	96	4			64	1			160	5	3.0		
216.57	24/1/27-29	upper Tt	*Gc. miotumida*	0	0			176	4			176	4	2.2		
216.73	24/1/43-45	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
216.94	24/1/64-66	upper Tt	*Gc. miotumida*	99	1			108	3			207	4	1.9		
217.12	24/1/82-84	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
217.34	24/1/104-106	upper Tt	*Gc. miotumida*	99	1			89	1			188	2	1.1		
217.53	24/1/123-125	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
217.72	24/1/142-144	upper Tt	*Gc. miotumida*	97	3			104	2			201	5	2.4		
217.92	24/2/12-14	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
218.08	24/2/28-30	upper Tt	*Gc. miotumida*	98	2			107	0			205	2	1.0		
218.26	24/2/46-48	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
218.52	24/2/72-74	upper Tt	*Gc. miotumida*	0	0			201	2			201	2	1.0		
218.67	24/2/87-89	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
218.87	24/2/107-109	upper Tt	*Gc. miotumida*	98	2			125	3			223	5	2.2		
219.15	24/2/135-137	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		

Data Appendix 1.3

Globoconellid coiling data, DSDP Site 593-14X to 37X (120.30–347.50 mbsf)

Top depth (mbsf)	Core/Section/Interval	NZ Stage	Species	*Globoconella miotumida* bioseries (excludes *Gc. mons* and *Gc. pliozea*)												
				Supplementary (Sin)	Supplementary (Dex)	Ontogeny count (Sin)	Ontogeny count (Dex)	Census (Sin)	Census (Dex)	GHS data (Sin)	GHS data (Dex)	Total (Dextral)	Total (Sinistral)	Dextral perecentage	Gm/Gc-Interval	Coiling Zone
219.31	24/3/1-3	upper Tt	*Gc. miotumida*	96	4			69	3			165	7	4.1		
219.53	24/3/23-25	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
219.72	24/3/42-44	upper Tt	*Gc. miotumida*	98	2			62	4			160	6	3.6		
219.86	24/3/56-58	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
220.12	24/3/82-84	upper Tt	*Gc. miotumida*	97	3			88	1			185	4	2.1		
220.32	24/3/102-104	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
220.46	24/3/116-118	upper Tt	*Gc. miotumida*	96	4			54	2			150	6	3.8		
220.54	24/3/124-126	upper Tt	*Gc. miotumida*							79	1	79	1	1.3		
220.63	24/3/133-135	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
220.87	24/4/7-9	upper Tt	*Gc. miotumida*	98	2			38	0			136	2	1.4		
221.12	24/4/32-34	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
221.27	24/4/47-49	upper Tt	*Gc. miotumida*	99	1			35	0			134	1	0.7		
221.52	24/4/72-74	upper Tt	*Gc. miotumida*	94	6							94	6	6.0		
221.66	24/4/86-88	upper Tt	*Gc. miotumida*	97	3			64	3			161	6	3.6		
221.92	24/4/112-114	upper Tt	*Gc. miotumida*	95	5							95	5	5.0		
222.13	24/4/133-135	upper Tt	*Gc. miotumida*	99	1			51	2			150	3	2.0		
222.31	24/5/1-3	upper Tt	*Gc. miotumida*	95	5							95	5	5.0		
222.45	24/5/15-17	upper Tt	*Gc. miotumida*	98	2			37	4			135	6	4.3		
222.73	24/5/43-45	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
222.93	24/5/63-65	upper Tt	*Gc. miotumida*	95	5			54	1			149	6	3.9		
223.14	24/5/84-86	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
223.33	24/5/103-105	upper Tt	*Gc. miotumida*	96	4			62	1			158	5	3.1		
223.48	24/5/118-120	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
223.72	24/5/142-144	upper Tt	*Gc. miotumida*	98	2			55	2			153	4	2.5		
223.87	24/6/7-9	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
224.07	24/6/27-29	upper Tt	*Gc. miotumida*	96	4			55	1			151	5	3.2		
224.27	24/6/47-49	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
224.47	24/6/67-69	upper Tt	*Gc. miotumida*	97	3			81	3			178	6	3.3		
224.66	24/6/86-88	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
224.87	24/6/107-109	upper Tt	*Gc. miotumida*	98	2			43	2			141	4	2.8		
225.12	24/6/132-134	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
225.36	24CC/9-11	upper Tt	*Gc. miotumida*	100	0			55	3			155	3	1.9		
225.91	25/1/1-3	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
226.13	25/1/23-25	upper Tt	*Gc. miotumida*	94	6			52	1			146	7	4.6		
226.32	25/1/42-44	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
226.53	25/1/63-65	upper Tt	*Gc. miotumida*	0	0			159	3			159	3	1.9		
226.75	25/1/85-87	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
226.93	25/1/103-105	upper Tt	*Gc. miotumida*	99	1			51	2			150	3	2.0		
227.13	25/1/125-123	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
227.34	25/1/144-146	upper Tt	*Gc. miotumida*	95	5			37	2			132	7	5.0		
227.45	25/2/5-7	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
227.72	25/2/-32-34	upper Tt	*Gc. miotumida*	98	2			56	2			154	4	2.5		
227.93	25/2/53-55	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
228.12	25/2/72-74	upper Tt	*Gc. miotumida*	100	0			59	4			159	4	2.5		
228.35	25/2/95-97	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
228.52	25/2/112-114	upper Tt	*Gc. miotumida*	98	2			48	1			146	3	2.0		
228.74	25/2/134-136	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
228.90	25/3/0-2	upper Tt	*Gc. miotumida*	98	2			35	1			133	3	2.2		
229.13	25/3/23-25	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
229.33	25/3/43-45	upper Tt	*Gc. miotumida*	96	4			62	1			158	5	3.1		
229.53	25/3/63-65	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
229.85	25/3/95-97	upper Tt	*Gc. miotumida*	97	3			61	1			158	4	2.5		
230.08	25/3/118-120	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
230.27	25/3/137-139	upper Tt	*Gc. miotumida*	99	1			33	0			132	1	0.8		
230.47	25/4/7-9	upper Tt	*Gc. miotumida*	98	2			57	2			155	4	2.5		
230.67	25/4/27-29	upper Tt	*Gc. miotumida*							47	0	47	0	0.0		
230.72	25/4/32-34	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
230.93	25/4/53-55	upper Tt	*Gc. miotumida*	98	2			20	1			118	3	2.5		
231.14	25/4/74-76	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
231.33	25/4/93-95	upper Tt	*Gc. miotumida*	99	1			26	1			125	2	1.6		
231.52	25/4/112-114	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
231.73	25/4/133-135	upper Tt	*Gc. miotumida*	98	2			32	0			130	2	1.5		
231.91	25/5/1-3	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
232.06	25/5/16-18	upper Tt	*Gc. miotumida*	97	3			33	0			130	3	2.3		
232.28	25/5/38-40	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
232.52	25/5/62-64	upper Tt	*Gc. miotumida*	97	3			71	4			168	7	4.0		
232.72	25/5/82-84	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
232.92	25/5/102-104	upper Tt	*Gc. miotumida*	98	2			46	1			144	3	2.0		
233.07	25/5/117-119	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
233.27	25/5137-139	upper Tt	*Gc. miotumida*	98	2			23	1			121	3	2.4		
233.47	25/6/7-9	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
233.67	25/6/27-29	upper Tt	*Gc. miotumida*	99	1			41	1			140	2	1.4		
233.88	25/6/48-50	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
234.15	25/6/75-77	upper Tt	*Gc. miotumida*	97	3			53	3			150	6	3.8		

Data Appendix 1.3

Globoconellid coiling data, DSDP Site 593-14X to 37X (120.30–347.50 mbsf)

Top depth (mbsf)	Core/Section/Interval	NZ Stage	Species	*Globoconella miotumida* bioseries (excludes *Gc. mons* and *Gc. pliozea*)												
				Supplementary (Sin)	Supplementary (Dex)	Ontogeny count (Sin)	Ontogeny count (Dex)	Census (Sin)	Census (Dex)	GHS data (Sin)	GHS data (Dex)	Total (Dextral)	Total (Sinistral)	Dextral perecentage	Gm/Gc-Interval	Coiling Zone
234.33	25/6/93-95	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
234.52	25/6/112-114	upper Tt	*Gc. miotumida*	96	4			59	2			155	6	3.7		
234.73	25/6/133-135	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
234.91	25/7/1-3	upper Tt	*Gc. miotumida*	99	1			66	0			165	1	0.6		
235.07	25/7/17-19	upper Tt	*Gc. miotumida*	98	3							98	3	3.0		
235.26	25CC/10-22	upper Tt	*Gc. miotumida*	98	2			28	2			126	4	3.1		
235.51	26/1/1-3	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
235.73	26/1/23-25	upper Tt	*Gc. miotumida*	98	2			33	0			131	2	1.5		
235.91	26/1/41-43	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
236.08	26/1/58-60	upper Tt	*Gc. miotumida*	98	2			66	2			164	4	2.4		
236.32	26/1/82-84	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
236.52	26/1/102-104	upper Tt	*Gc. miotumida*	97	3			93	1			190	4	2.1		
236.67	26/1/117-119	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
236.92	26/1/142-144	upper Tt	*Gc. miotumida*	97	3			84	1			181	4	2.2		
237.13	26/2/13-15	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
237.32	26/2/32-34	upper Tt	*Gc. miotumida*	98	2			94	4			192	6	3.0		
237.56	26/2/56-58	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
237.93	26/2/93-95	upper Tt	*Gc. miotumida*	98	2			76	2			174	4	2.2		
238.12	26/2/112-114	upper Tt	*Gc. miotumida*	95	5							95	5	5.0		
238.33	26/2/133-135	upper Tt	*Gc. miotumida*	99	1			35	4			134	5	3.6		
238.51	26/3/1-3	upper Tt	*Gc. miotumida*	95	5			39	1			134	6	4.3		
238.72	26/3/22-24	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
238.93	26/3/43-45	upper Tt	*Gc. miotumida*	96	4			21	0			117	4	3.3		
239.06	26/3/56-58	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
239.32	26/3/82-84	upper Tt	*Gc. miotumida*	98	2			46	5			144	7	4.6		
239.52	26/3/102-104	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
239.67	26/3/117-119	upper Tt	*Gc. miotumida*	98	2			30	0			128	2	1.5		
239.72	26/3/122-124	upper Tt	*Gc. miotumida*							51	2	51	2	3.8		
239.83	26/3/133-135	upper Tt	*Gc. miotumida*	100	0							100	0	0.0		
240.07	26/4/7-9	upper Tt	*Gc. miotumida*	96	4			46	3			142	7	4.7		
240.32	26/4/32-34	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
240.52	26/4/52-54	upper Tt	*Gc. miotumida*	97	3			53	2			150	5	3.2		
240.72	26/4/72-74	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
240.92	26/4/92-94	upper Tt	*Gc. miotumida*	98	2			49	2			147	4	2.6		
241.12	26/4/112-114	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
241.32	26/4/132-134	upper Tt	*Gc. miotumida*	99	1			57	0			156	1	0.6		
241.50	26/5/0-2	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
241.65	26/5/15-17	upper Tt	*Gc. miotumida*	97	3			54	0			151	3	1.9		
241.92	26/5/42-44	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
242.13	26/5/63-65	upper Tt	*Gc. miotumida*	98	2			56	2			154	4	2.5		
242.32	26/5/82-84	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
242.52	26/5/102-104	upper Tt	*Gc. miotumida*	0	0			101	2			101	2	1.9		
242.67	26/5/117-119	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
242.92	26/5/142-144	upper Tt	*Gc. miotumida*	100	0			95	1			195	1	0.5		
243.07	26/6/7-9	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
243.26	26/6/26-28	upper Tt	*Gc. miotumida*	96	4			54	1			150	5	3.2		
243.47	26/6/47-49	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
243.63	26/6/63-65	upper Tt	*Gc. miotumida*	98	2			38	0			136	2	1.4		
243.86	26CC/13-15	upper Tt	*Gc. miotumida*	99	1			45	0			144	1	0.7		
245.11	27/1/1-3	upper Tt	*Gc. miotumida*	99	1			59	2			158	3	1.9		
245.35	27/1/25-27	upper Tt	*Gc. miotumida*	95	5							95	5	5.0		
245.53	27/1/43-45	upper Tt	*Gc. miotumida*	98	2			31	0			129	2	1.5		
245.75	27/1/65-67	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
245.91	27/1/81-83	upper Tt	*Gc. miotumida*	100	0			30	0			130	0	0.0		
246.06	27/1/96-98	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
246.27	27/1/117-119	upper Tt	*Gc. miotumida*	100	0			40	3			140	3	2.1		
246.52	27/1/142-144	upper Tt	*Gc. miotumida*	100	0			66	0			166	0	0.0		
246.65	27/2/5-7	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
246.87	27/2/27-29	upper Tt	*Gc. miotumida*	100	0			53	0			153	0	0.0		
247.13	27/2/53-55	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
247.33	27/2/73-76	upper Tt	*Gc. miotumida*	99	1			40	0			139	1	0.7		
247.53	27/2/93-95	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
247.67	27/2/107-109	upper Tt	*Gc. miotumida*	95	5			53	1			148	6	3.9		
247.92	27/2/132-134	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
248.11	27/3/1-3	upper Tt	*Gc. miotumida*	99	1			39	1			138	2	1.4		
248.26	27/3/16-18	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
248.47	27/3/37-39	upper Tt	*Gc. miotumida*	99	1			53	3			152	4	2.6		
248.66	27/3/56-58	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		
248.93	27/3/83-85	upper Tt	*Gc. miotumida*	96	4			21	1			117	5	4.1		
249.14	27/3/104-106	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
249.27	27/3/117-119	upper Tt	*Gc. miotumida*	97	3			25	1			122	4	3.2		
249.52	27/3/142-144	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
249.67	27/4/7-9	upper Tt	*Gc. miotumida*	99	1			34	0			133	1	0.7		
249.92	27/4/32-34	upper Tt	*Gc. miotumida*	96	4							96	4	4.0		

Data Appendix 1.3

Globoconellid coiling data, DSDP Site 593-14X to 37X (120.30–347.50 mbsf)

Top depth (mbsf)	Core/Section/Interval	NZ Stage	Species	*Globoconella miotumida* bioseries (excludes *Gc. mons* and *Gc. pliozea*)												
				Supplementary (Sin)	Supplementary (Dex)	Ontogeny count (Sin)	Ontogeny count (Dex)	Census (Sin)	Census (Dex)	GHS data (Sin)	GHS data (Dex)	Total (Dextral)	Total (Sinistral)	Dextral perecentage	Gm/Gc-Interval	Coiling Zone
250.12	27/4/52-54	upper Tt	*Gc. miotumida*	98	2			62	0			160	2	1.2		
250.27	27/4/67-69	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
250.36	27/4/76-78	upper Tt	*Gc. miotumida*							39	0	39	0	0.0		
250.46	27/4/86-88	upper Tt	*Gc. miotumida*	99	1			44	1			143	2	1.4		
250.72	27/4/112-114	upper Tt	*Gc. miotumida*	97	3							97	3	3.0		
250.92	27/4/132-134	upper Tt	*Gc. miotumida*	98	2			64	2			162	4	2.4		
251.10	27/5/0-2	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
251.33	27/5/23-26	upper Tt	*Gc. miotumida*	98	2			39	2			137	4	2.8		
251.48	27/5/38-40	upper Tt	*Gc. miotumida*	94	6							94	6	6.0		
251.67	27/5/57-59	upper Tt	*Gc. miotumida*	96	4			33	2			129	6	4.4		
251.93	27/5/83-85	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
252.13	27/5/103-105	upper Tt	*Gc. miotumida*	99	1			48	2			147	3	2.0		
252.28	27/5/118-120	upper Tt	*Gc. miotumida*	95	5							95	5	5.0		
252.53	27/5/143-145	upper Tt	*Gc. miotumida*	95	5			57	1			152	6	3.8		
252.67	27/6/7-9	upper Tt	*Gc. miotumida*	99	1							99	1	1.0		
252.92	27/6/32-34	upper Tt	*Gc. miotumida*	99	1			62	1			161	2	1.2		
253.13	27/6/53-55	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
253.33	27/6/73-75	upper Tt	*Gc. miotumida*	99	1			45	1			144	2	1.4		
253.47	27/6/87-89	upper Tt	*Gc. miotumida*	98	2							98	2	2.0		
253.67	27/6/107-109	upper Tt	*Gc. miotumida*	96	4			87	2			183	6	3.2		
253.92	27/6/132-134	upper Tt	*Gc. miotumida*	95	5							95	5	5.0		
254.10	27/7/0-2	upper Tt	*Gc. miotumida*	99	1			63	3			162	4	2.4		
254.27	27/7/17-19	upper Tt	*Gc. miotumida*	95	5							95	5	5.0		
254.49	27CC/10-12	lower Tt	*Gc. miotumida*	96	4			59	1			155	5	3.1		
254.74	28/1/4-6	lower Tt	*Gc. miotumida*	97	3							97	3	3.0		
254.93	28/1/23-25	lower Tt	*Gc. miotumida*	98	2			51	3			149	5	3.2		
255.12	28/1/42-44	lower Tt	*Gc. miotumida*	98	2							98	2	2.0		
255.28	28/1/58-60	lower Tt	*Gc. miotumida*	96	4			65	1			161	5	3.0		
255.53	28/1/83-85	lower Tt	*Gc. miotumida*	98	2							98	2	2.0		
255.73	28/1/103-105	lower Tt	*Gc. miotumida*	98	2			93	2			191	4	2.1		
255.91	28/1/121-123	lower Tt	*Gc. miotumida*	97	3							97	3	3.0		
256.11	28/1/141-143	lower Tt	*Gc. miotumida*	98	2			51	3			149	5	3.2		
256.27	28/2/7-9	lower Tt	*Gc. miotumida*	98	2							98	2	2.0		
256.53	28/2/33-35	lower Tt	*Gc. miotumida*	98	2			47	4			145	6	4.0		
256.74	28/2/54-56	lower Tt	*Gc. miotumida*	96	4							96	4	4.0		
257.03	28/2/83-85	lower Tt	*Gc. miotumida*	97	3			60	1			157	4	2.5		
257.18	28/2/98-100	lower Tt	*Gc. miotumida*	99	1							99	1	1.0		
257.33	28/2/113-115	lower Tt	*Gc. miotumida*	99	1			58	1			157	2	1.3		
257.53	28/2/133-135	lower Tt	*Gc. miotumida*	98	2							98	2	2.0		
257.71	28/3/1-3	lower Tt	*Gc. miotumida*	99	1			43	1			142	2	1.4		
257.95	28/3/25-27	lower Tt	*Gc. miotumida*	94	6							94	6	6.0		
258.12	28/3/42-44	lower Tt	*Gc. miotumida*	97	3			52	0			149	3	2.0		
258.25	28/3/55-57	lower Tt	*Gc. miotumida*	97	3							97	3	3.0		
258.54	28/3/84-86	lower Tt	*Gc. miotumida*	99	1			66	4			165	5	2.9		
258.88	28/3/118-120	lower Tt	*Gc. miotumida*	92	8							92	8	8.0		
258.92	28/3/122-124	lower Tt	*Gc. miotumida*							84	1	84	1	1.2		
259.07	28/3/137-139	lower Tt	*Gc. miotumida*	97	3			42	1			139	4	2.8		
259.26	28/4/6-8	lower Tt	*Gc. miotumida*	96	4							96	4	4.0		
259.53	28/4/33-35	lower Tt	*Gc. miotumida*	98	2			83	3			181	5	2.7		
259.67	28/4/47-49	lower Tt	*Gc. miotumida*	99	1							99	1	1.0		
259.86	28/4/66-68	lower Tt	*Gc. miotumida*	99	1			71	3			170	4	2.3		
260.13	28/4/93-95	lower Tt	*Gc. miotumida*	100	0							100	0	0.0		
260.28	28/4/108-110	lower Tt	*Gc. miotumida*	96	4			60	3			156	7	4.3		
260.54	28/4/134-136	lower Tt	*Gc. miotumida*	99	1			50	1			149	2	1.3		
260.71	28/5/1-3	lower Tt	*Gc. miotumida*	100	0							100	0	0.0		
260.86	28/5/16-18	lower Tt	*Gc. miotumida*	98	2			48	2			146	4	2.7		
261.12	28/5/42-44	lower Tt	*Gc. miotumida*	99	1							99	1	1.0		
261.31	28/5/61-63	lower Tt	*Gc. miotumida*	96	4			48	2			144	6	4.0		
261.55	28/5/85-87	lower Tt	*Gc. miotumida*	99	1							99	1	1.0		
261.72	28/5/102-104	lower Tt	*Gc. miotumida*	98	2			64	2			162	4	2.4		
261.91	28/5/121-123	lower Tt	*Gc. miotumida*	100	0							100	0	0.0		
262.11	28/5/141-143	lower Tt	*Gc. miotumida*	98	2			29	1			127	3	2.3		
262.28	28/6/8-10	lower Tt	*Gc. miotumida*	98	2							98	2	2.0		
262.45	28CC/8-10	lower Tt	*Gc. miotumida*	98	2			63	1			161	3	1.8		
264.30	29/1/0-2	lower Tt	*Gc. miotumida*	96	4			30	0			126	4	3.1		
264.64	29/1/34-36	lower Tt	*Gc. miotumida*	95	5			78	2			173	7	3.9		
264.88	29/1/58-60	lower Tt	*Gc. miotumida*	100	0			71	0			171	0	0.0		
265.10	29/1/80-82	lower Tt	*Gc. miotumida*	99	1							99	1	1.0		
265.26	29/1/96-98	lower Tt	*Gc. miotumida*	98	2			70	2			168	4	2.3		
265.47	29/1/117-119	lower Tt	*Gc. miotumida*	97	3							97	3	3.0		
265.72	29/1/142-144	lower Tt	*Gc. miotumida*	95	5			79	5			174	10	5.4		
265.92	29/2/12-14	lower Tt	*Gc. miotumida*	98	2							98	2	2.0		
266.12	29/2/32-34	lower Tt	*Gc. miotumida*	96	4			79	0			175	4	2.2		
266.26	29/2/46-48	lower Tt	*Gc. miotumida*	96	4							96	4	4.0		

Data Appendix 1.3

Globoconellid coiling data, DSDP Site 593-14X to 37X (120.30–347.50 mbsf)

Top depth (mbsf)	Core/Section/Interval	NZ Stage	Species	*Globoconella miotumida* bioseries (excludes *Gc. mons and Gc. pliozea*)												
				Supplementary (Sin)	Supplementary (Dex)	Ontogeny count (Sin)	Ontogeny count (Dex)	Census (Sin)	Census (Dex)	GHS data (Sin)	GHS data (Dex)	Total (Dextral)	Total (Sinistral)	Dextral perecentage	Gm/Gc-Interval	Coiling Zone
266.44	29/2/64-66	lower Tt	*Gc. miotumida*	98	2			53	1			151	3	1.9		
266.65	29/2/85-87	lower Tt	*Gc. miotumida*	100	0							100	0	0.0		
266.87	29/2/107-109	lower Tt	*Gc. miotumida*	99	1			64	1			163	2	1.2		
267.13	29/2/133-135	lower Tt	*Gc. miotumida*	99	1							99	1	1.0		
267.31	29/3/1-3	lower Tt	*Gc. miotumida*	98	2	587	13	86	0			771	15	1.9		
267.53	29/3/23-25	lower Tt	*Gc. miotumida*	98	2	579	21	70	1			747	24	3.1		
267.72	29/3/42-44	lower Tt	*Gc. miotumida*	93	7	577	23	63	0			733	30	3.9		
267.87	29/3/57-59	lower Tt	*Gc. miotumida*	97	3	574	26	72	3			743	32	4.1		
268.14	29/3/84-86	lower Tt	*Gc. miotumida*	93	7	772	28	46	3			911	38	4.0		
268.34	29/3/104-106	lower Tt	*Gc. miotumida*	98	2	584	16	93	5			775	23	2.9		
268.47	29/3/117-119	lower Tt	*Gc. miotumida*	0	0	570	30	123	1			693	31	4.3		
268.52	29/3/122-124	lower Tt	*Gc. miotumida*							51	0	51	0	0.0		
268.68	29/3/138-140	lower Tt	*Gc. miotumida*	99	1	581	19	63	2			743	22	2.9		
268.86	29/4/6-8	lower Tt	*Gc. miotumida*	98	2	572	28	44	5			714	35	4.7		
269.28	29/4/48-50	lower Tt	*Gc. miotumida*	67	33	422	178	27	18			516	229	30.7	*Gc*-593/C	Tukemokihi (TCZ)
269.52	29/4/72-74	lower Tt	*Gc. miotumida*	25	75	143	457	9	33			177	565	76.1	*Gc*-593/C	Tukemokihi (TCZ)
269.75	29/4/95-97	lower Tt	*Gc. miotumida*	0	0	317	283	50	58			367	341	48.2	*Gc*-593/C	Tukemokihi (TCZ)
269.87	29/4/107-109	lower Tt	*Gc. miotumida*	44	56	368	232	45	43			457	331	42.0	*Gc*-593/C	Tukemokihi (TCZ)
270.15	29/4/135-137	lower Tt	*Gc. miotumida*	42	58	251	349	34	51			327	458	58.3	*Gc*-593/C	Tukemokihi (TCZ)
270.31	29/5/1-3	lower Tt	*Gc. miotumida*	40	60	251	349	37	54			328	463	58.5	*Gc*-593/C	Tukemokihi (TCZ)
270.45	29/5/15-17	lower Tt	*Gc. miotumida*	40	60	243	357	19	40			302	457	60.2	*Gc*-593/C	Tukemokihi (TCZ)
270.72	29/5/42-44	lower Tt	*Gc. miotumida*	41	59	262	338	32	42			335	439	56.7	*Gc*-593/C	Tukemokihi (TCZ)
270.91	29/5/61-63	lower Tt	*Gc. miotumida*	86	14	543	57	75	6			704	77	9.9	???	???
271.15	29/5/85-87	lower Tt	*Gc. miotumida*	86	14	525	75	89	9			700	98	12.3	???	???
271.34	29/5/104-106	lower Tt	*Gc. miotumida*	92	8	557	43	85	5			734	56	7.1		
271.48	29/5/118-120	lower Tt	*Gc. miotumida*	99	1	574	26	98	3			771	30	3.7		
271.72	29/5/142-144	lower Tt	*Gc. miotumida*	94	6	572	28	40	1			706	35	4.7		
271.94	29/6/14-16	lower Tt	*Gc. miotumida*	90	10	527	73	57	11			674	94	12.2	???	???
272.19	29CC/17-19	lower Tt	*Gc. miotumida*	91	9	541	59	66	10			698	78	10.1	???	???
273.91	30/1/1-3	lower Tt	*Gc. miotumida*	187	10	548	52	62	12			797	74	8.5		
274.04	30/1/14-16	lower Tt	*Gc. miotumida*	97	3	581	19	68	1			746	23	3.0		
274.32	30/1/42-44	lower Tt	*Gc. miotumida*	0	0	563	37	103	2			666	39	5.5		
274.48	30/1/58-60	lower Tt	*Gc. miotumida*	97	3	566	34	75	1			738	38	4.9		
274.72	30/1/82-84	lower Tt	*Gc. miotumida*	98	2	573	27	86	2			757	31	3.9		
274.93	30/1/103-105	lower Tt	*Gc. miotumida*	98	2	577	23	77	1			752	26	3.3		
275.12	30/1/122-124	lower Tt	*Gc. miotumida*	96	4	582	18	69	5			747	27	3.5		
275.31	30/1/141-143	lower Tt	*Gc. miotumida*	100	0	580	20	70	2			750	22	2.8		
275.45	30/2/5-7	lower Tt	*Gc. miotumida*	95	5			51	2			146	7	4.6		
275.72	30/2/32-34	lower Tt	*Gc. miotumida*	96	4							96	4	4.0		
275.93	30/2/53-55	lower Tt	*Gc. miotumida*	97	3			59	0			156	3	1.9		
276.32	30/2/92-94	lower Tt	*Gc. miotumida*	98	2							98	2	2.0		
276.52	30/2/112-114	lower Tt	*Gc. miotumida*	94	6			59	2			153	8	5.0		
276.73	30/2/133-135	lower Tt	*Gc. miotumida*	95	5							95	5	5.0		
276.91	30/3/1-3	lower Tt	*Gc. miotumida*	98	2			47	2			145	4	2.7		
277.05	30/3/15-17	lower Tt	*Gc. miotumida*	98	2							98	2	2.0		
277.33	30/3/43-45	lower Tt	*Gc. miotumida*	97	3			57	1			154	4	2.5		
277.55	30/3/65-67	lower Tt	*Gc. miotumida*	98	2							98	2	2.0		
277.74	30/3/84-86	lower Tt	*Gc. miotumida*	95	5			72	5			167	10	5.6		
277.93	30/3/103-105	lower Tt	*Gc. miotumida*	97	3							97	3	3.0		
278.07	30/3/117-119	lower Tt	*Gc. miotumida*	97	3			71	4			168	7	4.0		
278.12	30/3/122-124	lower Tt	*Gc. miotumida*							94	4	94	4	4.1		
278.28	30/3/138-140	lower Tt	*Gc. miotumida*	92	8							92	8	8.0		
278.49	30/4/9-11	lower Tt	*Gc. miotumida*	99	1			65	1			164	2	1.2		
278.72	30/4/32-34	lower Tt	*Gc. miotumida*	97	3							97	3	3.0		
278.88	30/4/48-50	lower Tt	*Gc. miotumida*	97	3			56	5			153	8	5.0		
279.13	30/4/73-75	lower Tt	*Gc. miotumida*	96	4							96	4	4.0		
279.33	30/4/93-95	lower Tt	*Gc. miotumida*	99	1			34	3			133	4	2.9		
279.53	30/4/113-115	lower Tt	*Gc. miotumida*	95	5							95	5	5.0		
279.75	30/4/135-137	lower Tt	*Gc. miotumida*	91	9			35	0			126	9	6.7		
279.96	30/5/6-8	lower Tt	*Gc. miotumida*	98	2							98	2	2.0		
280.05	30/5/15-17	lower Tt	*Gc. miotumida*	97	3			56	1			153	4	2.5		
280.25	30/5/35-37	lower Tt	*Gc. miotumida*	99	1			44	0			143	1	0.7		
280.74	30/5/84-86	lower Tt	*Gc. miotumida*	97	3							97	3	3.0		
280.92	30/5/102-104	lower Tt	*Gc. miotumida*	95	5			41	1			136	6	4.2		
283.51	31/1/1-3	lower Tt	*Gc. miotumida*	94	6			69	2			163	8	4.7		
283.67	31/1/17-19	lower Tt	*Gc. miotumida*	94	6							94	6	6.0		
283.94	31/1/44-46	lower Tt	*Gc. miotumida*	99	1			59	3			158	4	2.5		
284.08	31/1/58-60	lower Tt	*Gc. miotumida*	97	3							97	3	3.0		
284.33	31/1/83-85	lower Tt	*Gc. miotumida*	98	2			53	3			151	5	3.2		
284.55	31/1/105-107	lower Tt	*Gc. miotumida*	96	4			76	7			172	11	6.0		
284.68	31/1/118-120	lower Tt	*Gc. miotumida*	97	3							97	3	3.0		
284.88	31/1/138-140	lower Tt	*Gc. miotumida*	98	2			35	2			133	4	2.9		
285.09	31/2/9-11	lower Tt	*Gc. miotumida*	97	3							97	3	3.0		
285.29	31/2/29-31	lower Tt	*Gc. miotumida*	97	3			35	0			132	3	2.2		

Data Appendix 1.3

Globoconellid coiling data, DSDP Site 593-14X to 37X (120.30–347.50 mbsf)

Top depth (mbsf)	Core/Section/Interval	NZ Stage	Species	*Globoconella miotumida* bioseries (excludes *Gc. mons* and *Gc. pliozea*)												
				Supplementary (Sin)	Supplementary (Dex)	Ontogeny count (Sin)	Ontogeny count (Dex)	Census (Sin)	Census (Dex)	GHS data (Sin)	GHS data (Dex)	Total (Dextral)	Total (Sinistral)	Dextral perecentage	Gm/Gc-Interval	Coiling Zone
285.48	31/2/48-50	lower Tt	*Gc. miotumida*	99	1							99	1	1.0		
285.73	31/2/73-75	lower Tt	*Gc. miotumida*	99	1			64	4			163	5	3.0		
285.88	31/2/88-90	lower Tt	*Gc. miotumida*	99	1							99	1	1.0		
286.10	31/2/110-112	lower Tt	*Gc. miotumida*	98	2			67	1			165	3	1.8		
286.34	31/2/134-136	lower Tt	*Gc. miotumida*	97	3							97	3	3.0		
286.51	31/3/1-3	lower Tt	*Gc. miotumida*	98	2			79	0			177	2	1.1		
286.73	31/3/23-25	lower Tt	*Gc. miotumida*	97	3							97	3	3.0		
286.88	31/3/38-40	lower Tt	*Gc. miotumida*	98	2			39	1			137	3	2.1		
287.04	31/3/57-59	lower Tt	*Gc. miotumida*	95	5							95	5	5.0		
287.32	31/3/82-84	lower Tt	*Gc. miotumida*	96	4			52	1			148	5	3.3		
287.52	31/3/102-104	lower Tt	*Gc. miotumida*	100	0							100	0	0.0		
287.67	31/3/117-119	lower Tt	*Gc. miotumida*	94	6			57	2			151	8	5.0		
287.72	31/3/122-124	lower Tt	*Gc. miotumida*							81	2	81	2	2.4		
287.91	31/3/141-143	lower Tt	*Gc. miotumida*	98	2							98	2	2.0		
288.08	31/4/8-10	lower Tt	*Gc. miotumida*	98	2			78	3			176	5	2.8		
288.30	31/4/30-32	lower Tt	*Gc. miotumida*	100	0							100	0	0.0		
288.55	31/4/55-57	lower Tt	*Gc. miotumida*	97	3			61	2			158	5	3.1		
288.70	31/4/70-72	lower Tt	*Gc. miotumida*	95	5							95	5	5.0		
288.89	31/4/89-91	lower Tt	*Gc. miotumida*	98	2			95	3			193	5	2.5		
289.10	31/4/110-112	lower Tt	*Gc. miotumida*	98	2							98	2	2.0		
289.34	31/4/134-136	lower Tt	*Gc. miotumida*	99	1			40	0			139	1	0.7		
289.50	31/5/0-2	lower Tt	*Gc. miotumida*	97	3							97	3	3.0		
289.73	31/5/23-25	lower Tt	*Gc. miotumida*	98	2			57	0			155	2	1.3		
289.93	31/5/43-45	lower Tt	*Gc. miotumida*	97	3							97	3	3.0		
290.12	31/5/62-64	lower Tt	*Gc. miotumida*	99	1			46	2			145	3	2.0		
290.33	31/5/83-85	lower Tt	*Gc. miotumida*	99	1							99	1	1.0		
290.51	31/5/101-103	lower Tt	*Gc. miotumida*	99	1			59	2			158	3	1.9		
290.70	31/5/120-122	lower Tt	*Gc. miotumida*	99	1							99	1	1.0		
290.74	31CC/0-2	lower Tt	*Gc. miotumida*	97	3			77	1			174	4	2.2		
293.11	32/1/1-3	lower Tt	*Gc. miotumida*	100	0			61	1			161	1	0.6		
293.33	32/1/23-25	lower Tt	*Gc. miotumida*	97	3			59	4			156	7	4.3		
293.51	32/1/41-43	lower Tt	*Gc. miotumida*	96	4							96	4	4.0		
293.71	32/1/61-63	lower Tt	*Gc. miotumida*	99	1			26	0			125	1	0.8		
293.93	32/1/83-85	lower Tt	*Gc. miotumida*	100	0							100	0	0.0		
294.12	32/1/102-104	lower Tt	*Gc. miotumida*	94	6			50	4			144	10	6.5		
294.31	32/1/121-123	lower Tt	*Gc. miotumida*	97	3							97	3	3.0		
294.51	32/1/141-143	lower Tt	*Gc. miotumida*	99	1			39	3			138	4	2.8		
294.71	32/2/11-13	lower Tt	*Gc. miotumida*	100	0							100	0	0.0		
294.90	32/2/30-32	lower Tt	*Gc. miotumida*	99	1			72	4			171	5	2.8		
295.12	32/2/52-54	lower Tt	*Gc. miotumida*	96	4							96	4	4.0		
295.33	32/2/73-75	lower Tt	*Gc. miotumida*	96	4			67	1			163	5	3.0		
295.53	32/2/93-95	lower Tt	*Gc. miotumida*	95	5							95	5	5.0		
295.73	32/2/113-115	lower Tt	*Gc. miotumida*	94	6			45	6			139	12	7.9		
295.93	32/2/133-135	lower Tt	*Gc. miotumida*	95	5			65	1			160	6	3.6		
296.11	32/3/1-3	lower Tt	*Gc. miotumida*	94	6							94	6	6.0		
296.50	32/3/40-42	lower Tt	*Gc. miotumida*	99	1			76	2			175	3	1.7		
296.72	32/3/62-64	lower Tt	*Gc. miotumida*	96	4							96	4	4.0		
296.93	32/3/83-85	lower Tt	*Gc. miotumida*	96	4			101	1			197	5	2.5		
297.12	32/3/102-104	lower Tt	*Gc. miotumida*	99	1							99	1	1.0		
297.31	32/3/121-123	lower Tt	*Gc. miotumida*							44	4	44	4	8.3		
297.33	32/3/123-125	lower Tt	*Gc. miotumida*	94	6			43	3			137	9	6.2		
297.50	32/3/140-142	lower Tt	*Gc. miotumida*	89	11							89	11	11.0	???	???
297.70	32/4/10-12	lower Tt	*Gc. miotumida*	92	8			47	6			139	14	9.2		
297.90	32/4/30-32	lower Tt	*Gc. miotumida*	93	7							93	7	7.0		
298.08	32/4/48-50	lower Tt	*Gc. miotumida*	97	3			62	1			159	4	2.5		
298.28	32/4/68-70	lower Tt	*Gc. miotumida*	98	2							98	2	2.0		
298.52	32/4/92-94	lower Tt	*Gc. miotumida*	98	2			36	2			134	4	2.9		
298.70	32/4/110-112	lower Tt	*Gc. miotumida*	96	4							96	4	4.0		
298.93	32/4/133-135	lower Tt	*Gc. miotumida*	95	5			108	1			203	6	2.9		
299.11	32/5/1-3	lower Tt	*Gc. miotumida*	98	2							98	2	2.0		
299.38	32/5/28-30	lower Tt	*Gc. miotumida*	96	4			57	6			153	10	6.1		
299.50	32/5/40-42	lower Tt	*Gc. miotumida*	96	4							96	4	4.0		
299.67	32CC/2-4	lower Tt	*Gc. miotumida*	95	5			72	2			167	7	4.0		
302.71	33/1/1-3	lower Tt	*Gc. miotumida*	97	3			62	2			159	5	3.0		
302.91	33/1/21-23	lower Tt	*Gc. miotumida*							96	2	96	2	2.0		
302.97	33/1/27-29	lower Tt	*Gc. miotumida*	97	3			70	3			167	6	3.5		
303.10	33/1/40-42	lower Tt	*Gc. miotumida*	90	10							90	10	10.0	???	???
303.29	33/1/59-61	lower Tt	*Gc. miotumida*	97	3			101	2			198	5	2.5		
303.53	33/1/83-85	lower Tt	*Gc. miotumida*	97	3							97	3	3.0		
303.77	33/1/107-109	lower Tt	*Gc. miotumida*	97	3			92	8			189	11	5.5		
303.90	33/1/120-122	lower Tt	*Gc. miotumida*							104	4	104	4	3.7		
303.91	33/1/121-123	lower Tt	*Gc. miotumida*	97	3							97	3	3.0		
304.13	33/1/143-145	lower Tt	*Gc. miotumida*	99	1			70	6			169	7	4.0		
304.29	33/2/9-11	lower Tt	*Gc. miotumida*	98	2	576	24	89	4			763	30	3.8		

Data Appendix 1.3

Globoconellid coiling data, DSDP Site 593-14X to 37X (120.30–347.50 mbsf)

Top depth (mbsf)	Core/Section/Interval	NZ Stage	Species	*Globoconella miotumida* bioseries (excludes *Gc. mons* and *Gc. pliozea*)												
				Supplementary (Sin)	Supplementary (Dex)	Ontogeny count (Sin)	Ontogeny count (Dex)	Census (Sin)	Census (Dex)	GHS data (Sin)	GHS data (Dex)	Total (Dextral)	Total (Sinistral)	Dextral perecentage	Gm/Gc-Interval	Coiling Zone
304.41	33/2/21-23	lower Tt	*Gc. miotumida*							105	2	105	2	1.9		
304.47	33/2/27-29	lower Tt	*Gc. miotumida*	0	0	578	22	119	1			697	23	3.2		
304.66	33/2/46-48	lower Tt	*Gc. miotumida*	97	3	583	17	60	2			740	22	2.9		
305.02	33/2/82-84	lower Tt	*Gc. miotumida*	97	3	581	19	88	2			766	24	3.0		
305.15	33/2/95-97	lower Tt	*Gc. miotumida*	98	2	585	15	58	1			741	18	2.4		
305.34	33/2/114-116	lower Tt	*Gc. miotumida*	97	3	580	20	73	2			750	25	3.2		
305.41	33/2/121-123	lower Tt	*Gc. miotumida*							96	3	96	3	3.0		
305.55	33/2/135-137	lower Tt	*Gc. miotumida*	98	2	572	28	100	3			770	33	4.1		
305.71	33/3/1-3	lower Tt	*Gc. miotumida*	94	6	566	34	92	3			752	43	5.4		
305.91	33/3/21-23	lower Tt	*Gc. miotumida*							96	7	96	7	6.8		
305.93	33/3/23-25	lower Tt	*Gc. miotumida*	90	10	555	45	89	2			734	57	7.2		
306.11	33/3/41-43	lower Tt	*Gc. miotumida*	56	44	315	285	18	19			389	348	47.2	*Gc*-593/B	Mapiri (MCZ)
306.27	33/3/57-59	lower Tt	*Gc. miotumida*	13	87	95	505	8	49			116	641	84.7	*Gc*-593/B	Mapiri (MCZ)
306.54	33/3/84-86	lower Tt	*Gc. miotumida*	53	47	334	266	29	16			416	329	44.2	*Gc*-593/B	Mapiri (MCZ)
306.75	33/3/105-107	lower Tt	*Gc. miotumida*	89	11	562	38	134	11			785	60	7.1		
306.86	33/3/116-118	lower Tt	*Gc. miotumida*	93	7	568	32	96	3			757	42	5.3		
306.92	33/3/122-124	lower Tt	*Gc. miotumida*							104	4	104	4	3.7		
307.08	33/3/138-140	lower Tt	*Gc. miotumida*	96	4	580	20	91	3			767	27	3.4		
307.30	33/4/10-12	lower Tt	*Gc. miotumida*	97	3	578	22	120	2			795	27	3.3		
307.36	33/4/16-18	lower Tt	*Gc. miotumida*							121	6	121	6	4.7		
307.49	33/4/29-31	lower Tt	*Gc. miotumida*	98	2	568	32	72	6			738	40	5.1		
307.70	33/4/50-52	lower Tt	*Gc. miotumida*	97	3	571	29	114	1			782	33	4.0		
307.93	33/4/73-75	lower Tt	*Gc. miotumida*	95	5	573	27	84	3			752	35	4.4		
308.14	33/4/94-96	lower Tt	*Gc. miotumida*	94	6	558	42	55	6			707	54	7.1		
308.30	33/4/110-112	lower Tt	*Gc. miotumida*	93	7	564	36	36	1			693	44	6.0		
308.42	33/4/122-125	lower Tt	*Gc. miotumida*							94	3	94	3	3.1		
308.53	33/4/133/135	lower Tt	*Gc. miotumida*	0	0	572	28	92	9			664	37	5.3		
308.71	33/5/1-3	lower Tt	*Gc. miotumida*	96	4	577	23	92	2			765	29	3.7		
308.92	33/5/22-25	lower Tt	*Gc. miotumida*							86	10	86	10	10.4	???	???
308.99	33/5/29-31	lower Tt	*Gc. miotumida*	96	4	532	68	65	7			693	79	10.2	???	???
309.11	33/5/41-43	lower Tt	*Gc. miotumida*	78	22	448	152	52	7			578	181	23.8	*Gc*-593/A	upper Kaiti (KCZ)
309.28	33/5/58-60	lower Tt	*Gc. miotumida*	20	80	119	481	35	94			174	655	79.0	*Gc*-593/A	upper Kaiti (KCZ)
309.54	33/5/84-86	lower Tt	*Gc. miotumida*	0	0	62	538	16	97			78	635	89.1	*Gc*-593/A	upper Kaiti (KCZ)
309.67	33/5/97-100	lower Tt	*Gc. miotumida*							13	107	13	107	89.2	*Gc*-593/A	upper Kaiti (KCZ)
309.74	33/5/104-106	lower Tt	*Gc. miotumida*	12	88	88	512	16	94			116	694	85.7	*Gc*-593/A	upper Kaiti (KCZ)
312.31	34/1/1-3	lower Tt	*Gc. miotumida*	11	89	91	509	14	62			116	660	85.1	*Gc*-593/A	upper Kaiti (KCZ)
312.46	34/1/16-19	lower Tt	*Gc. miotumida*							16	98	16	98	86.0	*Gc*-593/A	upper Kaiti (KCZ)
312.54	34/1/24-26	lower Tt	*Gc. miotumida*	21	79	125	475	34	40			180	594	76.7	*Gc*-593/A	upper Kaiti (KCZ)
312.67	34/1/37-39	lower Tt	*Gc. miotumida*	19	81	100	500	9	36			128	617	82.8	*Gc*-593/A	upper Kaiti (KCZ)
312.87	34/1/57-59	lower Tt	*Gc. miotumida*	15	85	111	489	10	38			136	612	81.8	*Gc*-593/A	upper Kaiti (KCZ)
313.07	34/1/77-79	lower Tt	*Gc. miotumida*	18	82	129	471	26	76			173	629	78.4	*Gc*-593/A	upper Kaiti (KCZ)
313.31	34/1/101-103	lower Tt	*Gc. miotumida*	25	75	149	451	12	43			186	569	75.4	*Gc*-593/A	upper Kaiti (KCZ)
313.48	34/1/118-120	lower Tt	*Gc. miotumida*							54	54	54	54	50.0	*Gc*-593/A	upper Kaiti (KCZ)
313.53	34/1/123-125	lower Tt	*Gc. miotumida*	77	23	431	169	53	21			561	213	27.5	*Gc*-593/A	lower Kaiti (KCZ)
313.71	34/1/141-143	lower Tt	*Gc. miotumida*	88	12	537	63	54	3			679	78	10.3	*Gc*-593/A	lower Kaiti (KCZ)
313.90	34/2/10- 12	lower Tt	*Gc. miotumida*	95	5	545	55	70	6			710	66	8.5	*Gc*-593/A	lower Kaiti (KCZ)
314.02	34/2/22-25	lower Tt	*Gc. miotumida*							85	22	85	22	20.6	*Gc*-593/A	lower Kaiti (KCZ)
314.09	34/2/29-31	lower Tt	*Gc. miotumida*	70	30	443	157	58	17			571	204	26.3	*Gc*-593/A	lower Kaiti (KCZ)
314.29	34/2/49-51	lower Tt	*Gc. miotumida*	85	15	514	86	55	14			654	115	15.0	*Gc*-593/A	lower Kaiti (KCZ)
314.45	34/2/65-67	lower Tt	*Gc. miotumida*	94	6	558	42	63	0			715	48	6.3	*Gc*-593/A	lower Kaiti (KCZ)
314.69	34/2/89-91	lower Tt	*Gc. miotumida*	87	13	489	111	44	10			620	134	17.8	*Gc*-593/A	lower Kaiti (KCZ)
314.83	34/2/103-106	lower Tt	*Gc. miotumida*							70	39	70	39	35.8	*Gc*-593/A	lower Kaiti (KCZ)
314.90	34/2/110-112	lower Tt	*Gc. miotumida*	68	32	433	167	20	12			521	211	28.8	*Gc*-593/A	lower Kaiti (KCZ)
315.02	34/2/122-125	lower Tt	*Gc. miotumida*							84	44	84	44	34.4	*Gc*-593/A	lower Kaiti (KCZ)
315.13	34/2/133-135	lower Tt	*Gc. miotumida*	62	38	377	223	45	22			484	283	36.9	*Gc*-593/A	lower Kaiti (KCZ)
315.19	34/2/139-142	lower Tt	*Gc. miotumida*							88	31	88	31	26.1	*Gc*-593/A	lower Kaiti (KCZ)
315.30	34/3/0-2	Waiauan	*Gc. miotumida*	97	3	554	46	54	6			705	55	7.2		
315.43	34/3/13-16	Waiauan	*Gc. miotumida*							108	3	108	3	2.7		
315.52	34/3/22-24	Waiauan	*Gc. miotumida*	95	5	566	34	60	2			721	41	5.4		
315.71	34/3/41-43	Waiauan	*Gc. miotumida*	96	4	574	26	38	1			708	31	4.2		
316.06	34/3/76-78	Waiauan	*Gc. miotumida*	95	5	582	18	62	1			739	24	3.1		
316.10	34/3/80-83	Waiauan	*Gc. miotumida*							109	1	109	1	0.9		
316.27	34/3/97-99	Waiauan	*Gc. miotumida*	97	3	578	22	81	3			756	28	3.6		
316.48	34/3/118-120	Waiauan	*Gc. miotumida*	95	5	567	33	73	1			735	39	5.0		
316.67	34/3/137-139	Waiauan	*Gc. miotumida*	98	2	586	14	55	2			739	18	2.4		
316.71	34/3/141-144	Waiauan	*Gc. miotumida*							102	4	102	4	3.8		
316.88	34/4/8-10	Waiauan	*Gc. miotumida*	95	5							95	5	5.0		
316.95	34/4/15-18	Waiauan	*Gc. miotumida*							144	5	144	5	3.4		
317.10	34/4/30-32	Waiauan	*Gc. miotumida*	97	3			51	2			148	5	3.3		
317.30	34/4/50-52	Waiauan	*Gc. miotumida*	94	6							94	6	6.0		
317.50	34/4/70-72	Waiauan	*Gc. miotumida*	99	1			103	3			202	4	1.9		
317.59	34/4/79-82	Waiauan	*Gc. miotumida*							109	1	109	1	0.9		
317.68	34/4/88-90	Waiauan	*Gc. miotumida*	99	1							99	1	1.0		
317.90	34/4/110-112	Waiauan	*Gc. miotumida*	94	6			65	5			159	11	6.5		

Data Appendix 1.3

Globoconellid coiling data, DSDP Site 593-14X to 37X (120.30–347.50 mbsf)

Top depth (mbsf)	Core/Section/Interval	NZ Stage	Species	*Globoconella miotumida* bioseries (excludes *Gc. mons* and *Gc. pliozea*)												
				Supplementary (Sin)	Supplementary (Dex)	Ontogeny count (Sin)	Ontogeny count (Dex)	Census (Sin)	Census (Dex)	GHS data (Sin)	GHS data (Dex)	Total (Dextral)	Total (Sinistral)	Dextral perecentage	Gm/Gc-Interval	Coiling Zone
318.13	34/4/133-135	Waiauan	*Gc. miotumida*	98	2							98	2	2.0		
318.21	34/4/141-143	Waiauan	*Gc. miotumida*							107	3	107	3	2.7		
318.35	34/5/5-7	Waiauan	*Gc. miotumida*	93	7			66	3			159	10	5.9		
318.45	34/5/15-18	Waiauan	*Gc. miotumida*							102	3	102	3	2.9		
318.60	34/5/30-32	Waiauan	*Gc. miotumida*	96	4			53	0			149	4	2.6		
321.91	35/1/1-3	Waiauan	*Gc. miotumida*	99	1			58	3			157	4	2.5		
322.13	35/1/23-25	Waiauan	*Gc. miotumida*	96	4							96	4	4.0		
322.33	35/1/43-45	Waiauan	*Gc. miotumida*	98	2			62	4			160	6	3.6		
322.54	35/1/64-66	Waiauan	*Gc. miotumida*	98	2							98	2	2.0		
322.72	35/1/82-84	Waiauan	*Gc. miotumida*	91	9			53	5			144	14	8.9		
322.90	35/1/100-102	Waiauan	*Gc. miotumida*	95	5							95	5	5.0		
323.09	35/1/119-121	Waiauan	*Gc. miotumida*	94	6			56	4			150	10	6.3		
323.31	35/1/141-143	Waiauan	*Gc. miotumida*	96	4							96	4	4.0		
323.48	35/2/8-10	Waiauan	*Gc. miotumida*	96	4			43	0			139	4	2.8		
323.72	35/2/32-34	Waiauan	*Gc. miotumida*	97	3							97	3	3.0		
323.91	35/2/51-53	Waiauan	*Gc. miotumida*	95	5			99	1			194	6	3.0		
324.30	35/2/90-92	Waiauan	*Gc. miotumida*	99	1							99	1	1.0		
324.50	35/2/110-112	Waiauan	*Gc. miotumida*	100	0			38	0			138	0	0.0		
324.70	35/2/130-132	Waiauan	*Gc. miotumida*	100	0							100	0	0.0		
324.91	35/3/1-3	Waiauan	*Gc. miotumida*	96	4			40	1			136	5	3.5		
325.12	35/3/22-24	Waiauan	*Gc. miotumida*	96	4							96	4	4.0		
325.33	35/3/43-45	Waiauan	*Gc. miotumida*	98	2			73	1			171	3	1.7		
325.57	35/3/67-69	Waiauan	*Gc. miotumida*	99	1							99	1	1.0		
325.71	35/3/81-83	Waiauan	*Gc. miotumida*	96	4			48	1			144	5	3.4		
325.94	35/3/104-106	Waiauan	*Gc. miotumida*	94	6			51	0			145	6	4.0		
326.07	35/3/117-119	Waiauan	*Gc. miotumida*	97	3							97	3	3.0		
326.13	35/3/123-125	Waiauan	*Gc. miotumida*							86	2	86	2	2.3		
326.28	35/3/138-140	Waiauan	*Gc. miotumida*	98	2			54	6			152	8	5.0		
326.50	35/4/10-12	Waiauan	*Gc. miotumida*	98	2							98	2	2.0		
326.70	35/4/30-32	Waiauan	*Gc. miotumida*	94	6			67	1			161	7	4.2		
326.88	35/4/48-50	Waiauan	*Gc. miotumida*	99	1							99	1	1.0		
327.09	35/4/69-71	Waiauan	*Gc. miotumida*	93	7			42	3			135	10	6.9		
327.28	35/4/88-90	Waiauan	*Gc. miotumida*	97	3							97	3	3.0		
327.50	35/4/110-112	Waiauan	*Gc. miotumida*	95	5			31	7			126	12	8.7		
327.74	35/4/134-136	Waiauan	*Gc. miotumida*	96	4							96	4	4.0		
327.91	35/5/1-3	Waiauan	*Gc. miotumida*	100	0			40	1			140	1	0.7		
328.06	35/5/16-18	Waiauan	*Gc. miotumida*	96	4							96	4	4.0		
328.27	35/5/37-39	Waiauan	*Gc. miotumida*	99	1			31	0			130	1	0.8		
328.47	35/5/57-59	Waiauan	*Gc. miotumida*	96	4							96	4	4.0		
328.72	35/5/82-84	Waiauan	*Gc. miotumida*	96	4			25	0			121	4	3.2		
331.69	36/1/19-21	Waiauan	*Gc. miotumida*	95	5			32	3			127	8	5.9		
332.11	36/1/61-63	Waiauan	*Gc. miotumida*	97	3			63	0			160	3	1.8		
332.68	36/1/118-120	Waiauan	*Gc. miotumida*	98	2			58	1			156	3	1.9		
332.98	36/1/148-150	Waiauan	*Gc. miotumida*	97	3			60	2			157	5	3.1		
333.40	36/2/40-42	Waiauan	*Gc. miotumida*	100	0			30	1			130	1	0.8		
334.00	36/2/100-102	Waiauan	*Gc. miotumida*	97	3			44	2			141	5	3.4		
334.36	36/2/136-138	Waiauan	*Gc. miotumida*	98	2			15	0			113	2	1.7		
334.87	36/3/37-39	Waiauan	*Gc. miotumida*	96	4			19	0			115	4	3.4		
335.47	36/3/97-99	Waiauan	*Gc. miotumida*	97	3			14	0			111	3	2.6		
335.88	36/3/138-140	Waiauan	*Gc. miotumida*	97	3			10	0			107	3	2.7		
336.20	36/4/20-22	Waiauan	*Gc. miotumida*	97	3			26	1			123	4	3.1		
336.60	36/4/60-62	Waiauan	*Gc. miotumida*	97	3			21	2			118	5	4.1		
341.29	37/1/19-21	Waiauan	*Gc. miotumida*	99	1							99	1	1.0		
341.70	37/1/60-62	Waiauan	*Gc. miotumida*	96	4							96	4	4.0		
342.28	37/1/118-120	Waiauan	*Gc. miotumida*	99	1							99	1	1.0		
342.57	37/1/147-149	Waiauan	*Gc. miotumida*	97	3							97	3	3.0		
343.00	37/2/40-42	Waiauan	*Gc. miotumida*	97	3							97	3	3.0		
343.60	37/2/100-102	Waiauan	*Gc. miotumida*	97	3							97	3	3.0		
343.98	37/2/138-140	Waiauan	*Gc. miotumida*	95	5							95	5	5.0		
344.30	37/3/20-22	Waiauan	*Gc. miotumida*	96	4							96	4	4.0		
344.71	37/3/61-63	Waiauan	*Gc. miotumida*	98	2							98	2	2.0		
345.28	37/3/118-120	Waiauan	*Gc. miotumida*	99	1							99	1	1.0		
345.80	37/4/20-22	Waiauan	*Gc. miotumida*	97	3							97	3	3.0		
346.18	37/4/58-60	Waiauan	*Gc. miotumida*	98	2							98	2	2.0		
346.79	37/4/119-121	Waiauan	*Gc. miotumida*	94	6							94	6	6.0		
347.08	37/4/148-150	Waiauan	*Gc. miotumida*	97	3							97	3	3.0		
347.50	37/5/40-42	Waiauan	*Gc. miotumida*	98	2							98	2	2.0		

Data Appendix 1.4

Neogloboquadrinid coiling data, DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top depth (mbsf)	Interval	NZ Stage	Species	*Neogloboquadrina* (all species)									
				Census (Sin)	Census (Dex)	Supp. count (Sin)	Supp. count (Dex)	Total (Sinistral)	Total (Dextral)	Total	Dextral percentage	Dextral intervals	Coiling zone
120.30	14/1/0-3	lower Wo	*Nq. pachyderma* s.l.	43	2			43	2	45	4.4		
120.51	14/1/21-24	lower Wo	*Nq. pachyderma* s.l.	52	2			52	2	54	3.7		
120.69	14/1/39-42	lower Wo	*Nq. pachyderma* s.l.	51	4			51	4	55	7.3		
120.90	14/1/60-63	lower Wo	*Nq. pachyderma* s.l.	69	4			69	4	73	5.5		
121.11	14/1/81-84	lower Wo	*Nq. pachyderma* s.l.	60	3			60	3	63	4.8		
121.26	14/1/96-99	lower Wo	*Nq. pachyderma* s.l.	42	2			42	2	44	4.5		
121.49	14/1/119-122	lower Wo	*Nq. pachyderma* s.l.	19	3			19	3	22	13.6		
121.69	14/1/139-142	lower Wo	*Nq. pachyderma* s.l.	51	2			51	2	53	3.8		
121.90	14/2/10-13	lower Wo	*Nq. pachyderma* s.l.	38	1			38	1	39	2.6		
122.09	14/2/29-32	lower Wo	*Nq. pachyderma* s.l.	29	7			29	7	36	19.4	???	???
122.26	14/2/46-49	lower Wo	*Nq. pachyderma* s.l.	24	2			24	2	26	7.7		
122.51	14/2/71-75	lower Wo	*Nq. pachyderma* s.l.	39	3			39	3	42	7.1		
122.71	14/2/91-94	lower Wo	*Nq. pachyderma* s.l.	78	10			78	10	88	11.4		
122.92	14/2/112-115	lower Wo	*Nq. pachyderma* s.l.	58	15			58	15	73	20.5	???	???
123.10	14/2/130-133	upper Tk	*Nq. pachyderma* s.l.	67	10			67	10	77	13.0		
123.30	14/3/0-3	upper Tk	*Nq. pachyderma* s.l.	38	16			38	16	54	29.6	???	???
123.53	14/3/23-26	upper Tk	*Nq. pachyderma* s.l.	41	27			41	27	68	39.7	*Nq*-593/B	Challenger (CCZ)
123.69	14/3/39-42	upper Tk	*Nq. pachyderma* s.l.	28	12			28	12	40	30.0	*Nq*-593/B	Challenger (CCZ)
123.88	14/3/58-61	upper Tk	*Nq. pachyderma* s.l.	50	10			50	10	60	16.7	*Nq*-593/B	Challenger (CCZ)
124.11	14/3/81-84	upper Tk	*Nq. pachyderma* s.l.	48	16			48	16	64	25.0	*Nq*-593/B	Challenger (CCZ)
124.30	14/3/100-103	upper Tk	*Nq. pachyderma* s.l.	32	14			32	14	46	30.4	*Nq*-593/B	Challenger (CCZ)
124.50	14/3/120-123	upper Tk	*Nq. pachyderma* s.l.	24	17			24	17	41	41.5	*Nq*-593/B	Challenger (CCZ)
124.68	14/3/138-141	upper Tk	*Nq. pachyderma* s.l.	45	8			45	8	53	15.1	*Nq*-593/B	Challenger (CCZ)
124.90	14/4/10-13	upper Tk	*Nq. pachyderma* s.l.	73	13			73	13	86	15.1	*Nq*-593/B	Challenger (CCZ)
125.10	14/4/30-33	upper Tk	*Nq. pachyderma* s.l.	27	22			27	22	49	44.9	*Nq*-593/B	Challenger (CCZ)
125.30	14/4/50-53	upper Tk	*Nq. pachyderma* s.l.	31	17			31	17	48	35.4	*Nq*-593/B	Challenger (CCZ)
125.48	14/4/68-71	upper Tk	*Nq. pachyderma* s.l.	61	7			61	7	68	10.3	*Nq*-593/B	Challenger (CCZ)
125.71	14/4/91-94	upper Tk	*Nq. pachyderma* s.l.	50	5			50	5	55	9.1	*Nq*-593/B	Challenger (CCZ)
125.91	14/4/111-114	upper Tk	*Nq. pachyderma* s.l.	68	18			68	18	86	20.9	*Nq*-593/B	Challenger (CCZ)
126.10	14/4/130-133	upper Tk	*Nq. pachyderma* s.l.	33	9			33	9	42	21.4	*Nq*-593/B	Challenger (CCZ)
126.30	14/5/0-3	upper Tk	*Nq. pachyderma* s.l.	31	6			31	6	37	16.2	*Nq*-593/B	Challenger (CCZ)
126.56	14/5/26-29	upper Tk	*Nq. pachyderma* s.l.	21	21			21	21	42	50.0	*Nq*-593/B	Challenger (CCZ)
126.70	14/5/40-43	upper Tk	*Nq. pachyderma* s.l.	6	13			6	13	19	68.4	*Nq*-593/B	Challenger (CCZ)
126.90	14/5/60-63	upper Tk	*Nq. pachyderma* s.l.	9	16			9	16	25	64.0	*Nq*-593/B	Challenger (CCZ)
127.12	14/5/82-85	upper Tk	*Nq. pachyderma* s.l.	5	33			5	33	38	86.8	*Nq*-593/B	Challenger (CCZ)
127.30	14/5/100-103	upper Tk	*Nq. pachyderma* s.l.	5	20			5	20	25	80.0	*Nq*-593/B	Challenger (CCZ)
127.51	14/5/121-124	upper Tk	*Nq. pachyderma* s.l.	9	27			9	27	36	75.0	*Nq*-593/B	Challenger (CCZ)
127.70	14/5/140-143	upper Tk	*Nq. pachyderma* s.l.	15	28			15	28	43	65.1	*Nq*-593/B	Challenger (CCZ)
127.90	14/6/10-13	upper Tk	*Nq. pachyderma* s.l.	30	34			30	34	64	53.1	*Nq*-593/B	Challenger (CCZ)
128.29	14/6/49-52	upper Tk	*Nq. pachyderma* s.l.	5	31			5	31	36	86.1	*Nq*-593/B	Challenger (CCZ)
128.72	14/6/92-95	upper Tk	*Nq. pachyderma* s.l.	4	27			4	27	31	87.1	*Nq*-593/B	Challenger (CCZ)
129.10	14/6/130-133	upper Tk	*Nq. pachyderma* s.l.	3	9			3	9	12	75.0	*Nq*-593/B	Challenger (CCZ)
129.50	14/7/20-23	upper Tk	*Nq. pachyderma* s.l.	7	22			7	22	29	75.9	*Nq*-593/B	Challenger (CCZ)
129.90	15/1/0-3	upper Tk	*Nq. pachyderma* s.l.	4	3			4	3	7	42.9	*Nq*-593/B	Challenger (CCZ)
130.29	15/1/39-42	upper Tk	*Nq. pachyderma* s.l.	6	4			6	4	10	40.0	*Nq*-593/B	Challenger (CCZ)
130.69	15/1/79-82	upper Tk	*Nq. pachyderma* s.l.	23	3			23	3	26	11.5	*Nq*-593/B	Challenger (CCZ)
131.10	15/1/120-123	upper Tk	*Nq. pachyderma* s.l.	10	16			10	16	26	61.5	*Nq*-593/B	Challenger (CCZ)
131.51	15/2/11-14	upper Tk	*Nq. pachyderma* s.l.	16	8			16	8	24	33.3	*Nq*-593/B	Challenger (CCZ)
131.91	15/2/51-53	upper Tk	*Nq. pachyderma* s.l.	11	1			11	1	12	8.3		
132.33	15/2/93-96	upper Tk	*Nq. pachyderma* s.l.	15	0			15	0	15	0.0		
132.74	15/2/134-136	upper Tk	*Nq. pachyderma* s.l.	16	1			16	1	17	5.9		
133.07	15/3/17-20	upper Tk	*Nq. pachyderma* s.l.	10	2			10	2	12	16.7	???	???
133.46	15/3/56-59	upper Tk	*Nq. pachyderma* s.l.	6	1			6	1	7	14.3		
133.89	15/3/99-102	upper Tk	*Nq. pachyderma* s.l.	19	0			19	0	19	0.0		
134.30	15/3/140-143	upper Tk	*Nq. pachyderma* s.l.	10	0			10	0	10	0.0		
134.70	15/4/30-33	upper Tk	*Nq. pachyderma* s.l.	24	3			24	3	27	11.1		
135.10	15/4/70-73	upper Tk	*Nq. pachyderma* s.l.	16	1			16	1	17	5.9		
135.30	15/4/90-93	upper Tk	*Nq. pachyderma* s.l.	16	3			16	3	19	15.8		
135.50	15/4/110-113	upper Tk	*Nq. pachyderma* s.l.	7	0			7	0	7	0.0		
135.70	15/4/130-133	upper Tk	*Nq. pachyderma* s.l.	27	4			27	4	31	12.9		
135.90	15/5/0-3	upper Tk	*Nq. pachyderma* s.l.	38	0			38	0	38	0.0		
136.06	15/5/16-19	upper Tk	*Nq. pachyderma* s.l.	33	1			33	1	34	2.9		
136.32	15/5/42-45	upper Tk	*Nq. pachyderma* s.l.	30	2			30	2	32	6.3		
136.51	15/5/61-63	upper Tk	*Nq. pachyderma* s.l.	75	4			75	4	79	5.1		
136.92	15/5/102-105	upper Tk	*Nq. pachyderma* s.l.	36	1			36	1	37	2.7		
137.13	15/5/123-126	upper Tk	*Nq. pachyderma* s.l.	16	1			16	1	17	5.9		
137.52	15/6/12-15	upper Tk	*Nq. pachyderma* s.l.	5	1			5	1	6	16.7	???	???
137.91	15/6/51-54	upper Tk	*Nq. pachyderma* s.l.	5	0			5	0	5	0.0		
138.27	15/6/87-90	upper Tk	*Nq. pachyderma* s.l.	4	2	24	1	28	3	31	9.7		
138.66	15/6/126-129	upper Tk	*Nq. pachyderma* s.l.	8	0			8	0	8	0.0		
139.07	15/7/17-20	upper Tk	*Nq. pachyderma* s.l.	1	0			1	0	1	0.0		
139.50	16/1/0-3	upper Tk	*Nq. pachyderma* s.l.	5	0			5	0	5	0.0		
139.93	16/1/43-46	upper Tk	*Nq. pachyderma* s.l.	3	0			3	0	3	0.0		
140.34	16/1/84-87	upper Tk	*Nq. pachyderma* s.l.	3	1	15	10	18	11	29	37.9	???	???
140.73	16/1/123-126	upper Tk	*Nq. pachyderma* s.l.	2	0			2	0	2	0.0		
141.13	16/2/13-16	upper Tk	*Nq. pachyderma* s.l.	7	0			7	0	7	0.0		
141.54	16/2/54-57	upper Tk	*Nq. pachyderma* s.l.	5	0			5	0	5	0.0		
141.92	16/2/92-95	upper Tk	*Nq. pachyderma* s.l.	2	0			2	0	2	0.0		
142.32	16/2/132-135	upper Tk	*Nq. pachyderma* s.l.	8	0			8	0	8	0.0		
142.75	16/3/25-28	upper Tk	*Nq. pachyderma* s.l.	11	0			11	0	11	0.0		
143.15	16/3/65-68	upper Tk	*Nq. pachyderma* s.l.	4	0			4	0	4	0.0		
143.53	16/3/103-106	upper Tk	*Nq. pachyderma* s.l.	14	0			14	0	14	0.0		
143.84	16/3/134-137	lower Tk	*Nq. pachyderma* s.l.	7	0			7	0	7	0.0		

Data Appendix 1.4

Neogloboquadrinid coiling data, DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top depth (mbsf)	Interval	NZ Stage	Species	*Neogloboquadrina* (all species)									
				Census (Sin)	Census (Dex)	Supp. count (Sin)	Supp. count (Dex)	Total (Sinistral)	Total (Dextral)	Total	Dextral percentage	Dextral intervals	Coiling zone
144.26	16/4/26-29	lower Tk	*Nq. pachyderma* s.l.	5	0			5	0	5	0.0		
144.67	16/4/67-70	lower Tk	*Nq. pachyderma* s.l.	6	0			6	0	6	0.0		
145.13	16/4/113-116	lower Tk	*Nq. pachyderma* s.l.	9	1			9	1	10	10.0		
145.50	16/5/0-3	lower Tk	*Nq. pachyderma* s.l.	10	1			10	1	11	9.1		
145.93	16/5/43-46	lower Tk	*Nq. pachyderma* s.l.	4	0			4	0	4	0.0		
146.36	16/5/86-88	lower Tk	*Nq. pachyderma* s.l.	12	2			12	2	14	14.3		
146.71	16/5/121-124	lower Tk	*Nq. pachyderma* s.l.	8	0			8	0	8	0.0		
147.06	16/6/6-9	lower Tk	*Nq. pachyderma* s.l.	10	0			10	0	10	0.0		
147.47	16/6/47-50	lower Tk	*Nq. pachyderma* s.l.	14	1			14	1	15	6.7		
147.93	16/6/93-96	lower Tk	*Nq. pachyderma* s.l.	9	0			9	0	9	0.0		
148.33	16/6/133-136	lower Tk	*Nq. pachyderma* s.l.	16	1			16	1	17	5.9		
148.67	16/7/17-19	lower Tk	*Nq. pachyderma* s.l.	8	0			8	0	8	0.0		
149.10	17/1/0-3	lower Tk	*Nq. pachyderma* s.l.	12	0			12	0	12	0.0		
149.52	17/1/42-45	lower Tk	*Nq. pachyderma* s.l.	10	3	30	0	40	3	43	7.0		
150.11	17/1/101-104	lower Tk	*Nq. pachyderma* s.l.	13	0			13	0	13	0.0		
150.51	17/1/141-144	lower Tk	*Nq. pachyderma* s.l.	15	0			15	0	15	0.0		
150.87	17/2/27-30	lower Tk	*Nq. pachyderma* s.l.	14	0			14	0	14	0.0		
151.07	17/2/47-50	lower Tk	*Nq. pachyderma* s.l.	9	0			9	0	9	0.0		
151.52	17/2/92-95	lower Tk	*Nq. pachyderma* s.l.	15	1			15	1	16	6.3		
151.96	17/2/136-138	lower Tk	*Nq. pachyderma* s.l.	12	0			12	0	12	0.0		
152.10	17/3/0-3	lower Tk	*Nq. pachyderma* s.l.	13	1			13	1	14	7.1		
152.25	17/3/15-18	lower Tk	*Nq. pachyderma* s.l.	15	1			15	1	16	6.3		
152.47	17/3/37-40	lower Tk	*Nq. pachyderma* s.l.	10	0			10	0	10	0.0		
152.75	17/3/65-67	lower Tk	*Nq. pachyderma* s.l.	24	0			24	0	24	0.0		
152.91	17/3/81-84	lower Tk	*Nq. pachyderma* s.l.	11	1			11	1	12	8.3		
153.12	17/3/102-105	lower Tk	*Nq. pachyderma* s.l.	9	1			9	1	10	10.0		
153.26	17/3/116-119	lower Tk	*Nq. pachyderma* s.l.	20	0			20	0	20	0.0		
153.45	17/3/135-138	lower Tk	*Nq. pachyderma* s.l.	10	1			10	1	11	9.1		
153.66	17/4/6-9	lower Tk	*Nq. pachyderma* s.l.	11	0			11	0	11	0.0		
153.97	17/4/37-39	lower Tk	*Nq. pachyderma* s.l.	8	0			8	0	8	0.0		
154.13	17/4/53-56	lower Tk	*Nq. pachyderma* s.l.	8	1			8	1	9	11.1		
154.32	17/4/72-75	lower Tk	*Nq. pachyderma* s.l.	11	0			11	0	11	0.0		
154.54	17/4/94-97	lower Tk	*Nq. pachyderma* s.l.	20	1			20	1	21	4.8		
154.77	17/4/117-119	lower Tk	*Nq. pachyderma* s.l.	10	2			10	2	12	16.7	???	???
154.95	17/4/135-138	lower Tk	*Nq. pachyderma* s.l.	40	7			40	7	47	14.9		
155.10	17/5/0-3	lower Tk	*Nq. pachyderma* s.l.	12	3	25	15	37	18	55	32.7	???	???
155.24	17/5/14-17	lower Tk	*Nq. pachyderma* s.l.	10	3	28	22	38	25	63	39.7	???	???
155.48	17/5/38-40	lower Tk	*Nq. pachyderma* s.l.	7	0			7	0	7	0.0		
155.67	17/5/57-60	lower Tk	*Nq. pachyderma* s.l.	10	0			10	0	10	0.0		
155.94	17/5/84-87	lower Tk	*Nq. pachyderma* s.l.	18	3			18	3	21	14.3		
156.13	17/5/103-106	lower Tk	*Nq. pachyderma* s.l.	9	1			9	1	10	10.0		
156.27	17/5/117-120	lower Tk	*Nq. pachyderma* s.l.	5	2	44	6	49	8	57	14.0		
156.47	17/5/137-140	lower Tk	*Nq. pachyderma* s.l.	17	0			17	0	17	0.0		
156.71	17/6/11-14	lower Tk	*Nq. pachyderma* s.l.	7	5	39	11	46	16	62	25.8	???	???
156.95	17/6/35-38	lower Tk	*Nq. pachyderma* s.l.	9	0			9	0	9	0.0		
157.12	17/6/52-55	lower Tk	*Nq. pachyderma* s.l.	19	4			19	4	23	17.4		
157.37	17/6/77-79	lower Tk	*Nq. pachyderma* s.l.	14	2			14	2	16	12.5		
157.52	17/6/92-95	lower Tk	*Nq. pachyderma* s.l.	10	2			10	2	12	16.7		
157.76	17/6/116-119	lower Tk	*Nq. pachyderma* s.l.	30	12	35	15	65	27	92	29.3	???	???
157.93	17/6/133-136	lower Tk	*Nq. pachyderma* s.l.	24	4			24	4	28	14.3		
158.10	17/7/0-3	lower Tk	*Nq. pachyderma* s.l.	30	3			30	3	33	9.1		
158.27	17/7/17-20	lower Tk	*Nq. pachyderma* s.l.	37	3			37	3	40	7.5		
158.52	17CC/6-9	lower Tk	*Nq. pachyderma* s.l.	15	2			15	2	17	11.8		
158.70	18/1/0-3	lower Tk	*Nq. pachyderma* s.l.	32	6			32	6	38	15.8	???	???
158.95	18/1/25-28	lower Tk	*Nq. pachyderma* s.l.	18	1			18	1	19	5.3		
159.13	18/1/43-46	lower Tk	*Nq. pachyderma* s.l.	12	2			12	2	14	14.3		
159.35	18/1/65-68	lower Tk	*Nq. pachyderma* s.l.	30	0			30	0	30	0.0		
159.49	18/1/79-82	lower Tk	*Nq. pachyderma* s.l.	22	3			22	3	25	12.0		
159.72	18/1/102-105	lower Tk	*Nq. pachyderma* s.l.	27	1			27	1	28	3.6		
159.86	18/1/116-119	lower Tk	*Nq. pachyderma* s.l.	20	3			20	3	23	13.0		
160.11	18/1/141-144	lower Tk	*Nq. pachyderma* s.l.	15	1			15	1	16	6.3		
160.33	18/2/13-16	lower Tk	*Nq. pachyderma* s.l.	27	3			27	3	30	10.0		
160.73	18/2/53-56	lower Tk	*Nq. pachyderma* s.l.	15	4	25	5	40	9	49	18.4	???	???
161.16	18/2/96-99	lower Tk	*Nq. pachyderma* s.l.	33	3			33	3	36	8.3		
161.53	18/2/133-136	lower Tk	*Nq. pachyderma* s.l.	30	3			30	3	33	9.1		
161.84	18/3/14-17	lower Tk	*Nq. pachyderma* s.l.	17	1			17	1	18	5.6		
162.26	18/3/56-59	lower Tk	*Nq. pachyderma* s.l.	8	4	81	17	89	21	110	19.1	???	???
162.87	18/3/117-120	lower Tk	*Nq. pachyderma* s.l.	11	0			11	0	11	0.0		
163.33	18/4/13-16	lower Tk	*Nq. pachyderma* s.l.	19	1			19	1	20	5.0		
163.56	18/4/36-39	lower Tk	*Nq. pachyderma* s.l.	44	3			44	3	47	6.4		
163.93	18/4/73-76	lower Tk	*Nq. pachyderma* s.l.	16	0			16	0	16	0.0		
164.31	18/4/111-113	lower Tk	*Nq. pachyderma* s.l.	6	0			6	0	6	0.0		
164.70	18/5/0-3	lower Tk	*Nq. pachyderma* s.l.	9	1			9	1	10	10.0		
165.13	18/5/43-46	lower Tk	*Nq. pachyderma* s.l.	35	1			35	1	36	2.8		
165.50	18/5/80-83	lower Tk	*Nq. pachyderma* s.l.	31	1			31	1	32	3.1		
165.95	18/5/125-127	lower Tk	*Nq. pachyderma* s.l.	14	0			14	0	14	0.0		
166.26	18/6/6-9	lower Tk	*Nq. pachyderma* s.l.	21	2			21	2	23	8.7		
166.66	18/6/46-49	lower Tk	*Nq. pachyderma* s.l.	29	0			29	0	29	0.0		
167.06	18/6/86-89	lower Tk	*Nq. pachyderma* s.l.	32	0			32	0	32	0.0		
167.44	18/6/124-127	upper Tt	*Nq. pachyderma* s.l.	38	1			38	1	39	2.6		
168.30	19/1/0-3	upper Tt	*Nq. pachyderma* s.l.	9	1			9	1	10	10.0		
168.71	19/1/41-44	upper Tt	*Nq. pachyderma* s.l.	22	4			22	4	26	15.4	???	???
169.13	19/1/83-85	upper Tt	*Nq. pachyderma* s.l.	25	1			25	1	26	3.8		

Data Appendix 1.4

Neogloboquadrinid coiling data, DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top depth (mbsf)	Interval	NZ Stage	Species	*Neogloboquadrina* (all species)									
				Census (Sin)	Census (Dex)	Supp. count (Sin)	Supp. count (Dex)	Total (Sinistral)	Total (Dextral)	Total	Dextral percentage	Dextral intervals	Coiling zone
169.51	19/1/121-124	upper Tt	*Nq. pachyderma* s.l.	11	1			11	1	12	8.3		
169.85	19/2/5-8	upper Tt	*Nq. pachyderma* s.l.	14	2			14	2	16	12.5		
170.32	19/2/52-55	upper Tt	*Nq. pachyderma* s.l.	8	0			8	0	8	0.0		
170.73	19/2/93-96	upper Tt	*Nq. pachyderma* s.l.	9	3	19	0	28	3	31	9.7		
171.15	19/2/135-138	upper Tt	*Nq. pachyderma* s.l.	14	0			14	0	14	0.0		
171.57	19/3/27-29	upper Tt	*Nq. pachyderma* s.l.	17	0			17	0	17	0.0		
171.92	19/3/62-64	upper Tt	*Nq. pachyderma* s.l.	13	1			13	1	14	7.1		
172.32	19/3/102-105	upper Tt	*Nq. pachyderma* s.l.	20	1			20	1	21	4.8		
172.66	19/3/136-138	upper Tt	*Nq. pachyderma* s.l.	21	0			21	0	21	0.0		
173.07	19/4/27-29	upper Tt	*Nq. pachyderma* s.l.	15	0			15	0	15	0.0		
173.52	19/4/72-74	upper Tt	*Nq. pachyderma* s.l.	7	1			7	1	8	12.5		
173.93	19/4/113-115	upper Tt	*Nq. pachyderma* s.l.	18	1			18	1	19	5.3		
174.30	19/5/0-3	upper Tt	*Nq. pachyderma* s.l.	10	0			10	0	10	0.0		
174.72	19/5/42-45	upper Tt	*Nq. pachyderma* s.l.	24	0			24	0	24	0.0		
175.26	19/5/96-99	upper Tt	*Nq. pachyderma* s.l.	6	0			6	0	6	0.0		
175.71	19/5/141-144	upper Tt	*Nq. pachyderma* s.l.	10	1			10	1	11	9.1		
176.06	19/6/26-29	upper Tt	*Nq. pachyderma* s.l.	13	0			13	0	13	0.0		
176.47	19/6/67-69	upper Tt	*Nq. pachyderma* s.l.	18	0			18	0	18	0.0		
176.92	19/6/112-114	upper Tt	*Nq. pachyderma* s.l.	27	0			27	0	27	0.0		
177.30	19/7/0-3	upper Tt	*Nq. pachyderma* s.l.	15	0			15	0	15	0.0		
177.52	19/7/22-25	upper Tt	*Nq. pachyderma* s.l.	33	3			33	3	36	8.3		
177.90	20/1/0-3	upper Tt	*Nq. pachyderma* s.l.	37	5			37	5	42	11.9		
178.27	20/1/37-40	upper Tt	*Nq. pachyderma* s.l.	34	1			34	1	35	2.9		
178.68	20/1/78-80	upper Tt	*Nq. pachyderma* s.l.	48	0			48	0	48	0.0		
179.08	20/1/118-120	upper Tt	*Nq. pachyderma* s.l.	25	1			25	1	26	3.8		
179.45	20/2/5-7	upper Tt	*Nq. pachyderma* s.l.	21	2			21	2	23	8.7		
179.86	20/2/46-48	upper Tt	*Nq. pachyderma* s.l.	46	2			46	2	48	4.2		
180.33	20/2/93-95	upper Tt	*Nq. pachyderma* s.l.	37	0			37	0	37	0.0		
180.73	20/2/133-135	upper Tt	*Nq. pachyderma* s.l.	19	1			19	1	20	5.0		
181.14	20/3/24-26	upper Tt	*Nq. pachyderma* s.l.	17	0			17	0	17	0.0		
181.57	20/3/67-69	upper Tt	*Nq. pachyderma* s.l.	21	2			21	2	23	8.7		
181.86	20/3/96-98	upper Tt	*Nq. pachyderma* s.l.	39	1			39	1	40	2.5		
182.23	20/3/133-135	upper Tt	*Nq. pachyderma* s.l.	27	0			27	0	27	0.0		
182.68	20/4/28-30	upper Tt	*Nq. pachyderma* s.l.	25	3			25	3	28	10.7		
183.08	20/4/68-70	upper Tt	*Nq. pachyderma* s.l.	12	0			12	0	12	0.0		
183.45	20/4/105-107	upper Tt	*Nq. pachyderma* s.l.	44	2			44	2	46	4.3		
183.91	20/5/1-3	upper Tt	*Nq. pachyderma* s.l.	38	1			38	1	39	2.6		
184.32	20/5/42-44	upper Tt	*Nq. pachyderma* s.l.	25	1			25	1	26	3.8		
184.72	20/5/82-84	upper Tt	*Nq. pachyderma* s.l.	32	0			32	0	32	0.0		
185.07	20/5/117-119	upper Tt	*Nq. pachyderma* s.l.	24	1			24	1	25	4.0		
185.47	20/6/7-9	upper Tt	*Nq. pachyderma* s.l.	9	0			9	0	9	0.0		
185.92	20/6/52-54	upper Tt	*Nq. pachyderma* s.l.	12	4	20	0	32	4	36	11.1		
186.32	20/6/92-94	upper Tt	*Nq. pachyderma* s.l.	20	2			20	2	22	9.1		
186.72	20/6/132-134	upper Tt	*Nq. pachyderma* s.l.	25	1			25	1	26	3.8		
187.07	20/7/17-19	upper Tt	*Nq. pachyderma* s.l.	59	3			59	3	62	4.8		
187.51	21/1/1-3	upper Tt	*Nq. pachyderma* s.l.	65	8			65	8	73	11.0		
187.93	21/1/43-45	upper Tt	*Nq. pachyderma* s.l.	41	3			41	3	44	6.8		
188.32	21/182-84	upper Tt	*Nq. pachyderma* s.l.	23	1			23	1	24	4.2		
188.67	21/1/117-119	upper Tt	*Nq. pachyderma* s.l.	22	0			22	0	22	0.0		
189.08	21/2/8-10	upper Tt	*Nq. pachyderma* s.l.	17	0			17	0	17	0.0		
189.46	21/2/46-48	upper Tt	*Nq. pachyderma* s.l.	20	2			20	2	22	9.1		
189.93	21/2/93-96	upper Tt	*Nq. pachyderma* s.l.	20	0			20	0	20	0.0		
190.42	21/2/142-144	upper Tt	*Nq. pachyderma* s.l.	24	0			24	0	24	0.0		
190.66	21/3/16-18	upper Tt	*Nq. pachyderma* s.l.	14	1			14	1	15	6.7		
191.12	21/3/62-64	upper Tt	*Nq. pachyderma* s.l.	22	1			22	1	23	4.3		
191.52	21/3/102-104	upper Tt	*Nq. pachyderma* s.l.	42	0			42	0	42	0.0		
191.86	21/3/136-139	upper Tt	*Nq. pachyderma* s.l.	25	2			25	2	27	7.4		
192.36	21/4/36-38	upper Tt	*Nq. pachyderma* s.l.	36	1			36	1	37	2.7		
192.73	21/4/73-75	upper Tt	*Nq. pachyderma* s.l.	19	0			19	0	19	0.0		
193.12	21/4/112-114	upper Tt	*Nq. pachyderma* s.l.	20	2			20	2	22	9.1		
193.50	21/5/0-2	upper Tt	*Nq. pachyderma* s.l.	49	1			49	1	50	2.0		
193.92	21/5/42-44	upper Tt	*Nq. pachyderma* s.l.	20	0			20	0	20	0.0		
194.34	21/5/84-86	upper Tt	*Nq. pachyderma* s.l.	15	0			15	0	15	0.0		
194.72	21/5/122-124	upper Tt	*Nq. pachyderma* s.l.	49	2			49	2	51	3.9		
195.07	21/6/7-9	upper Tt	*Nq. pachyderma* s.l.	27	0			27	0	27	0.0		
195.49	21/6/49-51	upper Tt	*Nq. pachyderma* s.l.	36	2			36	2	38	5.3		
195.87	21/6/87-89	upper Tt	*Nq. pachyderma* s.l.	71	1			71	1	72	1.4		
196.34	21/6/134-136	upper Tt	*Nq. pachyderma* s.l.	29	0			29	0	29	0.0		
196.72	21/7/22-24	upper Tt	*Nq. pachyderma* s.l.	52	1			52	1	53	1.9		
197.11	22/1/1-3	upper Tt	*Nq. pachyderma* s.l.	29	1			29	1	30	3.3		
197.48	22/1/38-40	upper Tt	*Nq. pachyderma* s.l.	54	3			54	3	57	5.3		
197.94	22/1/84-86	upper Tt	*Nq. pachyderma* s.l.	42	4			42	4	46	8.7		
198.32	22/1/122-124	upper Tt	*Nq. pachyderma* s.l.	39	2			39	2	41	4.9		
198.73	22/2/13-15	upper Tt	*Nq. pachyderma* s.l.	32	2			32	2	34	5.9		
199.14	22/2/54-56	upper Tt	*Nq. pachyderma* s.l.	73	14			73	14	87	16.1	???	???
199.53	22/2/93-95	upper Tt	*Nq. pachyderma* s.l.	33	3			33	3	36	8.3		
199.93	22/2/133-135	upper Tt	*Nq. pachyderma* s.l.	81	13			81	13	94	13.8		
200.25	22/3/15-17	upper Tt	*Nq. pachyderma* s.l.	102	11			102	11	113	9.7		
200.66	22/3/56-58	upper Tt	*Nq. pachyderma* s.l.	34	3			34	3	37	8.1		
201.05	22/3/95-97	upper Tt	*Nq. pachyderma* s.l.	95	9			95	9	104	8.7		
201.42	22/3/132-134	upper Tt	*Nq. pachyderma* s.l.	11	10	14	6	25	16	41	39.0	???	???
201.93	22/4/33-35	upper Tt	*Nq. pachyderma* s.l.	23	3			23	3	26	11.5		
202.52	22/4/92-95	upper Tt	*Nq. pachyderma* s.l.	26	3			26	3	29	10.3		

Data Appendix 1.4

Neogloboquadrinid coiling data, DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top depth (mbsf)	Interval	NZ Stage	Species	*Neogloboquadrina* (all species)									
				Census (Sin)	Census (Dex)	Supp. count (Sin)	Supp. count (Dex)	Total (Sinistral)	Total (Dextral)	Total	Dextral percentage	Dextral intervals	Coiling zone
202.93	22/4/133-135	upper Tt	*Nq. pachyderma* s.l.	35	4			35	4	39	10.3		
203.17	22CC/7-10	upper Tt	*Nq. pachyderma* s.l.	18	0			18	0	18	0.0		
206.71	23/1/1-3	upper Tt	*Nq. pachyderma* s.l.	21	0			21	0	21	0.0		
207.13	23/1/43-45	upper Tt	*Nq. pachyderma* s.l.	11	0			11	0	11	0.0		
207.48	23/1/78-80	upper Tt	*Nq. pachyderma* s.l.	6	0			6	0	6	0.0		
207.88	23/1/118-120	upper Tt	*Nq. pachyderma* s.l.	4	0			4	0	4	0.0		
208.26	23/2/6-8	upper Tt	*Nq. pachyderma* s.l.	9	0			9	0	9	0.0		
208.52	23/2/32-34	upper Tt	*Nq. pachyderma* s.l.	18	1			18	1	19	5.3		
209.06	23/2/86-88	upper Tt	*Nq. pachyderma* s.l.	5	0			5	0	5	0.0		
209.54	23/2/134-136	upper Tt	*Nq. pachyderma* s.l.	13	0			13	0	13	0.0		
209.85	23/3/15-17	upper Tt	*Nq. pachyderma* s.l.	9	0			9	0	9	0.0		
210.33	23/3/63-65	upper Tt	*Nq. pachyderma* s.l.	9	0			9	0	9	0.0		
210.53	23/3/83-85	upper Tt	*Nq. pachyderma* s.l.	17	1			17	1	18	5.6		
210.87	23/3/117-119	upper Tt	*Nq. pachyderma* s.l.	13	2			13	2	15	13.3		
211.27	23/4/7-9	upper Tt	*Nq. pachyderma* s.l.	3	0			3	0	3	0.0		
211.72	23/4/52-54	upper Tt	*Nq. pachyderma* s.l.	16	0			16	0	16	0.0		
212.13	23/4/93-95	upper Tt	*Nq. pachyderma* s.l.	6	0			6	0	6	0.0		
212.32	23/4/112-114	upper Tt	*Nq. pachyderma* s.l.	28	2			28	2	30	6.7		
212.71	23/5/1-3	upper Tt	*Nq. pachyderma* s.l.	23	1			23	1	24	4.2		
213.12	23/5/42-44	upper Tt	*Nq. pachyderma* s.l.	31	4			31	4	35	11.4		
213.72	23/5/102-104	upper Tt	*Nq. pachyderma* s.l.	23	1			23	1	24	4.2		
214.12	23/5/142-144	upper Tt	*Nq. pachyderma* s.l.	20	1			20	1	21	4.8		
214.51	23/6/31-33	upper Tt	*Nq. pachyderma* s.l.	40	5			40	5	45	11.1		
215.05	23/6/85-87	upper Tt	*Nq. pachyderma* s.l.	6	2	18	1	24	3	27	11.1		
215.53	23/6/133-135	upper Tt	*Nq. pachyderma* s.l.	9	2	28	2	37	4	41	9.8		
215.93	23/7/23-25	upper Tt	*Nq. pachyderma* s.l.	10	0			10	0	10	0.0		
216.31	24/1/1-3	upper Tt	*Nq. pachyderma* s.l.	20	1			20	1	21	4.8		
216.57	24/1/27-29	upper Tt	*Nq. pachyderma* s.l.	92	12			92	12	104	11.5		
216.94	24/1/64-66	upper Tt	*Nq. pachyderma* s.l.	18	2			18	2	20	10.0		
217.34	24/1/104-106	upper Tt	*Nq. pachyderma* s.l.	21	1			21	1	22	4.5		
217.72	24/1/142-144	upper Tt	*Nq. pachyderma* s.l.	15	0			15	0	15	0.0		
218.08	24/2/28-30	upper Tt	*Nq. pachyderma* s.l.	11	0			11	0	11	0.0		
218.52	24/2/72-74	upper Tt	*Nq. pachyderma* s.l.	53	4			53	4	57	7.0		
218.87	24/2/107-109	upper Tt	*Nq. pachyderma* s.l.	31	2			31	2	33	6.1		
219.31	24/3/1-3	upper Tt	*Nq. pachyderma* s.l.	97	6			97	6	103	5.8		
219.72	24/3/42-44	upper Tt	*Nq. pachyderma* s.l.	113	3			113	3	116	2.6		
220.12	24/3/82-84	upper Tt	*Nq. pachyderma* s.l.	73	5			73	5	78	6.4		
220.46	24/3/116-118	upper Tt	*Nq. pachyderma* s.l.	104	10			104	10	114	8.8		
220.87	24/4/7-9	upper Tt	*Nq. pachyderma* s.l.	48	8			48	8	56	14.3		
221.27	24/4/47-49	upper Tt	*Nq. pachyderma* s.l.	66	1			66	1	67	1.5		
221.66	24/4/86-88	upper Tt	*Nq. pachyderma* s.l.	50	0			50	0	50	0.0		
222.13	24/4/133-135	upper Tt	*Nq. pachyderma* s.l.	45	2			45	2	47	4.3		
222.45	24/5/15-17	upper Tt	*Nq. pachyderma* s.l.	70	6			70	6	76	7.9		
222.93	24/5/63-65	upper Tt	*Nq. pachyderma* s.l.	34	4			34	4	38	10.5		
223.33	24/5/103-105	upper Tt	*Nq. pachyderma* s.l.	52	3			52	3	55	5.5		
223.72	24/5/142-144	upper Tt	*Nq. pachyderma* s.l.	83	3			83	3	86	3.5		
224.07	24/6/27-29	upper Tt	*Nq. pachyderma* s.l.	68	1			68	1	69	1.4		
224.47	24/6/67-69	upper Tt	*Nq. pachyderma* s.l.	112	9			112	9	121	7.4		
224.87	24/6/107-109	upper Tt	*Nq. pachyderma* s.l.	31	2			31	2	33	6.1		
225.36	24CC/9-11	upper Tt	*Nq. pachyderma* s.l.	43	2			43	2	45	4.4		
226.13	25/1/23-25	upper Tt	*Nq. pachyderma* s.l.	36	3			36	3	39	7.7		
226.53	25/1/63-65	upper Tt	*Nq. pachyderma* s.l.	69	7			69	7	76	9.2		
226.93	25/1/103-105	upper Tt	*Nq. pachyderma* s.l.	37	5			37	5	42	11.9		
227.34	25/1/144-146	upper Tt	*Nq. pachyderma* s.l.	26	1			26	1	27	3.7		
227.72	25/2/-32-34	upper Tt	*Nq. pachyderma* s.l.	21	1			21	1	22	4.5		
228.12	25/2/72-74	upper Tt	*Nq. pachyderma* s.l.	34	1			34	1	35	2.9		
228.52	25/2/112-114	upper Tt	*Nq. pachyderma* s.l.	36	3			36	3	39	7.7		
228.90	25/3/0-2	upper Tt	*Nq. pachyderma* s.l.	33	2			33	2	35	5.7		
229.33	25/3/43-45	upper Tt	*Nq. pachyderma* s.l.	18	0			18	0	18	0.0		
229.85	25/3/95-97	upper Tt	*Nq. pachyderma* s.l.	15	1			15	1	16	6.3		
230.27	25/3/137-139	upper Tt	*Nq. pachyderma* s.l.	16	0			16	0	16	0.0		
230.47	25/4/7-9	upper Tt	*Nq. pachyderma* s.l.	44	1			44	1	45	2.2		
230.93	25/4/53-55	upper Tt	*Nq. pachyderma* s.l.	20	3			20	3	23	13.0		
231.33	25/4/93-95	upper Tt	*Nq. pachyderma* s.l.	23	4			23	4	27	14.8		
231.73	25/4/133-135	upper Tt	*Nq. pachyderma* s.l.	90	3			90	3	93	3.2		
232.06	25/5/16-18	upper Tt	*Nq. pachyderma* s.l.	3	0			3	0	3	0.0		
232.52	25/5/62-64	upper Tt	*Nq. pachyderma* s.l.	8	1			8	1	9	11.1		
232.92	25/5/102-104	upper Tt	*Nq. pachyderma* s.l.	28	4			28	4	32	12.5		
233.27	25/5137-139	upper Tt	*Nq. pachyderma* s.l.	37	0			37	0	37	0.0		
233.67	25/6/27-29	upper Tt	*Nq. pachyderma* s.l.	4	0			4	0	4	0.0		
234.15	25/6/75-77	upper Tt	*Nq. pachyderma* s.l.	4	0			4	0	4	0.0		
234.52	25/6/112-114	upper Tt	*Nq. pachyderma* s.l.	9	1	28	2	37	3	40	7.5		
234.91	25/7/1-3	upper Tt	*Nq. pachyderma* s.l.	11	1			11	1	12	8.3		
235.26	25CC/10-22	upper Tt	*Nq. pachyderma* s.l.	20	0			20	0	20	0.0		
235.73	26/1/23-25	upper Tt	*Nq. pachyderma* s.l.	32	2			32	2	34	5.9		
236.08	26/1/58-60	upper Tt	*Nq. pachyderma* s.l.	56	2			56	2	58	3.4		
236.52	26/1/102-104	upper Tt	*Nq. pachyderma* s.l.	21	3			21	3	24	12.5		
236.92	26/1/142-144	upper Tt	*Nq. pachyderma* s.l.	9	0			9	0	9	0.0		
237.32	26/2/32-34	upper Tt	*Nq. pachyderma* s.l.	49	5			49	5	54	9.3		
237.93	26/2/93-95	upper Tt	*Nq. pachyderma* s.l.	19	1			19	1	20	5.0		
238.33	26/2/133-135	upper Tt	*Nq. pachyderma* s.l.	41	3			41	3	44	6.8		
238.51	26/3/1-3	upper Tt	*Nq. pachyderma* s.l.	74	2			74	2	76	2.6		
238.93	26/3/43-45	upper Tt	*Nq. pachyderma* s.l.	17	0			17	0	17	0.0		

Data Appendix 1.4

Neogloboquadrinid coiling data, DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top depth (mbsf)	Interval	NZ Stage	Species	*Neogloboquadrina* (all species)									
				Census (Sin)	Census (Dex)	Supp. count (Sin)	Supp. count (Dex)	Total (Sinistral)	Total (Dextral)	Total	Dextral percentage	Dextral intervals	Coiling zone
239.32	26/3/82-84	upper Tt	*Nq. pachyderma* s.l.	55	1			55	1	56	1.8		
239.67	26/3/117-119	upper Tt	*Nq. pachyderma* s.l.	15	1			15	1	16	6.3		
240.07	26/4/7-9	upper Tt	*Nq. pachyderma* s.l.	21	2			21	2	23	8.7		
240.52	26/4/52-54	upper Tt	*Nq. pachyderma* s.l.	52	2			52	2	54	3.7		
240.92	26/4/92-94	upper Tt	*Nq. pachyderma* s.l.	17	1			17	1	18	5.6		
241.32	26/4/132-134	upper Tt	*Nq. pachyderma* s.l.	9	2	30	0	39	2	41	4.9		
241.65	26/5/15-17	upper Tt	*Nq. pachyderma* s.l.	33	0			33	0	33	0.0		
242.13	26/5/63-65	upper Tt	*Nq. pachyderma* s.l.	9	2	29	1	38	3	41	7.3		
242.52	26/5/102-104	upper Tt	*Nq. pachyderma* s.l.	15	3	29	1	44	4	48	8.3		
242.92	26/5/142-144	upper Tt	*Nq. pachyderma* s.l.	57	0			57	0	57	0.0		
243.26	26/6/26-28	upper Tt	*Nq. pachyderma* s.l.	31	1			31	1	32	3.1		
243.63	26/6/63-65	upper Tt	*Nq. pachyderma* s.l.	77	2			77	2	79	2.5		
243.86	26CC/13-15	upper Tt	*Nq. pachyderma* s.l.	56	2			56	2	58	3.4		
245.11	27/1/1-3	upper Tt	*Nq. pachyderma* s.l.	91	4			91	4	95	4.2		
245.53	27/1/43-45	upper Tt	*Nq. pachyderma* s.l.	48	2			48	2	50	4.0		
245.91	27/1/81-83	upper Tt	*Nq. pachyderma* s.l.	22	0			22	0	22	0.0		
246.27	27/1/117-119	upper Tt	*Nq. pachyderma* s.l.	11	2			11	2	13	15.4	???	???
246.52	27/1/142-144	upper Tt	*Nq. pachyderma* s.l.	33	3			33	3	36	8.3		
246.87	27/2/27-29	upper Tt	*Nq. pachyderma* s.l.	46	1			46	1	47	2.1		
247.33	27/2/73-76	upper Tt	*Nq. pachyderma* s.l.	44	1			44	1	45	2.2		
247.67	27/2/107-109	upper Tt	*Nq. pachyderma* s.l.	60	5			60	5	65	7.7		
248.11	27/3/1-3	upper Tt	*Nq. pachyderma* s.l.	33	1			33	1	34	2.9		
248.47	27/3/37-39	upper Tt	*Nq. pachyderma* s.l.	74	6			74	6	80	7.5		
248.93	27/3/83-85	upper Tt	*Nq. pachyderma* s.l.	38	1			38	1	39	2.6		
249.27	27/3/117-119	upper Tt	*Nq. pachyderma* s.l.	62	2			62	2	64	3.1		
249.67	27/4/7-9	upper Tt	*Nq. pachyderma* s.l.	57	1			57	1	58	1.7		
250.12	27/4/52-54	upper Tt	*Nq. pachyderma* s.l.	26	0			26	0	26	0.0		
250.46	27/4/86-88	upper Tt	*Nq. pachyderma* s.l.	28	3			28	3	31	9.7		
250.92	27/4/132-134	upper Tt	*Nq. pachyderma* s.l.	63	2			63	2	65	3.1		
251.33	27/5/23-26	upper Tt	*Nq. pachyderma* s.l.	92	2			92	2	94	2.1		
251.67	27/5/57-59	upper Tt	*Nq. pachyderma* s.l.	119	4			119	4	123	3.3		
252.13	27/5/103-105	upper Tt	*Nq. pachyderma* s.l.	114	1			114	1	115	0.9		
252.53	27/5/143-145	upper Tt	*Nq. pachyderma* s.l.	37	0			37	0	37	0.0		
252.92	27/6/32-34	upper Tt	*Nq. pachyderma* s.l.	55	7			55	7	62	11.3		
253.33	27/6/73-75	upper Tt	*Nq. pachyderma* s.l.	25	4			25	4	29	13.8		
253.67	27/6/107-109	upper Tt	*Nq. pachyderma* s.l.	23	1			23	1	24	4.2		
254.10	27/7/0-2	upper Tt	*Nq. pachyderma* s.l.	26	0			26	0	26	0.0		
254.49	27CC/10-12	lower Tt	*Nq. pachyderma* s.l.	84	9			84	9	93	9.7		
254.93	28/1/23-25	lower Tt	*Nq. pachyderma* s.l.	26	1			26	1	27	3.7		
255.28	28/1/58-60	lower Tt	*Nq. pachyderma* s.l.	44	3			44	3	47	6.4		
255.73	28/1/103-105	lower Tt	*Nq. pachyderma* s.l.	32	2			32	2	34	5.9		
256.11	28/1/141-143	lower Tt	*Nq. pachyderma* s.l.	14	0			14	0	14	0.0		
256.53	28/2/33-35	lower Tt	*Nq. pachyderma* s.l.	13	0			13	0	13	0.0		
257.03	28/2/83-85	lower Tt	*Nq. pachyderma* s.l.	3	0			3	0	3	0.0		
257.33	28/2/113-115	lower Tt	*Nq. pachyderma* s.l.	1	0			1	0	1	0.0		
257.71	28/3/1-3	lower Tt	*Nq. pachyderma* s.l.	3	0			3	0	3	0.0		
258.12	28/3/42-44	lower Tt	*Nq. pachyderma* s.l.	3	0			3	0	3	0.0		
258.54	28/3/84-86	lower Tt	*Nq. pachyderma* s.l.	4	1	10	0	14	1	15	6.7		
259.07	28/3/137-139	lower Tt	*Nq. pachyderma* s.l.	32	2			32	2	34	5.9		
259.53	28/4/33-35	lower Tt	*Nq. pachyderma* s.l.	49	0			49	0	49	0.0		
259.86	28/4/66-68	lower Tt	*Nq. pachyderma* s.l.	45	1			45	1	46	2.2		
260.28	28/4/108-110	lower Tt	*Nq. pachyderma* s.l.	43	0			43	0	43	0.0		
260.54	28/4/134-136	lower Tt	*Nq. pachyderma* s.l.	3	1	44	6	47	7	54	13.0		
260.86	28/5/16-18	lower Tt	*Nq. pachyderma* s.l.	9	0			9	0	9	0.0		
261.31	28/5/61-63	lower Tt	*Nq. pachyderma* s.l.	35	1			35	1	36	2.8		
261.72	28/5/102-104	lower Tt	*Nq. pachyderma* s.l.	20	0			20	0	20	0.0		
262.11	28/5/141-143	lower Tt	*Nq. pachyderma* s.l.	23	2			23	2	25	8.0		
262.45	28CC/8-10	lower Tt	*Nq. pachyderma* s.l.	17	2			17	2	19	10.5		
264.30	29/1/0-2	lower Tt	*Nq. pachyderma* s.l.	8	0			8	0	8	0.0		
264.64	29/1/34-36	lower Tt	*Nq. pachyderma* s.l.	34	1			34	1	35	2.9		
264.88	29/1/58-60	lower Tt	*Nq. pachyderma* s.l.	35	3			35	3	38	7.9		
265.26	29/1/96-98	lower Tt	*Nq. pachyderma* s.l.	65	9			65	9	74	12.2		
265.72	29/1/142-144	lower Tt	*Nq. pachyderma* s.l.	45	2			45	2	47	4.3		
266.12	29/2/32-34	lower Tt	*Nq. pachyderma* s.l.	40	0			40	0	40	0.0		
266.44	29/2/64-66	lower Tt	*Nq. pachyderma* s.l.	35	5			35	5	40	12.5		
266.87	29/2/107-109	lower Tt	*Nq. pachyderma* s.l.	39	1			39	1	40	2.5		
267.31	29/3/1-3	lower Tt	*Nq. pachyderma* s.l.	34	0			34	0	34	0.0		
267.53	29/3/23-25	lower Tt	*Nq. pachyderma* s.l.	41	1			41	1	42	2.4		
267.72	29/3/42-44	lower Tt	*Nq. pachyderma* s.l.	45	1			45	1	46	2.2		
267.87	29/3/57-59	lower Tt	*Nq. pachyderma* s.l.	43	1			43	1	44	2.3		
268.14	29/3/84-86	lower Tt	*Nq. pachyderma* s.l.	36	1			36	1	37	2.7		
268.34	29/3/104-106	lower Tt	*Nq. pachyderma* s.l.	25	0			25	0	25	0.0		
268.47	29/3/117-119	lower Tt	*Nq. pachyderma* s.l.	30	1			30	1	31	3.2		
268.68	29/3/138-140	lower Tt	*Nq. pachyderma* s.l.	14	1			14	1	15	6.7		
268.86	29/4/6-8	lower Tt	*Nq. pachyderma* s.l.	11	0			11	0	11	0.0		
269.28	29/4/48-50	lower Tt	*Nq. pachyderma* s.l.	4	0			4	0	4	0.0		
269.52	29/4/72-74	lower Tt	*Nq. pachyderma* s.l.	18	5	97	3	115	8	123	6.5		
269.75	29/4/95-97	lower Tt	*Nq. pachyderma* s.l.	14	2			14	2	16	12.5		
269.87	29/4/107-109	lower Tt	*Nq. pachyderma* s.l.	7	0			7	0	7	0.0		
270.15	29/4/135-137	lower Tt	*Nq. pachyderma* s.l.	16	1			16	1	17	5.9		
270.31	29/5/1-3	lower Tt	*Nq. pachyderma* s.l.	14	2	46	4	60	6	66	9.1		
270.45	29/5/15-17	lower Tt	*Nq. pachyderma* s.l.	11	1			11	1	12	8.3		
270.72	29/5/42-44	lower Tt	*Nq. pachyderma* s.l.	8	3	38	1	46	4	50	8.0		

Data Appendix 1.4

Neogloboquadrinid coiling data, DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top depth (mbsf)	Interval	NZ Stage	Species	*Neogloboquadrina* (all species)									
				Census (Sin)	Census (Dex)	Supp. count (Sin)	Supp. count (Dex)	Total (Sinistral)	Total (Dextral)	Total	Dextral percentage	Dextral intervals	Coiling zone
270.91	29/5/61-63	lower Tt	*Nq. pachyderma* s.l.	13	0			13	0	13	0.0		
271.15	29/5/85-87	lower Tt	*Nq. pachyderma* s.l.	28	2			28	2	30	6.7		
271.34	29/5/104-106	lower Tt	*Nq. pachyderma* s.l.	9	1			9	1	10	10.0		
271.48	29/5/118-120	lower Tt	*Nq. pachyderma* s.l.	1	0			1	0	1	0.0		
271.72	29/5/142-144	lower Tt	*Nq. pachyderma* s.l.	0	0			0	0	0	0.0		
271.94	29/6/14-16	lower Tt	*Nq. pachyderma* s.l.	0	0			0	0	0	0.0		
272.19	29CC/17-19	lower Tt	*Nq. pachyderma* s.l.	1	0			1	0	1	0.0		
273.91	30/1/1-A7303	lower Tt	*Nq. pachyderma* s.l.	1	1	11	0	12	1	13	7.7		
274.04	30/1/14-16	lower Tt	*Nq. pachyderma* s.l.	0	0			0	0	0	0.0		
274.32	30/1/42-44	lower Tt	*Nq. pachyderma* s.l.	0	0			0	0	0	0.0		
274.48	30/1/58-60	lower Tt	*Nq. pachyderma* s.l.	0	0			0	0	0	0.0		
274.72	30/1/82-84	lower Tt	*Nq. pachyderma* s.l.	17	2			17	2	19	10.5		
274.93	30/1/103-105	lower Tt	*Nq. pachyderma* s.l.	24	1			24	1	25	4.0		
275.12	30/1/122-124	lower Tt	*Nq. pachyderma* s.l.	3	1	35	4	38	5	43	11.6		
275.31	30/1/141-143	lower Tt	*Nq. pachyderma* s.l.	16	1			16	1	17	5.9		
275.45	30/2/5-7	lower Tt	*Nq. pachyderma* s.l.	31	1			31	1	32	3.1		
275.93	30/2/53-55	lower Tt	*Nq. pachyderma* s.l.	28	2			28	2	30	6.7		
276.52	30/2/112-114	lower Tt	*Nq. pachyderma* s.l.	34	2			34	2	36	5.6		
276.91	30/3/1-3	lower Tt	*Nq. pachyderma* s.l.	34	1			34	1	35	2.9		
277.33	30/3/43-45	lower Tt	*Nq. pachyderma* s.l.	26	0			26	0	26	0.0		
277.74	30/3/84-86	lower Tt	*Nq. pachyderma* s.l.	26	1			26	1	27	3.7		
278.07	30/3/117-119	lower Tt	*Nq. pachyderma* s.l.	22	2			22	2	24	8.3		
278.49	30/4/9-11	lower Tt	*Nq. pachyderma* s.l.	32	1			32	1	33	3.0		
278.88	30/4/48-50	lower Tt	*Nq. pachyderma* s.l.	31	0			31	0	31	0.0		
279.33	30/4/93-95	lower Tt	*Nq. pachyderma* s.l.	17	0			17	0	17	0.0		
279.75	30/4/135-137	lower Tt	*Nq. pachyderma* s.l.	22	0			22	0	22	0.0		
280.05	30/5/15-17	lower Tt	*Nq. pachyderma* s.l.	19	0			19	0	19	0.0		
280.25	30/5/35-37	lower Tt	*Nq. pachyderma* s.l.	39	2			39	2	41	4.9		
280.92	30/5/102-104	lower Tt	*Nq. pachyderma* s.l.	59	3			59	3	62	4.8		
283.51	31/1/1-3	lower Tt	*Nq. pachyderma* s.l.	54	6			54	6	60	10.0		
283.94	31/1/44-46	lower Tt	*Nq. pachyderma* s.l.	67	1			67	1	68	1.5		
284.33	31/1/83-85	lower Tt	*Nq. pachyderma* s.l.	59	3			59	3	62	4.8		
284.55	31/1/105-107	lower Tt	*Nq. pachyderma* s.l.	82	0			82	0	82	0.0		
284.88	31/1/138-140	lower Tt	*Nq. pachyderma* s.l.	88	4			88	4	92	4.3		
285.29	31/2/29-31	lower Tt	*Nq. pachyderma* s.l.	43	1			43	1	44	2.3		
285.73	31/2/73-75	lower Tt	*Nq. pachyderma* s.l.	9	0			9	0	9	0.0		
286.10	31/2/110-112	lower Tt	*Nq. pachyderma* s.l.	23	0			23	0	23	0.0		
286.51	31/3/1-3	lower Tt	*Nq. pachyderma* s.l.	24	1			24	1	25	4.0		
286.88	31/3/38-40	lower Tt	*Nq. pachyderma* s.l.	23	0			23	0	23	0.0		
287.32	31/3/82-84	lower Tt	*Nq. pachyderma* s.l.	41	1			41	1	42	2.4		
287.67	31/3/117-119	lower Tt	*Nq. pachyderma* s.l.	86	7			86	7	93	7.5		
288.08	31/4/8-10	lower Tt	*Nq. pachyderma* s.l.	36	2			36	2	38	5.3		
288.55	31/4/55-57	lower Tt	*Nq. pachyderma* s.l.	55	1			55	1	56	1.8		
288.89	31/4/89-91	lower Tt	*Nq. pachyderma* s.l.	12	3	31	4	43	7	50	14.0		
289.34	31/4/134-136	lower Tt	*Nq. pachyderma* s.l.	137	10			137	10	147	6.8		
289.73	31/5/23-25	lower Tt	*Nq. pachyderma* s.l.	112	4			112	4	116	3.4		
290.12	31/5/62-64	lower Tt	*Nq. pachyderma* s.l.	40	1			40	1	41	2.4		
290.51	31/5/101-103	lower Tt	*Nq. pachyderma* s.l.	55	3			55	3	58	5.2		
290.74	31CC/0-2	lower Tt	*Nq. pachyderma* s.l.	102	5			102	5	107	4.7		
293.11	32/1/1-3	lower Tt	*Nq. pachyderma* s.l.	55	5			55	5	60	8.3		
293.33	32/1/23-25	lower Tt	*Nq. pachyderma* s.l.	100	0			100	0	100	0.0		
293.71	32/1/61-63	lower Tt	*Nq. pachyderma* s.l.	121	9			121	9	130	6.9		
294.12	32/1/102-104	lower Tt	*Nq. pachyderma* s.l.	69	8			69	8	77	10.4		
294.51	32/1/141-143	lower Tt	*Nq. pachyderma* s.l.	56	118			56	118	174	67.8	*Nq*-593/A2	upper Glomar (GCZ)
294.90	32/2/30-32	lower Tt	*Nq. pachyderma* s.l.	3	45			3	45	48	93.8	*Nq*-593/A2	upper Glomar (GCZ)
295.12	32/2/73-75	lower Tt	*Nq. pachyderma* s.l.	0	0	36	5	36	5	41	87.8	*Nq*-593/A2	upper Glomar (GCZ)
295.33	32/2/73-75	lower Tt	*Nq. pachyderma* s.l.	1	14			1	14	15	93.3	*Nq*-593/A2	upper Glomar (GCZ)
295.73	32/2/113-115	lower Tt	*Nq. pachyderma* s.l.	0	0			0	0	0	0.0	*Nq*-593/A2	upper Glomar (GCZ)
295.93	32/2/133-135	lower Tt	*Nq. pachyderma* s.l.	0	0			0	0	0	0.0	*Nq*-593/A2	upper Glomar (GCZ)
296.50	32/3/40-42	lower Tt	*Nq. pachyderma* s.l.	1	0			1	0	1	0.0	*Nq*-593/A2	upper Glomar (GCZ)
296.93	32/3/83-85	lower Tt	*Nq. pachyderma* s.l.	1	0			1	0	1	0.0	*Nq*-593/A2	upper Glomar (GCZ)
297.33	32/3/123-125	lower Tt	*Nq. pachyderma* s.l.	0	0			0	0	0	0.0	*Nq*-593/A2	upper Glomar (GCZ)
297.70	32/4/10-12	lower Tt	*Nq. pachyderma* s.l.	2	0			2	0	2	0.0	*Nq*-593/A2	upper Glomar (GCZ)
298.08	32/4/48-50	lower Tt	*Nq. pachyderma* s.l.	0	0			0	0	0	0.0	*Nq*-593/A2	upper Glomar (GCZ)
298.52	32/4/92-94	lower Tt	*Nq. pachyderma* s.l.	0	0			0	0	0	0.0	*Nq*-593/A2	upper Glomar (GCZ)
298.93	32/4/133-135	lower Tt	*Nq. pachyderma* s.l.	1	0			1	0	1	0.0	*Nq*-593/A2	upper Glomar (GCZ)
299.38	32/5/28-30	lower Tt	*Nq. pachyderma* s.l.	0	0			0	0	0	0.0	*Nq*-593/A2	upper Glomar (GCZ)
299.67	32CC/2-4	lower Tt	*Nq. pachyderma* s.l.	28	3			28	3	31	9.7	*Nq*-593/A2	upper Glomar (GCZ)
302.71	33/1/1-3	lower Tt	*Nq. mayeri* s.l.	0	0	2	0	2	0	2	0.0	*Nq*-593/A1	lower Glomar (GCZ)
302.97	33/1/27-29	lower Tt	*Nq. mayeri* s.l.	2	1	4	3	6	4	10	40.0	*Nq*-593/A1	lower Glomar (GCZ)
303.29	33/1/59-61	lower Tt	*Nq. mayeri* s.l.	0	1	1	0	1	1	2	50.0	*Nq*-593/A1	lower Glomar (GCZ)
303.77	33/1/107-109	lower Tt	*Nq. mayeri* s.l.	5	2	5	5	10	7	17	41.2	*Nq*-593/A1	lower Glomar (GCZ)
304.13	33/1/143-145	lower Tt	*Nq. mayeri* s.l.	1	1	8	4	9	5	14	35.7	*Nq*-593/A1	lower Glomar (GCZ)
304.29	33/2/9-11	lower Tt	*Nq. mayeri* s.l.	2	0	4	2	6	2	8	25.0	*Nq*-593/A1	lower Glomar (GCZ)
304.47	33/2/27-29	lower Tt	*Nq. mayeri* s.l.	0	2	1	5	1	7	8	87.5	*Nq*-593/A1	lower Glomar (GCZ)
304.66	33/2/46-48	lower Tt	*Nq. mayeri* s.l.	2	1	12	18	14	19	33	57.6	*Nq*-593/A1	lower Glomar (GCZ)
305.02	33/2/82-84	lower Tt	*Nq. mayeri* s.l.	1	2	7	4	8	6	14	43.0	*Nq*-593/A1	lower Glomar (GCZ)
305.15	33/2/95-97	lower Tt	*Nq. mayeri* s.l.	1	2	15	15	16	17	33	51.5	*Nq*-593/A1	lower Glomar (GCZ)
305.34	33/2/114-116	lower Tt	*Nq. mayeri* s.l.	3	1	37	26	40	27	67	41.0	*Nq*-593/A1	lower Glomar (GCZ)
305.55	33/2/135-137	lower Tt	*Nq. mayeri* s.l.	2	1	28	26	30	27	57	47.4	*Nq*-593/A1	lower Glomar (GCZ)
305.71	33/3/1-3	lower Tt	*Nq. mayeri* s.l.	0	0	2	4	2	4	6	66.7	*Nq*-593/A1	lower Glomar (GCZ)
305.93	33/3/23-25	lower Tt	*Nq. mayeri* s.l.	0	0	0	0	0	0	0	0.0	*Nq*-593/A1	lower Glomar (GCZ)
306.11	33/3/41-43	lower Tt	*Nq. mayeri* s.l.	1	2	4	2	5	4	9	44.4	*Nq*-593/A1	lower Glomar (GCZ)

Data Appendix 1.4

Neogloboquadrinid coiling data, DSDP Site 593-14X to 36X (120.30–336.60 mbsf)

Top depth (mbsf)	Interval	NZ Stage	Species	*Neogloboquadrina* (all species)									
				Census (Sin)	Census (Dex)	Supp. count (Sin)	Supp. count (Dex)	Total (Sinistral)	Total (Dextral)	Total	Dextral percentage	Dextral intervals	Coiling zone
306.27	33/3/57-59	lower Tt	*Nq. mayeri* s.l.	0	0	0	0	0	0	0	0.0	*Nq*-593/A1	lower Glomar (GCZ)
306.54	33/3/84-86	lower Tt	*Nq. mayeri* s.l.	0	0	0	1	0	1	1	100.0	*Nq*-593/A1	lower Glomar (GCZ)
306.75	33/3/105-107	lower Tt	*Nq. mayeri* s.l.	0	0	0	0	0	0	0	0.0	*Nq*-593/A1	lower Glomar (GCZ)
306.86	33/3/116-118	lower Tt	*Nq. mayeri* s.l.	0	0	0	0	0	0	0	0.0	*Nq*-593/A1	lower Glomar (GCZ)
307.08	33/3/138-140	lower Tt	*Nq. mayeri* s.l.	0	0	5	2	5	2	7	28.6	*Nq*-593/A1	lower Glomar (GCZ)
307.30	33/4/10-12	lower Tt	*Nq. mayeri* s.l.	2	0	6	1	8	1	9	11.1	*Nq*-593/A1	lower Glomar (GCZ)
307.49	33/4/29-31	lower Tt	*Nq. mayeri* s.l.	0	0	9	4	9	4	13	30.8	*Nq*-593/A1	lower Glomar (GCZ)
307.70	33/4/50-52	lower Tt	*Nq. mayeri* s.l.	0	1	10	2	10	3	13	23.1	*Nq*-593/A1	lower Glomar (GCZ)
307.93	33/4/73-75	lower Tt	*Nq. mayeri* s.l.	2	1	7	4	9	5	14	35.7	*Nq*-593/A1	lower Glomar (GCZ)
308.14	33/4/94-96	lower Tt	*Nq. mayeri* s.l.	1	0	4	1	5	1	6	16.7	*Nq*-593/A1	lower Glomar (GCZ)
308.30	33/4/110-112	lower Tt	*Nq. mayeri* s.l.	1	0	1	0	2	0	2	0.0	*Nq*-593/A1	lower Glomar (GCZ)
308.53	33/4/133-135	lower Tt	*Nq. mayeri* s.l.	0	0	0	0	0	0	0	0.0	*Nq*-593/A1	lower Glomar (GCZ)
308.71	33/5/1-3	lower Tt	*Nq. mayeri* s.l.	0	0	5	0	5	0	5	0.0	*Nq*-593/A1	lower Glomar (GCZ)
308.99	33/5/29-31	lower Tt	*Nq. mayeri* s.l.	2	1	2	2	4	3	7	42.9	*Nq*-593/A1	lower Glomar (GCZ)
309.11	33/5/41-43	lower Tt	*Nq. mayeri* s.l.	0	1	9	2	9	3	12	25.0	???	???
309.28	33/5/58-60	lower Tt	*Nq. mayeri* s.l.	5	1	27	0	32	1	33	3.0		
309.54	33/5/84-86	lower Tt	*Nq. mayeri* s.l.	18	1	69	12	87	13	100	13.0		
309.74	33/5/104-106	lower Tt	*Nq. mayeri* s.l.	20	3	72	5	92	8	100	8.0		
312.31	34/1/1-3	lower Tt	*Nq. mayeri* s.l.	19	2	70	9	89	11	100	11.0		
312.54	34/1/24-26	lower Tt	*Nq. mayeri* s.l.	12	2	80	6	92	8	100	8.0		
312.67	34/1/37-39	lower Tt	*Nq. mayeri* s.l.	15	2	72	11	87	13	100	13.0		
312.87	34/1/57-59	lower Tt	*Nq. mayeri* s.l.	14	3	70	13	84	16	100	16.0	???	???
313.07	34/1/77-79	lower Tt	*Nq. mayeri* s.l.	9	1	73	5	82	6	88	6.8		
313.31	34/1/101-103	lower Tt	*Nq. mayeri* s.l.	20	3	73	4	93	7	100	7.0		
313.53	34/1/123-125	lower Tt	*Nq. mayeri* s.l.	26	4	64	6	90	10	100	10.0		
313.71	34/1/141-143	lower Tt	*Nq. mayeri* s.l.	38	3	49	10	87	13	100	13.0		
313.90	34/2/10-12	lower Tt	*Nq. mayeri* s.l.	49	6	39	6	88	12	100	12.0		
314.09	34/2/29-31	lower Tt	*Nq. mayeri* s.l.	49	4	43	4	92	8	100	8.0		
314.29	34/2/49-51	lower Tt	*Nq. mayeri* s.l.	39	6	52	3	91	9	100	9.0		
314.45	34/2/65-67	lower Tt	*Nq. mayeri* s.l.	195	21			195	21	216	9.7		
314.69	34/2/89-91	lower Tt	*Nq. mayeri* s.l.	143	10			143	10	153	6.5		
314.90	34/2/110-112	lower Tt	*Nq. mayeri* s.l.	63	9	23	6	86	15	101	14.9		
315.13	34/2/133-135	lower Tt	*Nq. mayeri* s.l.	104	11			104	11	115	9.6		
315.30	34/3/0-2	lower Tt	*Nq. mayeri* s.l.	28	1	74	5	102	6	108	5.6		
315.52	34/3/22-24	lower Tt	*Nq. mayeri* s.l.	34	1	59	6	93	7	100	7.0		
315.71	34/3/41-43	lower Tt	*Nq. mayeri* s.l.	26	3	73	6	99	9	108	8.3		
316.06	34/3/76-78	lower Tt	*Nq. mayeri* s.l.	42	9	47	2	89	11	100	11.0		
316.27	34/3/97-99	lower Tt	*Nq. mayeri* s.l.	119	13			119	13	132	9.8		
316.48	34/3/118-120	lower Tt	*Nq. mayeri* s.l.	63	8	27	2	90	10	100	10.0		
316.67	34/3/137-139	upper Sw	*Nq. mayeri* s.l.	65	8	23	4	88	12	100	12.0		
317.10	34/4/30-32	upper Sw	*Nq. mayeri* s.l.	76	6	16	2	92	8	100	8.0		
317.50	34/4/70-72	upper Sw	*Nq. mayeri* s.l.	59	12	24	5	83	17	100	17.0		
317.90	34/4/110-112	upper Sw	*Nq. mayeri* s.l.	64	7	25	4	89	11	100	11.0		
318.35	34/5/5-7	upper Sw	*Nq. mayeri* s.l.	84	9	7	0	91	9	100	9.0		
318.60	34/5/30-32	upper Sw	*Nq. mayeri* s.l.	94	14			94	14	108	13.0		
321.91	35/1/1-3	upper Sw	*Nq. mayeri* s.l.	87	5	8	0	95	5	100	5.0		
322.33	35/1/43-45	upper Sw	*Nq. mayeri* s.l.	93	11			93	11	104	10.6		
322.72	35/1/82-84	upper Sw	*Nq. mayeri* s.l.	54	12	32	2	86	14	100	14.0		
323.09	35/1/119-121	upper Sw	*Nq. mayeri* s.l.	59	10	29	2	88	12	100	12.0		
323.48	35/2/8-10	upper Sw	*Nq. mayeri* s.l.	84	7	8	1	92	8	100	8.0		
323.91	35/2/51-53	upper Sw	*Nq. mayeri* s.l.	388	40			388	40	428	9.3		
324.50	35/2/110-112	upper Sw	*Nq. mayeri* s.l.	135	20			135	20	155	12.9		
324.91	35/3/1-3	upper Sw	*Nq. mayeri* s.l.	95	12			95	12	107	11.2		
325.33	35/3/43-45	upper Sw	*Nq. mayeri* s.l.	184	35			184	35	219	16.0	???	???
325.71	35/3/81-83	upper Sw	*Nq. mayeri* s.l.	188	34			188	34	222	15.3	???	???
325.94	35/3/104-106	upper Sw	*Nq. mayeri* s.l.	271	43			271	43	314	13.7		
326.28	35/3/138-140	upper Sw	*Nq. mayeri* s.l.	91	15			91	15	106	14.2		
326.70	35/4/30-32	upper Sw	*Nq. mayeri* s.l.	81	19			81	19	100	19.0	???	???
327.09	35/4/69-71	upper Sw	*Nq. mayeri* s.l.	29	8	53	10	82	18	100	18.0	???	???
327.50	35/4/110-112	upper Sw	*Nq. mayeri* s.l.	183	35			183	35	218	16.1		
327.91	35/5/1-3	upper Sw	*Nq. mayeri* s.l.	106	6			106	6	112	5.4		
328.27	35/5/37-39	upper Sw	*Nq. mayeri* s.l.	274	34			274	34	308	11.0		
328.72	35/5/82-84	upper Sw	*Nq. mayeri* s.l.	464	53			464	53	517	10.3		
331.69	36/1/19-21	upper Sw	*Nq. mayeri* s.l.	228	39			228	39	267	14.6		
332.11	36/1/61-63	upper Sw	*Nq. mayeri* s.l.	75	9	16	0	91	9	100	9.0		
332.68	36/1/118-120	upper Sw	*Nq. mayeri* s.l.	58	10	30	2	88	12	100	12.0		
332.98	36/1/148-150	upper Sw	*Nq. mayeri* s.l.	101	9			101	9	110	8.2		
333.40	36/2/40-42	upper Sw	*Nq. mayeri* s.l.	235	60			235	60	295	20.3	???	???
334.00	36/2/100-102	upper Sw	*Nq. mayeri* s.l.	149	27			149	27	176	15.3		
334.36	36/2/136-138	upper Sw	*Nq. mayeri* s.l.	177	25			177	25	202	12.4		
334.87	36/3/37-39	upper Sw	*Nq. mayeri* s.l.	33	4	53	10	86	14	100	14.0		
335.47	36/3/97-99	upper Sw	*Nq. mayeri* s.l.	20	6	67	7	87	13	100	13.0		
335.88	36/3/138-140	upper Sw	*Nq. mayeri* s.l.	34	6	52	8	86	14	100	14.0		
336.20	36/4/20-22	upper Sw	*Nq. mayeri* s.l.	30	6	58	6	88	12	100	12.0		
336.60	36/4/60-62	upper Sw	*Nq. mayeri* s.l.	35	5	55	5	90	10	100	10.0		

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Bolboforma as monitors of Cenozoic palaeoceanographic changes in the Southern Ocean

Penelope J. Cooke[a,*], Campbell S. Nelson[a], Martin P. Crundwell[a], Dorothee Spiegler[b]

[a] *Department of Earth Sciences, University of Waikato, Private Bag 3105, Hamilton, New Zealand*
[b] *GEOMAR, Wischofstraße 1–3, 24148 Kiel, Germany*

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Abstract

Bolboform distribution in space and time is analysed from a circum-Antarctic belt of lower Eocene to uppermost Miocene sediments from the Southwest Pacific, Southeast Pacific (Bellinghausen Basin), Maud Rise and South Atlantic, and Indian Ocean (Kerguelen Plateau) regions. A correlation panel using established Cenozoic planktic foraminiferal and calcareous nannofossil zones is linked to the *Bolboforma* zonation scheme for the Southern Ocean. Evolution of surface watermasses and their boundaries, the major oceanic fronts, are tracked using the microfossil distributions and general sediment characteristics, and are in turn linked to the *Bolboforma* distribution. Specifically, the migration of both the Antarctic Polar Front and the Subtropical Front northwards from continental Antarctica, starting in the earliest Oligocene and culminating in the late Miocene establishment of 'modern' conditions, links the bolboforms in the Southern Ocean with subantarctic watermass conditions between the equivalent of today's Subantarctic and Subtropical fronts. The occurrence of bolboforms in sediments including subtropical microfossil assemblages from north of the Subtropical Front, as in the Tasman Sea, is anomalous. We suggest that they were transported into this region by subsurface (intermediate depth) waters generated by subduction of subantarctic surface water at southern oceanic fronts. The distribution of bolboforms more widely outside the Southern Ocean may define the pathways of Southern Component Intermediate Water (Antarctic Intermediate Water) during the Tertiary, and may account for their bipolar distribution. Bolboforms exhibit a circum-Antarctic distribution prior to the development of a full circum-Antarctic circulation system following the opening of the Tasmanian and Drake gateways. It is inferred that a West Antarctic Seaway between the Ross Sea and Weddell Sea embayments may have afforded oceanic connection between the Southwest Pacific and the southern Atlantic during the Eocene–Oligocene, facilitating dispersal and such a distribution.
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Keywords: bolboforms; *Bolboforma*; Southern Ocean; Cenozoic; palaeoceanography; biostratigraphy

1. Introduction

In the course of documenting Tertiary benthic foraminifera from DSDP Hole 593 (Leg 90) in the southern Tasman Sea, Southwest Pacific, Boersma

* Corresponding author.
E-mail address: p.cooke@waikato.ac.nz (P.J. Cooke).

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(1986) mentioned the presence of radiolarians in the late Miocene section of core and used their occurrence to infer palaeoceanographic changes in Tasman Sea. In contrast, radiolarians were not reported by Caulet (1986) in his general overview of this microfossil group from Leg 90 sites. During our current high-resolution study of upper Miocene microfaunal assemblages from Hole 593, acid dissolution showed that the radiolarians noted by Boersma (1986) were in fact calcareous, not siliceous, and subsequently a radiolarian specialist confirmed we were not dealing with radiolarians (C. Hollis, 1997, personal communication). While viewing SEM images of these 'problematic' microfossils, A. Edwards (1997, personal communication) suggested that they appeared to be *Bolboforma*, an identification subsequently confirmed by D. Spiegler, a bolboform specialist. Misidentification of this group of calcareous microfossils may be applicable to other micropalaeontological studies where, due to their simple form, size, and often highly ornamented tests, bolboforms can be mistakenly identified as *Lagena*, a simple unilocular benthic foraminifer (Spiegler and von Daniels, 1991). The first descriptions of *Bolboforma costairregularis* (Toering and van Voorthuysen, 1973), *B. metzmacheri* (Clodius, 1922), and *B. pisiformis* (Margerel, 1968) were all under the benthic foraminiferal name *Lagena*.

1.1. Nature of bolboforms

Bolboforma was introduced by von Daniels and Spiegler (1974) as a genus of *Incertae sedis* belonging to a group of problematic marine protozoans, although the subsequent finding of encapsulated tests suggested a close affinity with marine protophytes (Spiegler, 1987). Bolboforms probably represent dormant protophyte cysts formed after the vegetative life phase (Spiegler and Erlenkeuser, 2001). However, Kennett and Kennett (1990) questioned why marine phytoplankton would produce resting cysts as part of their life cycle, which then sink to depths of over 2000 m in the open ocean, out of the photic zone. Hence the classification of this group remains uncertain. To date they have only been found in marine sediments (Table 1).

Bolboform tests generally consist of hollow, single spheroidal or subspheroidal chambers composed of monocrystalline low-Mg calcite (von Daniels and Spiegler, 1974). They have a simple aperture surrounded by a short neck or collar. Surface morphology ranges from smooth to highly ornamented, with spines, knobs, reticulations, ribs, ridges, and flanges. Several bolboform species are known to encapsulate a smaller chamber within the exterior test. Test sizes range from 70 to 250 μm, although most specimens are <150 μm. Most studies have used the >63 μm fraction to check for bolboforms (Kennett and Kennett, 1990; Spiegler, 1991; Mackensen and Spiegler, 1992; Grützmacher, 1993; Crundwell et al., 1997).

1.2. Global occurrence of bolboforms

Globally, the bolboform age distribution extends from early Eocene to late Pliocene. In the Southern Ocean region the distribution is from the early Eocene (ca 53 Ma) on Campbell Plateau (Grützmacher, 1993; Berggren et al., 1995) and the middle Eocene (ca 46–44 Ma) on Maud Rise (Kennett and Kennett, 1990; Spiegler, 1991) to the early Pliocene (ca 3.9 Ma) on Kerguelen Plateau (Mackensen and Spiegler, 1992). In the North Atlantic the youngest record was also early Pliocene (Poag and Karowe, 1986; Qvale and Spiegler, 1989) until a recent find at 2.84 Ma by Spiegler (1999) from Hatton–Rockall Basin. Bolboforms have not been recorded in Quaternary sediments anywhere to date. The greatest diversity and number of species occur during two time intervals, namely the late Eocene to early Oligocene, and in the middle to late Miocene (Kennett and Kennett, 1990; Spiegler and von Daniels, 1991; Mackensen and Spiegler, 1992; Grützmacher, 1993; Crundwell et al., 1997). Their distribution appears to be broadly bipolar and they occur most commonly in sediments interpreted to have originated in cool waters at mid to higher latitudes (Poag and Karowe, 1986; Spiegler and von Daniels, 1991; Crundwell et al., 1997). They appear resistant to dissolution and exhibit good preservation in sediments where planktic foraminifera otherwise indicate damage due to corrosive bottom waters (Müller et al., 1985).

Table 1
Sources of bolboform information referred to in this study

Bolboform studies	References
General introduction	Spiegler and von Daniels (1991)
South Pacific	Rögl and Hochuli (1976), Poag and Karowe (1986), Grützmacher (1993) and Crundwell et al. (1997)
South Atlantic	Kennett and Kennett (1990) and Spiegler (1991)
Southern Indian Ocean	Mackensen and Spiegler (1992)
North Atlantic/Mediterranean	Murray (1984, 1987), Müller et al. (1985), Spiegler (1987), Qvale and Spiegler (1989) and Spezzaferri et al. (2001)
Northern Europe	von Daniels and Spiegler (1974) and Spiegler and Erlenkeuser (2001)

1.3. Aim of this study

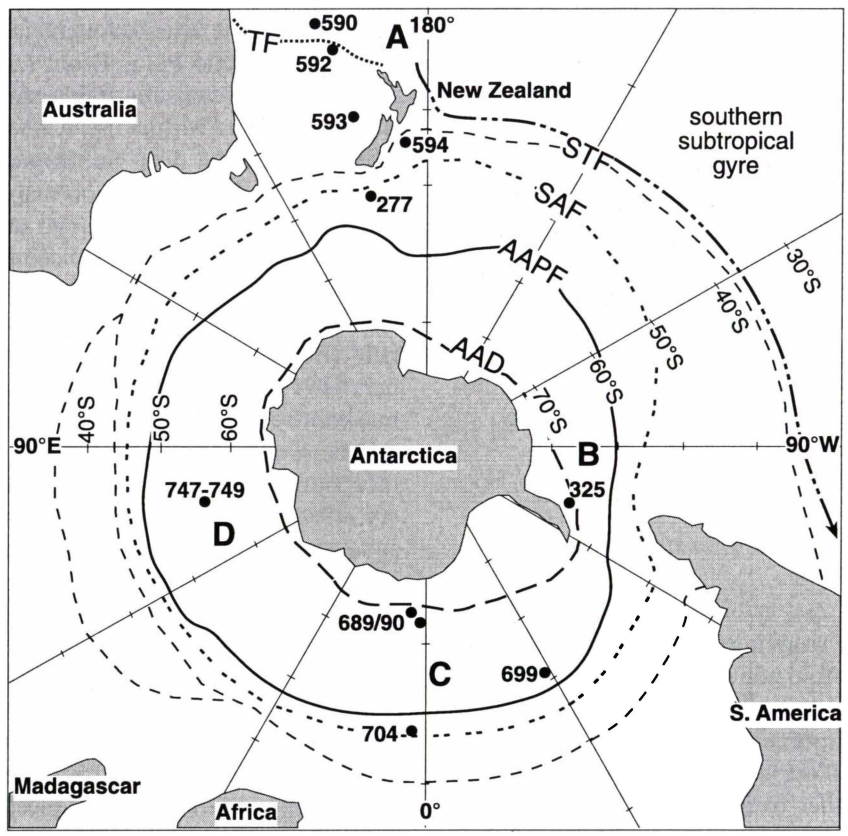
The catalyst for studying the bolboforms at Site 593 has been two-fold: one, to ascertain their potential for improving biostratigraphic subdivision within the late Miocene of the Southwest Pacific region (Crundwell et al., 1997; Crundwell, in prep.), and the other to attempt to better understand the palaeoceanographic significance of the bolboform distributions in the deposits, which is addressed here. Some previous studies at Southwest Pacific sites (e.g. Poag and Karowe, 1986; Grützmacher, 1993) have suggested an ecological preference of bolboforms for cool subtropical or temperate conditions. However, their occurrence in middle to late Miocene sediments at subantarctic Site 594 southeast of New Zealand necessitates reconsideration of their palaeoenvironmental implications. Here we explore the possibility that the circum-Antarctic distribution of *Bolboforma* is linked to the Cenozoic development of Southern Ocean palaeoceanography, and specifically to the evolution and migration of oceanic fronts that bound the subantarctic watermass.

2. Modern watermasses and oceanic fronts

In the modern Southern Ocean, surface watermasses are divided by oceanic fronts and underlain by characteristic sediment facies (Figs. 1 and 2). The Antarctic Polar Front (AAPF) forms the boundary between subantarctic and antarctic conditions and lies within the Antarctic Polar Front Zone (AAPFZ). The Subtropical Front (STF) separates surface waters of tropical origin from those of antarctic origin. The AAPFZ supports high surface-water biosiliceous productivity, which is reflected in the mainly diatomaceous siliceous sediments beneath it, the so-called 'diatom belt' (Burckle and Cirilli, 1987; Westall and Fenner, 1991). The northern boundary of this zone, marked by the Subantarctic Front (SAF; Belkin and Gordon, 1996), corresponds with the 8°C surface isotherm (Burling, 1961; Edwards and Emery, 1982) and divides the watermasses into cool subantarctic surface water (Circumpolar Surface Water – CSW) south of the SAF, and warm subantarctic surface water (Subantarctic Surface Water – SASW) between the SAF and the STF (Edwards and Emery, 1982; Heath, 1985).

South of the diatom belt and AAPFZ, winter sea-ice restricts phytoplankton productivity except during spring sea-ice meltback when reduced surface-water salinities allow upwelling to resume, increasing nutrient supply and instigating limited diatom productivity (Burckle and Cirilli, 1987). North of the SAF and the diatom belt, the sediments are higher in biogenic carbonate (Fig. 2). The boundary between subantarctic and subtropical surface waters occurs along the STF marked by the 15°C summer/10°C winter isotherm (Chiswell, 1994). The temperate surface watermass north of the STF is referred to as Cool Subtropical Water, and is separated from Warm Subtropical Water by the Tasman Front at the 20°C summer isotherm (Fig. 2).

In the modern Southern Ocean, subduction of surface waters at the AAPF and SAF forms the Antarctic Intermediate Water (AAIW) and Subantarctic Mode Water (SAMW), respectively, whose physical properties are noted in Fig. 2. Cenozoic precursors of the AAIW and SAMW have been named the Southern Component Intermediate Water (SCIW) and Southern Component Mode Water (SCMW) (e.g. Wright and Miller, 1993)



Region	Location	Leg	Sites
A	Southwest Pacific	90	590, 592-594
	Campbell Plateau	29	277
B	Bellinghausen Basin	35	325
C	Maud Rise	113	689, 690
	South Atlantic	114	699, 704
D	Kerguelen Plateau	120	747-749

Fig. 1. Modern ODP/DSDP site locations where bolboforms have been recorded in relation to modern Southern Ocean frontal positions. Physical oceanography after: Gordon et al. (1978), Tomczak and Godfrey (1994), Stramma et al. (1995), and Belkin and Gordon (1996). Bolboform distribution: Region A, Southwest Pacific (Poag and Karowe, 1986; Grützmacher, 1993; Crundwell et al., 1997); Region B, Bellinghausen Basin (Rögl and Hochuli, 1976); Region C, Maud Rise (Kennett and Kennett, 1990) and South Atlantic (Spiegler, 1991, unpublished data); Region D, Central Kerguelen Plateau (Mackensen and Spiegler, 1992). TF = Tasman Front; STF = Subtropical Front; SAF = Subantarctic Front; AAPF = Antarctic Polar Front; AAD = Antarctic Divergence.

2.1. *Recognising palaeofront positions*

As the oceanic fronts are surface-watermass features, an attempt is made here to reconstruct broad palaeoceanographic conditions in the Southern Ocean during the Eocene to Pliocene by correlating microfossil assemblages with inferred palaeopositions of the fronts based partic-

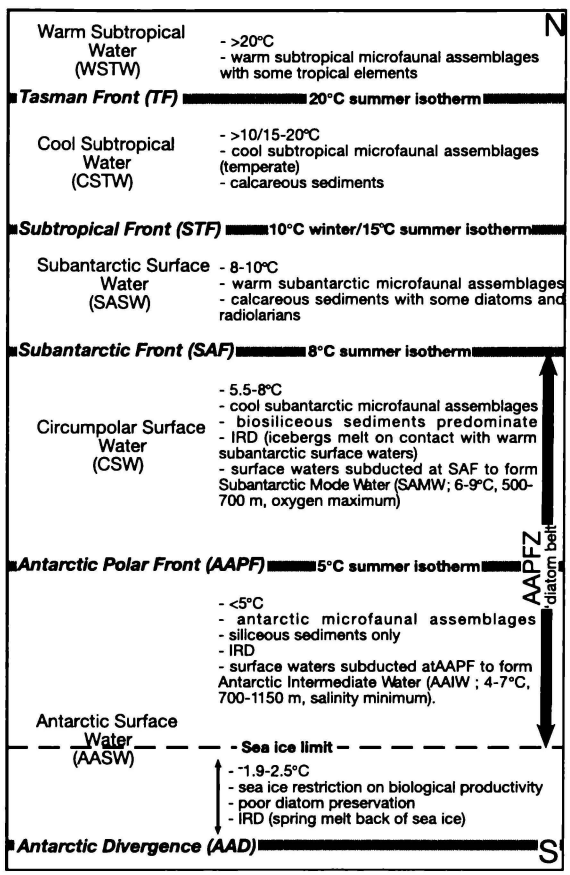


Fig. 2. Modern oceanic fronts and associated physical oceanographic features of the Tasman Sea and Southwest Pacific (after Wyrtki, 1962; Garner, 1962, 1967; Garner and Ridgway, 1965; Neil, 1997), and the associated sedimentological and micropalaeontological characteristics of the underlying sediments (after Burns and Andrews, 1973; Nelson, 1986). AAPFZ = Antarctic Polar Front Zone.

ularly on the nature of underlying sediments at sites (Fig. 2). The use of sediment proxies for inferring palaeofront positions has been attempted by several workers (e.g. Kennett, 1977; Wise et al., 1992), and most recently for the New Zealand sector of the Southern Ocean by Nelson and Cooke (2001); see Table 3. By way of example, Westall and Fenner (1991) interpreted the late Neogene sediment record from Hole 704B in the South Atlantic (Fig. 1). The occurrence of diatom ooze was taken to indicate the AAPFZ over the site; mixed siliceous–carbonate sediments were linked to the southward migration of SAF across the site; and calcareous ooze with poorly preserved diatoms equated with the site being bathed by subantarctic surface waters north of the SAF, with the AAPFZ well to the south.

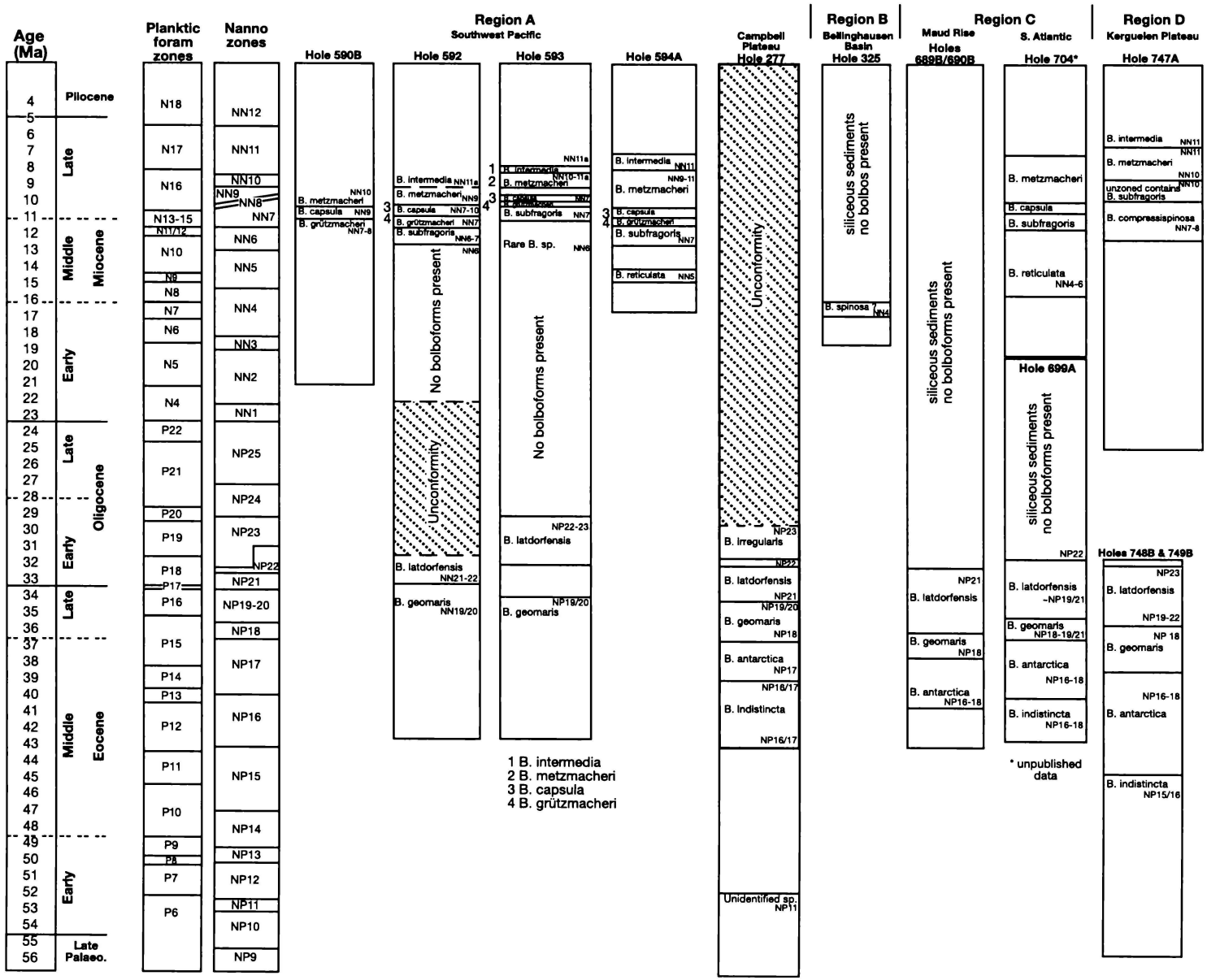
Additionally, in the modern ocean the combination of ice-rafted debris (IRD) found associated with poorly preserved siliceous sediments occurs south of the AAPFZ. This is linked to sea-ice restricting phytoplankton production in surface waters during the winter, and spring meltback of the ice resulting in deposition of IRD (Cooke and Hayes, 1982; Burckle and Cirilli, 1987). The IRD associated with the northern edge of the AAPFZ results from small icebergs melting on contact with warmer subantarctic surface waters in the vicinity of the SAF (Westall and Fenner, 1991).

Also, the microfossil assemblages themselves can be useful for suggesting relative surface-water temperatures. Thus, for example, temperate diatoms are usually found north of the STF (Froelich et al., 1991); radiolarian species can distin-

Table 2
Modern Southern Ocean site locations and watermass conditions where bolboforms have been reported in cored sediments

Region	Geographic location	DSDP/ODP Leg	Holes	Grid reference	Water depth (mbsf)	Bottom w/mass	Surface w/mass
A	Southwest Pacific	90	590B, 592, 593, 594A	31–45°S,163–174°E	1068–1299	AAIW	CSTW
	Campbell Plateau	29	277	52°S, 166°E	1232	AAIW	SASW
B	Bellinghausen Basin	35	325	65°S, 73°W	3745	CPDW	?AASW
C	Maud Rise	113	689B, 690B	64–65°S, 0–3°E	2080–2914	CPDW	CSW
	South Atlantic	114	699A, 704B	46–51°S, 30°W–7°E	1800–3700	CPDW	CSW
D	Kerguelen Plateau	120	747A, 748B, 749B, (737A)	54–58°S, 76–81°E	1070–2030	AAIW/ CPDW	AASW

AAIW = Antarctic Intermediate Water, CSTW = Cool Subtropical Water, SASW = Subantarctic Surface Water, CSW = Circumpolar Surface Water, CPDW = Circumpolar Deep Water, AASW = Antarctic Surface Water, mbsf = metres below sea floor.


Age (Ma)
Planktic foram zones
Nanno zones
Region A
Southwest Pacific
Region B
Region C
Region D
Hole 590B
Hole 592
Hole 593
Hole 594A
Campbell Plateau Hole 277
Bellinghausen Basin Hole 325
Maud Rise Holes 689B/690B
S. Atlantic Hole 704*
Kerguelen Plateau Hole 747A
Holes 748B & 749B
Hole 699A
Pliocene
Late Miocene
Middle Miocene
Early Miocene
Late Oligocene
Early Oligocene
Late Eocene
Middle Eocene
Early Eocene
Late Palaeo.
No bolboforms present
Unconformity
siliceous sediments no bolbos present
siliceous sediments no bolboforms present
1 B. intermedia
2 B. metzmacheri
3 B. capsula
4 B. grützmacheri
* unpublished data

guish antarctic versus subantarctic surface waters (Lazarus and Caulet, 1993); and planktic foraminifera can be used to distinguish between warm and cool subtropical surface waters (Kennett and Srinivasan, 1983; Jenkins and Srinivasan, 1986).

3. Southern Ocean bolboform distribution

Bolboforma species have been reported from only four regions around the Antarctic continent (Fig. 1; Table 2).

3.1. Region A – Southwest Pacific (Fig. 1)

Sites comprise a transect down the Tasman Sea west of New Zealand, north of the modern STF, to the southwest Pacific Ocean south and east of New Zealand where sites are south of the STF (Site 594) or the SAF (Site 277).

3.2. Region B – Bellinghausen Basin (Fig. 1)

Bellinghausen Basin is west of the Antarctic Peninsula in the Southeast Pacific Basin, and Site 325 sits south of the modern Antarctic Divergence (AAD).

3.3. Region C – Maud Rise and South Atlantic (Fig. 1)

Maud Rise localities (Sites 689 and 690), near the Weddell Sea, are located just north of the AAD, well south of the AAPF, and lie within the Weddell Polynya, which remains ice-free during many winter seasons, resulting in higher annual bioproductivity compared with other parts of the Weddell Sea (Leg 113 Shipboard Scientific Party, 1988a,b). In addition, the South Atlantic sites located north of Maud Rise straddle the modern AAPF, with Sites 703 and 704 north of this front and Sites 699–702 south of it (Allen and Warnke, 1991). Sites 704 and 699, respectively, are taken as representative of these South Atlantic locations in this account. Note that in the South Atlantic the tectonic configuration allows the modern AAPF to sit a lot further north (at 50–55°S) than in the South Pacific region (ca 60°S; Belkin and Gordon, 1996).

3.4. Region D – Central Kerguelen Plateau (Fig. 1)

Sites on Central Kerguelen Plateau are all located south of the AAPF (Schlich and Wise, 1992). Although all the principal Southern Ocean fronts (STF, SAF, and AAPF) are present in the southern Indian Ocean, they are compressed to within ca 5° latitude due to deflection of the AAPF north of Kerguelen Island (Belkin and Gordon, 1996), which has the potential to complicate palaeoceanographic reconstructions.

4. Bolboform biostratigraphy

Established regional planktic foraminiferal and calcareous nannofossil zonation schemes have been used to provide a time frame for the Southern Ocean bolboform biostratigraphy (Fig. 3), which differs only slightly from that established for the North Atlantic (Spiegler, 1987; Spiegler and von Daniels, 1991). A feature of the southern hemisphere scheme is the lack of bolboforms in sediments dated between the late Oligocene to latest early Miocene. The one exception is in Hole 325, Bellinghausen Basin, where they occur in the NN4 Zone in one sample only (Rögl and Hochuli, 1976), most likely related to the coring regime and sampling density. Absence of bolboforms from Southern Ocean sediments of this age is in contrast to the northern hemisphere, where they are found at various localities, but mostly in minor quantities (e.g. Müller et al., 1985; Spiegler and von Daniels, 1991). Where necessary, absolute ages reported here have been updated using

Fig. 3. Southern Ocean *Bolboforma* biostratigraphy correlated with calcareous nannofossil and planktic foraminiferal biostratigraphy for the region (after Rögl and Hochuli, 1976; Kennett and Kennett, 1990; Spiegler, 1991, unpublished data; Mackensen and Spiegler, 1992; Grützmacher, 1993; Berggren et al., 1995; Crundwell et al., 1997).

the geopolarity time scale of Berggren et al. (1995).

4.1. Bolboform zonation scheme

4.1.1. Region A (Southwest Pacific Sites 590, 592–594, and 277)

Three holes at Site 588 in the northern Tasman Sea, north of Site 590, were checked by Grützmacher (1993) for bolboforms, but none were found. The oldest sediments cored in Hole 590 are lower Miocene (Kennett and von der Borch, 1986b), but bolboforms occur only in upper Miocene sediments (Fig. 3), and then in very small numbers compared with other sites.

Holes 592 and 593 contain upper Eocene to lower Oligocene and upper Miocene bolboforms (Grützmacher, 1993), with the oldest sediments in the cores being middle Eocene (Kennett and von der Borch, 1986a). The upper Miocene low-resolution bolboform record at Hole 593 (Grützmacher, 1993) has been amended by a high-resolution study by Crundwell et al. (1997), with bolboforms recorded across Cores 36–26 (Fig. 3). Boersma (1986) reported radiolarians (= bolboforms, see Section 1) in Cores 39–37, but our subsequent checking of a higher-resolution suite of samples from these cores indicates that bolboforms are only present in Cores 40 and 36 (Elkington, 2000), as also reported by Grützmacher (1993).

In Hole 594 the oldest cored sediments are late early Miocene (Kennett and von der Borch, 1986b) and this hole contains the largest numbers of bolboforms of any of the Leg 90 sites (Grützmacher, 1993). Hole 594 contains a record of subantarctic microfossils and has done so since the late middle Miocene, coincident with the presence of bolboforms. At ca 8 Ma the radiolarian assemblage in this hole becomes entirely subantarctic/antarctic (Leg 90 Shipboard Scientific Party, 1986b) and the bolboforms disappear (Grützmacher, 1993).

Campbell Plateau Hole 277 contains the oldest bolboform record to date in the southern hemisphere, with specimens reported in lower Eocene (ca 53 Ma) sediments (Leg 29 Shipboard Scientific Party, 1975; Grützmacher, 1993). *Bolboforma* distribution (Fig. 3) extends to the upper Eocene to lower Oligocene *B. latdorfensis* Zone after which there is a barren section followed by the lower Oligocene *B. irregularis* Zone at ca 30 Ma (Grützmacher, 1993). Above this interval there is a major unconformity between the late early Oligocene and late Pliocene, with the Pliocene represented by only the top 4 m of core (Leg 29 Shipboard Scientific Party, 1975), and so the bolboform record is likely to be incomplete.

4.1.2. Region B (Bellinghausen Basin Site 325)

Core recovery from Hole 325 was limited (Leg 35 Shipboard Scientific Party, 1976) and age determinations often difficult. The oldest cored sediments contain the planktic foraminifera *Globorotalia zealandica incognita* marking the upper lower Miocene Zones N6 to early N7 (Rögl, 1976) with an age of ca 18.8–16.4 Ma. Bolboforms were recovered ca 90 m above the oldest sediments and are therefore younger than 18.8 Ma (Fig. 3). Sediments above the bolboforms were dated as N7 (Leg 35 Shipboard Scientific Party, 1976; Weaver et al., 1976), which suggests the bolboforms are no younger than 16.4 Ma. The low carbonate content and the dominance of arenaceous and deep-water calcareous benthic foraminifera are taken to indicate a depositional water depth of 2000–3000 m (Rögl and Hochuli, 1976). Poor preservation of calcite suggests the sediments were probably close to, or below, the CCD (Craddock and Hollister, 1976), which necessarily has implications for bolboform preservation.

4.1.3. Region C (Maud Rise Sites 689 and 690; South Atlantic Sites 699 and 704)

At Maud Rise sites *Bolboforma* are reported in middle Eocene to lower Oligocene sediments (Kennett and Kennett, 1990). The oldest sediments containing *Bolboforma* in the South Atlantic holes are middle Eocene to earliest Oligocene (Spiegler, 1991). Additionally, unpublished data (D. Spiegler) record bolboforms in upper Miocene sediments from Hole 704B.

4.1.4. Region D (Central Kerguelen Plateau Sites 747–749)

Bolboforms were recovered from all Leg 120

Table 3
Summary of timing of oceanic front development in the New Zealand sector of the Southern Ocean based on DSDP sites drilled during Legs 21, 29 and 90 (from Nelson and Cooke, 2001)

Time slices	Dominant sediments	Antarctic ice sheets	Surface currents[a]	Surface gateways	Oceanic fronts[b]
Paleocene 65–55 Ma	Calcareous	No	Warm (I–P)	Tasmanian closed Drake closed	None
Early–Middle Eocene 55–45 Ma	Calcareous	No	Warm (I–P)	Tasmanian closed Drake closed	None
Middle–Late Eocene 45–35 Ma	Calcareous	Mainly no, but growing	Warm (I–P)	Tasmanian closed Drake closed	None
Latest Eocene only	Terrigenous–siliceous Calcareous	Yes – East	Cool (Ant)	Tasmanian leaking West Antarctic open	Proto-STF
Oligocene 35–25 Ma	Terrigenous	Yes – East	Cold (Ant)	Tasmanian open	AAPF
	Calcareous–siliceous	No – West	Cool (Ant)	West Antarctic open	?Proto-SAF
	Calcareous		Warm (I–P)	Drake leaking–open	Proto-STF
Early–Middle Miocene 25–15 Ma	Terrigenous-siliceous	Yes – East	Cold (Ant)	Tasmanian open	AAPF
	Siliceous–calcareous	No – West	Cool (Ant)	West Antarctic closed	Proto-SAF
	Calcareous		Warm (I–P)	Drake open Indonesian restricted	Proto-STF
Middle–Late Miocene 15–5 Ma	Terrigenous–siliceous	Yes – East	Cold (Ant)	Tasmanian open	AAPF
	Siliceous–calcareous	Yes – West	Cool (Ant)	Drake open	SAF
	Calcareous		Warm (I–P)		STF
Pliocene–Present day 5–0 Ma	Terrigenous–siliceous	Yes – East	Cold (Ant)	Tasmanian open	AAPF
	Siliceous–calcareous	Yes – West	Cool (Ant)	Drake open	SAF
	Calcareous		Warm (I–P)		STF

[a] I–P = Indonesian–Pacific origin; Ant = Antarctic origin.
[b] AAPF = Antarctic Polar Front; Proto-SAF = Proto-Subantarctic Front; SAF = Subantarctic Front; Proto-STF = Proto-Subtropical Front; STF = Subtropical Front.

sites (747–751) on Central Kerguelen Plateau, but in only a few samples in Sites 750 and 751, which are not considered further. The oldest sediments containing bolboforms are middle Eocene (Holes 748B and 749B) and the youngest late Miocene (Hole 747A; Fig. 3) (Mackensen and Spiegler, 1992).

5. Occurrence of bolboforms in relation to other palaeoceanographic proxies

Elsewhere, Nelson and Cooke (2001) have presented a series of palaeoceanographic maps showing an inferred history of development of oceanic fronts in the New Zealand sector of the Southern Ocean based mainly on DSDP core data. A summary of that scheme is noted here in Table 3, and below we use it to continue to develop palaeoenvironmental interpretations at the study sites containing bolboforms using core sediment compositions, microfossil assemblage information, and isotopically derived marine palaeotemperatures.

5.1. Region A – Southwest Pacific

5.1.1. Palaeogene record

The late Eocene to Oligocene biostratigraphy of Southwest Pacific sites has been adjusted to account for recent changes in dates of events (Table 4). In Hole 277 rare early Eocene specimens of *Bolboforma* (Grützmacher, 1993) correspond to isotopically derived sea-surface palaeotempera-

Table 4
Biostratigraphic events used to update (after Berggren et al., 1995) the late Palaeogene isotope stratigraphy of Murphy and Kennett (1986) for Holes 592, 593, and 277 in region A

Age (Ma)		Biostratigraphic events	Sample Leg-Hole-Core, length (cm)	Depth (mbsf)
28.5		LCO *Chiloguembelina cubensis*	90-593-50, CC[a]	475.0
			90-593A-24, CC[a]	461.4
(29[b])		(hiatus starts at 4.5 mbsf)	277	4.5
30		LAD *Subbotina angiporoides*	29-277-9, CC[c]	83.0
			90-593-52, CC[a]	489.0
31.4	top NP22	(hiatus starts in NP22 youngest age)[d]	90-592-33-3, 90[e]	305.0
33.7	Eo/Olig boundary	LAD *Reticulofenestra oamaruensis*	90-592-35, CC[e]	330.9
			90-593-58-2, 110[e]	544.4
			29-277-20-4, 144[f]	184.0
35.40		FAD *Reticulofenestra oamaruensis*	90-592-37-4, 4[e]	345.0
			29-277-21, CC[f]	197.0
37.00	base NP18	FAD *Chiasmolithus oamaruensis*	90-592-40, CC[e]	379.0
			29-277-28, CC[f]	263.5

[a] Jenkins and Srinivasan (1986).
[b] LAD *C. cubensis* appears to be within an hiatus in Hole 277 (Murphy and Kennett, 1986).
[c] Jenkins (1975).
[d] Hiatus extends into NP22, therefore the maximum youngest age for the start of the hiatus in Hole 592 is the top of NP22 at 31.4 Ma (see Berggren et al., 1995).
[e] Martini (1986).
[f] Edwards and Perch-Nielsen (1975).

tures (SSPTs) of about 15°C (Shackleton and Kennett, 1975) (Fig. 4A). Bolboforms do not become common until the SSPTs drop to about 11°C in the upper Eocene section of the hole. Upper Eocene bolboforms are also present in Holes 592 and 593 (Grützmacher, 1993). The upper Eocene isotopically derived palaeotemperatures from all three sites are very similar, with Site 277 influenced by possibly slightly cooler surface waters. Indications are that the sites were bathed by the same surface and bottom watermasses with no significant thermal boundary or oceanic front between them (Murphy and Kennett, 1986) (Fig. 4B). Hole 592 includes an uppermost Eocene to lower Miocene unconformity (Kennett and von der Borch, 1986b), so no further Palaeogene comparison of bolboforms and SSPTs is possible based on this site.

Thermal segregation between Sites 277 and 593 began in the latest Eocene (ca 36–34 Ma) with calculated SSPTs at both sites of about 11°C and bottom water palaeotemperatures (BWPTs) of about 7°C (Fig. 5), but with Hole 277 recording slightly more enriched $\delta^{18}O$ values in both planktic and benthic samples (Murphy and Kennett, 1986). After the earliest Oligocene cooling event the SSPTs in Hole 277 decrease to about 8°C and in Hole 593 to about 9°C. This cooling of SSPTs in Hole 277 corresponds with the greatest abundance of bolboforms at the site (Grützmacher, 1993). During the early Oligocene the temperature gradient between the sites increased further, with SSPTs decreasing to 5–7°C in Hole 277, where bolboforms are present, and within the range 8–10°C in Hole 593, where bolboforms are absent. During the late Oligocene, SSPTs in Hole 593 increased to >10°C (Fig. 5). Hole 277 SSPTs are within the range of modern SASW (Fig. 2), suggesting a proto-STF migrated northward over the site in the early Oligocene (Fig. 4C) allowing cooler watermasses to reach the site (Nelson, 1996). Hole 593 SSPTs of >10°C are within the modern winter range of the Cool Subtropical Water (CSTW) north of the STF. The increase in SST in Hole 593 samples coincides with the disappearance of bolboforms (Fig. 4D), at least until the late Miocene. Sites 592 and 593 are considered to have remained at similar mid-bathyal water depths throughout this time (Kennett and von der Borch, 1986b), so dissolution is not con-

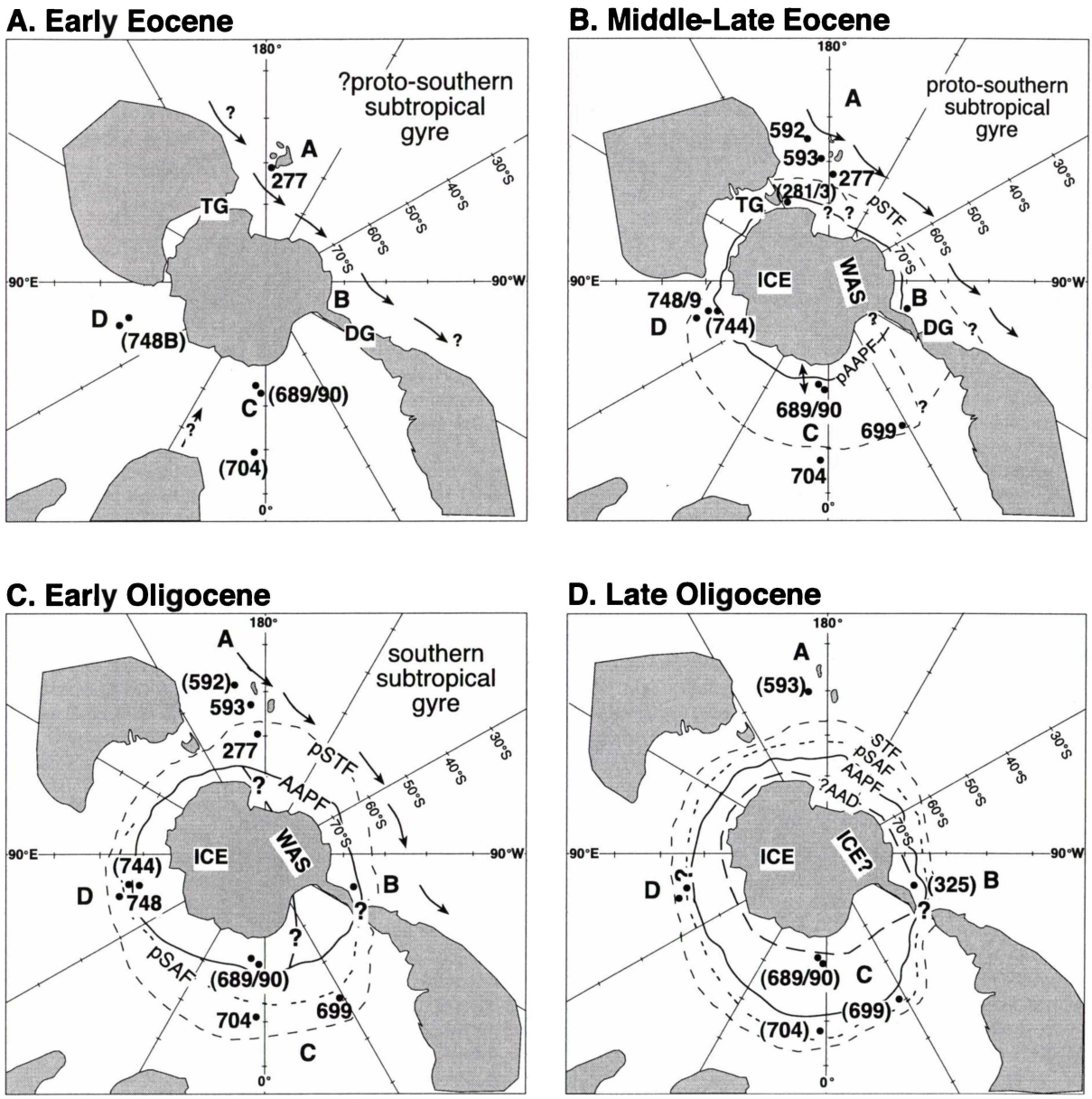


Fig. 4 (A–D) (*Continued overleaf*).

sidered to have been a factor in the disappearance of the bolboforms.

Prior to opening of the Tasmanian gateway between the South Tasman Rise and Antarctica near the Eocene–Oligocene boundary (Table 3), warm subtropical surface waters originating from the South Pacific gyre flowed southward through the Tasman Sea to south of the New Zealand landmass and eastwards off the coast of Antarctica (Kamp, 1986; Buening et al., 1998), as evident in the early Eocene warm SSPTs from Hole 277 (Shackleton and Kennett, 1975). Following opening of the Tasmanian gateway, cool surface waters from the southern Indian Ocean flowed into the Southwest Pacific and the SSPTs began to decrease (Murphy and Kennett, 1986;

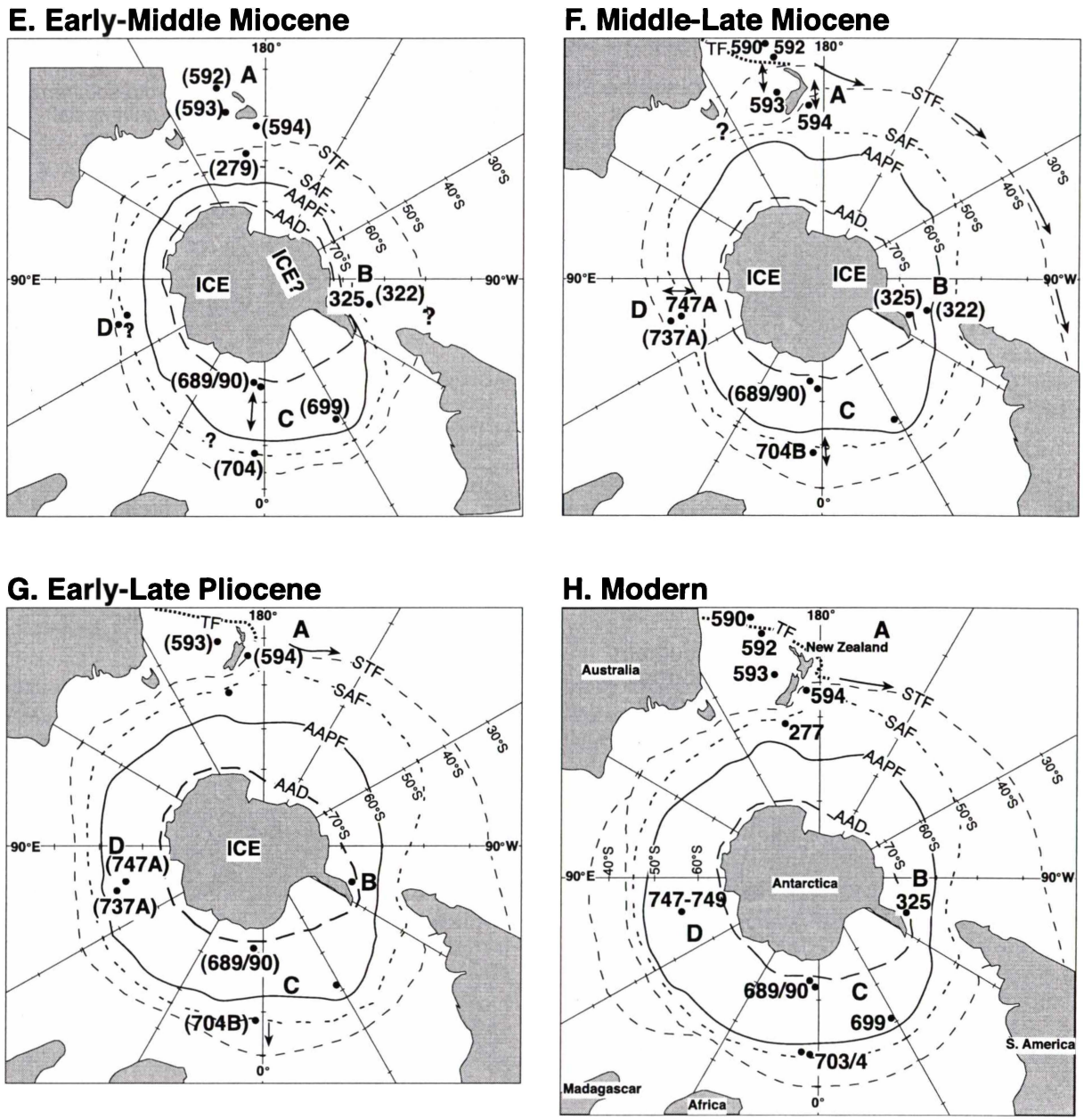


Fig. 4 (E–H).

Jenkins, 1993a; Buening et al., 1998). This probably resulted in a decoupling of the ocean circulation system (Kennett, 1977; Kamp et al., 1990) with separation of the subtropical gyre and west wind drift along a proto-STF. Unconformities recorded in Holes 588 (middle Eocene to upper Oligocene), 592 (upper Eocene to lower Miocene), and 277 (post-early Oligocene) have been inferred to relate to vigorous flows initiated by the opening of this gateway (Kennett and von der Borch, 1986b). This regional unconformity is not recorded in Hole 593, as it appears that the invigo-

rated bottom current circulation in the Tasman Sea did not extend as far east as this site (Nelson, 1986).

Breaching of the Tasmanian gateway may have established a proto-Antarctic circumpolar current with flow directed through a possible West Antarctic Seaway (WAS; Figs. 4B,C and 6) within the West Antarctic Rift system (Lawver and Gahagan, 1998; Cande et al., 2000). Cooling of surface waters in the region may be linked to such an early circum-Antarctic system (e.g. Nelson and Cooke, 2001).

Fig. 4. Schematic palaeogeographic/palaeoceanographic maps for the Southern Ocean at different times during the Cenozoic, emphasising changing and developing Southern Ocean frontal structures. Plate configurations follow Lawver et al. (1992), and the New Zealand outline King (2000). Ocean fronts are: AAD = Antarctic Divergence; (p)AAPF = (proto)Antarctic Polar Front; (p)SAF = (proto)Subantarctic Front; (p)STF = (proto)Subtropical Front. Region A, Southwest Pacific; region B, Bellinghausen Basin; region C, Maud Rise/South Atlantic; region D, Kerguelen Plateau (see Fig. 1). Sites shown with numbers indicate bolboforms present at that age; site numbers shown in brackets provide other sedimentological or microfossil indications of palaeoenvironmental conditions at that age. Note changing ice budget on East and West Antarctica. WAS = West Antarctic seaway; TG = Tasmanian gateway; DG = Drake gateway. (A) Early Eocene (from ca 53 Ma) – Bolboforms only present in Hole 277 where warm sea-surface palaeotemperatures are taken to indicate subtropical surface waters arriving via a proto-subtropical gyre (Kamp, 1986; Buening et al., 1998). Tasmanian and Drake gateways both closed. (B) Mid–late Eocene (from 42 Ma) – Bolboforms present in Holes 277, 593, 592, 699B, 689B, 690, 748B, and 749B. A thermal boundary is inferred between Sites 277 and 281/283 on South Tasman Rise (Nelson and Cooke, 2001). In South Atlantic holes, planktic foraminiferal diversity increases and indicates Sites 703/704 are warmer than Site 699 (Nocchi et al., 1991). In Kerguelen Plateau sediments, appearance of IRD (implying sea ice and AAPF formation) coincides with a shift in $\delta^{18}O$ to heavier values during the late Eocene/early Oligocene (Zachos et al., 1992). Drake gateway (DG) is closed and Tasmanian gateway (TG) has very restricted opening to surface flow only. If a West Antarctic seaway (WAS) existed prior to opening of the Drake gateway (e.g. Wise et al., 1991; Cande et al., 2000) then surface waters may have passed through it to produce a proto-circum-Antarctic current, if only extending to relatively shallow depths (Nelson and Cooke, 2001). (C) Early Oligocene (from 33.7 Ma) – Bolboforms present in Holes 277, 593, 699, 704 and in Hole 748B only in the very early Oligocene. In Hole 277 an uppermost Oligocene unconformity limits comparisons. An early Oligocene SSPT difference between Sites 592/593 and 277 suggests the presence of a front between them (Murphy and Kennett, 1986). At Maud Rise the high siliceous component of sediments (O'Connell, 1990) suggests sites were south of the AAPF. In Hole 748B bolboforms disappear (Mackensen, 1992) as IRD appears in sediments (Allen and Warnke, 1991; Breza and Wise, 1992). Tasmanian gateway open to surface flow (Jenkins, 1993a) and West Antarctic seaway (WAS) possibly open (Cande et al., 2000; Nelson and Cooke, 2001). Front migrations between South Atlantic Sites 699 and 704; when proto-STF is north of Site 704 bolboforms are present at that locality, and when proto-SAF is south of Site 699, bolboforms are present there. (D) Late Oligocene (from 28.5 to 23.8 Ma) – Bolboforms are not reported from any sites at this time. Microfaunal assemblage evidence suggests that Maud Rise was south of the AAPF (Leg 113 Shipboard Scientific Party, 1988a,b) and that South Atlantic sites were very close to the AAPFZ, with absence of IRD suggesting the AAPF was south of these sites. Site 593 was north of the STF (this front may link to gyre circulation) and Site 325 was south of the AAPFZ. Unsure of site position in relation to fronts at Kerguelen Plateau. Tasman gateway is fully open and Drake gateway is beginning to open (Lawver et al., 1992; Jenkins, 1993b). Modelling of Southern Ocean circulation suggests that Antarctic Divergence development is dependent on flow through, and the sill depth of, the Drake gateway (Gill and Bryan, 1971), so this front could date from near this time. (E) Early–middle Miocene (from 23.8 Ma) – Bolboforms are only present in Hole 325. SSPTs are ca 7–10°C in Hole 279A (near Hole 277) (Shackleton and Kennett, 1975). In Bellinghausen Basin, Site 322 (north of 325) is used to monitor sediment changes as the SAF migrates over both sites: SAF migration northwards over Site 322 is indicated by IRD in sediments and abundant diatoms in Hole 325. IRD is present in Hole 699A (Allen and Warnke, 1991), and so the site is inferred to lie south of the SAF and probably the AAPF. (F) Middle–late Miocene (from ca 16 Ma) – Bolboforms present in Holes 590B, 592-594A, 704B (unpublished), and 747A. Landmass configuration of New Zealand at this time may have resulted in two branches of the STF (like the modern Indian Ocean, see Belkin and Gordon, 1996), or initiation of the Tasman Front (see Fig. 1). Sedimentological changes at Kerguelen Plateau sites suggest major front migrations: in Hole 737A (north of Hole 747A) the change from upper Oligocene nannochalk to mid Miocene nanno/diatom ooze to upper Miocene (ca 6.3 Ma) subantarctic diatom ooze (Zachos et al., 1992) is inferred to reflect northward migration of the SAF. During the uppermost Miocene–earliest Pliocene (ca 5.8 Ma) Hole 737A sediments contain temperate water diatoms, and Hole 747A sediments consist of foraminifera- and diatom-bearing nanno-ooze with bolboforms (Mackensen, 1992; Zachos et al., 1992), inferred to indicate southward migration of the SAF over the site. (G) Early–late Pliocene (from ca 5 Ma) – No bolboforms reported from any sites. The presence of IRD and foraminifera-bearing diatom ooze in Holes 737A and 747A (Baldauf and Barron, 1991; Bohrmann and Ehrmann, 1991) is inferred to indicate northward migration of the SAF and AAPF over these sites. (H) Modern (see Fig. 1).

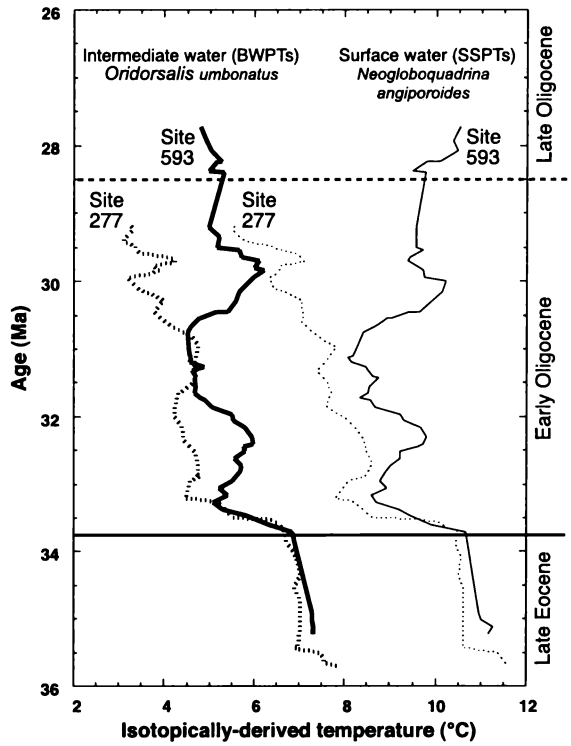


Fig. 5. Isotopically derived SSTs for Holes 277 and 593 (duplicates averaged, data smoothed and temperatures recalculated using Shackleton and Kennett (1975) for bottom waters and Zachos et al. (1994) for surface waters). Note that the planktic records for the two sites deviate after the earliest Oligocene cooling event, implying thermal separation by possibly the proto-STF (Fig. 4C) (after Keigwin and Shackleton, 1980; Murphy and Kennett, 1986; Berggren et al., 1995).

In Hole 592 a mainly poorly preserved, uppermost Eocene genuine radiolarian assemblage (*Cryptoprora ornata* Zone) with tropical affinities is reported in the core between ca 373 and 346 mbsf (Caulet, 1986). The radiolarians show reasonably good preservation from ca 373–371 mbsf, and the sediments also contain abundant tropical diatoms (Caulet, 1986) along with rare occurrences of bolboforms from the lower parts of the *B. geomaris* Zone (Grützmacher, 1993). However, from 371 to 346 mbsf preservation is very poor, consisting mainly of fragments (Caulet, 1986), and the number of bolboforms significantly increases (Grützmacher, 1993). As no Oligocene radiolarians are identified, the Eocene–Oligocene radiolarian boundary cannot be located in Hole 592, indicating deposition of radiolarians and other siliceous microfossils ceased prior to the Oligocene (Caulet, 1986). The well preserved tropical radiolarians and diatoms indicate that Site 592 was most likely located within southward-flowing tropical waters through the Tasman Sea (Caulet, 1986), probably driven by the proto-South Pacific gyre.

The complete absence of radiolarians in Hole 593 suggests this site was not bathed by such tropical waters, which could indicate the presence of a front between Sites 593 and 592. However, as the isotopically derived SSPTs indicate lack of a thermal gradient between these sites in the late Palaeogene (Murphy and Kennett, 1986), the presence both of tropical radiolarians and of bolboforms in Hole 592, but only bolboforms in Hole 593, may reflect watermasses entering the region from different directions, the radiolarians from the tropics and the bolboforms from the south, probably via a subsurface (possibly silica-dissolving) watermass (see later).

5.1.2. Neogene record

Bolboforms are not reported from Neogene sediments in Region A until the middle to late Miocene. As all of the Tasman Sea sites containing *Bolboforma* are currently north of the STF, a careful consideration of their palaeoposition in relation to this front is appropriate. The northernmost is Hole 590B, where there are only three bolboform zones (Fig. 3), and the bolboforms occur in much smaller numbers than at other sites to the south (Grützmacher, 1993). Site 590 appears to be the northernmost limit of their distribution in the region, as they are not found at Site 588 to the north (Grützmacher, 1993). Both planktic and benthic foraminiferal $\delta^{18}O$ records from Hole 590B exhibit significant cooling between calcareous nannofossil Zones NN7 to 9, with a large shift in the planktic $\delta^{18}O$ record of 0.7‰ (−0.92 to −0.21‰) corresponding with the top of Zone NN7 at ca 11 Ma (Kennett, 1986). This suggests surface waters over the site cooled rapidly by around 3°C and that the occurrence of *Bolboforma* is coincident with this shift. Subsequently to the cooling, both planktic and benthic foraminiferal $\delta^{18}O$ records exhibit significant

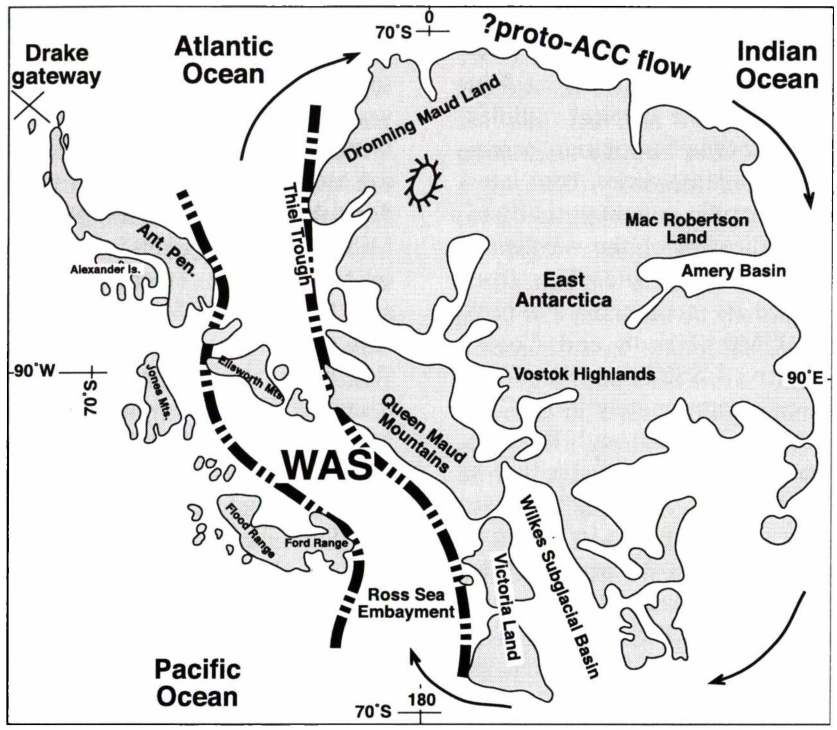


Fig. 6. Antarctic subglacial bedrock at 0 m elevation (Drewry, 1983) used to show possible West Antarctic Seaway (WAS) connecting the Pacific Ocean to the Indo/Atlantic Oceans at a time when Drake gateway was closed (see Cande et al., 2000; Nelson and Cooke, 2001). The WAS is inferred to have existed between the late Eocene to late Oligocene and may have accommodated circum-Antarctic flow prior to opening of the Drake gateway.

shifts of around 1–0.8‰ towards lighter, and therefore warmer, values (Kennett, 1986), and the bolboforms disappear. The site maintains isotopically derived SSPTs of 20–22°C for the rest of the Neogene section (Kennett, 1986) and bolboforms remain absent.

At Sites 592 and 593 surface-water conditions prior to the return of bolboforms at both sites are inferred to have been warm subtropical (Fig. 4E) based on the presence of the planktic foraminifer *Globorotalia peripheroronda*, which migrated from the tropics to reach these sites by ca 16 Ma (Jenkins and Srinivasan, 1986; Jenkins, 1993b). The disappearance of this species is associated with a steady decline in planktic foraminiferal diversity and inferred surface-water temperatures at both sites before the NN6/7 boundary at ca 11.8 Ma (Jenkins and Srinivasan, 1986; Jenkins, 1993b; Berggren et al., 1995). Gradual disappearance of the remaining warm subtropical planktic foraminifera from Hole 593, such as *Globigerinella aequilateralis*, *Globigerina nepenthes*, and *Menardella* sp., suggests partitioning of the Tasman Sea into a warm subtropical zone north of Site 593 and a cool subtropical zone to the south (Fig. 4F), as in the modern situation (Kennett and von der Borch, 1986b). The partitioning may mark establishment of the Tasman Front (Figs. 1 and 2). Alternation between the presence of bolboforms but an absence of warm subtropical planktic foraminifera, with the absence of bolboforms whenever warm subtropical planktic foraminifera are recorded, is taken to indicate alternating surface-water conditions over the site (Crundwell, in prep.). In addition, the final disappearance of the subtropical planktic foraminiferal signature and the bolboforms occurs at about the same sub-bottom depth at both Sites 593 and 592 (Crundwell, in prep.). This suggests further partitioning of surface watermasses to separate the

cooler, *Bolboforma*-containing waters from the subtropical waters.

The transition in Site 594, southeast of New Zealand, from middle Miocene tropical radiolarians, through a late Miocene radiolarian assemblage lacking warm-temperate species, to a latest Miocene to Pliocene antarctic–subantarctic-dominated assemblage is indicative of the northward migration of the STF over the site. This front appears to have reached its modern relative position by about ca 10 Ma (Nelson and Cooke, 2001). Isotopically derived SSPTs at Site 279A (close to Site 277) are approximately 7–10°C by the middle Miocene (Shackleton and Kennett, 1975), implying subantarctic surface water bathed the site (Fig. 4E).

The last occurrence of bolboforms in region A occurs within Zone NN11a (8.6–7.2 Ma) in Holes 594, 593, and 592 (Grützmacher, 1993; Berggren et al., 1995; Crundwell et al., 1997), and has been dated at ca 8 Ma in Hole 593 (Crundwell, in prep.) and Hole 594 (Grützmacher, 1993).

5.2. Region B – Bellinghausen Basin

5.2.1. Early Neogene record

The late early Miocene evidence for water temperature at this site comes from the sediment composition rather than from isotopically derived SSPTs, as used at other sites. The earliest IRD in Hole 325 is preceded in all cases by deposition of diatomaceous sediment, taken to indicate northward migration of the AAPFZ (Tucholke et al., 1976). The interspersing of very thin nannofossil claystone/chalk in Cores 325-8 and -7 with the diatomaceous sediments is associated with repeated migration of the SAF, the northern margin of the AAPFZ (Fig. 4E), over the site. Nannofossils in the claystones are a cold-water assemblage (Haq, 1976) linked to changes in surface-water conditions either by southward migration of AAPFZ over the site and/or local upwelling of carbonate-rich subsurface water (Tucholke et al., 1976). The earliest IRD occurs at ca 620 mbsf (Leg 35 Shipboard Scientific Party, 1976), with bolboforms reported at 615.3 mbsf from one of the thin nannofossil claystones (Rögl and Hochuli, 1976). Hence, when the SAF is located north of Hole 325, cold subantarctic surface water (equivalent to modern CSW) bathed the site and diatoms flourished. As the front migrated southward, warm subantarctic surface water (equivalent to modern SASW) bathed the site and high-latitude calcareous nannofossils and planktic foraminifera flourished, along with bolboforms. The late early Miocene (Zone N6–N7, 19–17 Ma) is a time of relative warmth around Antarctica (Shackleton and Kennett, 1975; Kennett, 1977), interspersed with several glacial events (e.g. Mi1b at ca 18 Ma; Wright et al., 1992). The appearance of bolboforms in Hole 325 may be linked to the southward migration of the AAPFZ during this warmer period (Kennett and Kennett, 1990) which ended just before Mi3 at ca 13.6 Ma (Wright et al., 1992). The cooling and expansion of the polar zone by the late Miocene is marked by IRD in Hole 322, north of Hole 325, signalling the arrival of the SAF (Tucholke et al., 1976). Hole 325 continues to record Antarctic assemblage diatoms above the claystones (Leg 35 Shipboard Scientific Party, 1976).

5.3. Region C – Maud Rise

5.3.1. Palaeogene and Neogene records

Isotopically derived SSPTs determined for Maud Rise sites indicate that surface waters were never colder than 8–9°C during the Palaeocene and early Eocene and reached maximum values of 15–18°C, suggesting Antarctic sea ice was not being formed (Stott et al., 1990). This temperature range (around 9–18°C) is very similar to the modern CSTW (Fig. 2), indicating the SSPTs at Maud Rise during the Palaeocene–Eocene were probably cool subtropical (Fig. 4A). By the early Eocene (ca 53 Ma) the SSPTs start to cool and the first occurrence of bolboforms in the middle Eocene (ca 44 Ma; Kennett and Kennett, 1990) coincides with significant surface-water cooling events between 52 and 36 Ma, reported by Stott et al. (1990). The largest numbers of *Bolboforma* occur in upper Eocene sediments which have taken on a polar character (Stott et al., 1990) and contain subantarctic radiolarians (Lazarus and Caulet, 1993), suggesting they lay south of a proto-STF (Fig. 4B). Large numbers of bolboforms

coincide with large numbers of radiolarians, which points to surface-water palaeoproductivity fluctuations, the bolboforms occurring in larger numbers when the surface waters were cooler and more nutrient-rich (Diester-Haass, 1992). Kennett and Kennett (1990) suggested that the last occurrence of bolboforms on Maud Rise is related to Southern Ocean surface waters becoming too cold for them, rather than due to their extinction.

Fluctuations between siliceous and calcareous sedimentation were established by late Eocene, inferred to reflect cyclical migration of a proto-AAPF across Maud Rise (Fig. 4B) (Leg 113 Shipboard Scientific Party, 1988a,b; O'Connell, 1990). There was a marked increase in biosiliceous sedimentation (both radiolarians and diatoms) by latest Eocene (Barker et al., 1988; Thomas et al., 1990), indicating sites were probably by then located south of the proto-AAPF. In the modern ocean the SAF marks the northern boundary of the diatom belt (Burckle and Cirilli, 1987), and diatomaceous sediments record its possible formation in the late Oligocene between the AAPF and proto-STF (Nelson, 1986). However, as diatom sedimentation is reported at Maud Rise from the latest Eocene to early Oligocene, this suggests either an earlier time of formation of the proto-SAF, at least in the South Atlantic, or that the AAPF marked this biosiliceous boundary until the former became established. Low sedimentation rates since the Eocene indicate these sites have been located away from the high productivity biogenic belt associated with the AAPFZ (Barker et al., 1988). Isotopic analysis of Maud Rise sediments led Kennett and Stott (1990) to conclude that the generation of high-latitude cool intermediate waters (either proto-AAIW or SCIW) occurred at this time. If this was the case, then the subduction of cold antarctic surface waters to form SCIW necessitates the presence of an oceanic front. In the modern ocean AAIW is generated at the AAPF, and so it is inferred that this front has existed in some form since the late Eocene (Fig. 4B).

During latest Eocene to early Oligocene, Maud Rise SSPTs cooled to 2–5°C (Stott et al., 1990) and there was a change from subantarctic to antarctic radiolarian species (Lazarus and Caulet, 1993), along with the earliest record of IRD (Barker et al., 1988) marking the formation of sea ice. The last occurrence of bolboforms in uppermost Eocene sediments (Kennett and Kennett, 1990) precedes lower Oligocene diatomaceous sedimentation (O'Connell, 1990) defining the diatom belt, between the AAPF (or proto-SAF) and the northern limit of Antarctic sea ice (Fig. 4C) as found in the modern ocean (Fig. 2). Alternation of nannofossil oozes and diatom-bearing nannofossil oozes until the middle upper Miocene in Hole 690B is interpreted to represent repeated migration of a front over the site (Fig. 4E,F) (Leg 113 Shipboard Scientific Party, 1988b). Diatomaceous sedimentation continued at Maud Rise without any carbonate accumulation until the Pleistocene, when in Hole 689B a calcareous component returned in the form of sinistral *Neogloboquadrina pachyderma* and a few calcareous nannofossils (Kennett and Kennett, 1990). The presence of calcareous sediments is most likely related to the Weddell Polynya and slightly warmer surface waters within the Weddell Gyre, rather than to southward migration of the AAPF or proto-SAF. The upper Neogene record of continuous diatomaceous sedimentation indicates the Maud Rise sites remained within, or south of, the diatom belt (Fig. 4G).

5.4. Region C – South Atlantic

5.4.1. Palaeogene and Neogene records

The South Atlantic record comes from Site 699, just south of the modern AAPF, and Site 704, between the STF and AAPF (Leg 114 Shipboard Scientific Party, 1988a,b). The Quaternary sedimentary record of alternating siliceous and calcareous sedimentation suggests Site 704 is located close to the SAF. Other South Atlantic sites contain warm planktic foraminiferal faunas from Palaeocene to early Eocene (Nocchi et al., 1991). During Zone P11 (ca 46–44 Ma) the faunas changed, but still represented 'warm temperate' conditions (Nocchi et al., 1991). Middle upper Eocene sediments in Hole 699A are nannofossil ooze containing bolboforms, which by lower Oligocene include increasing amounts of biosiliceous

sediment in which bolboforms are rare (Spiegler, 1991). The change from calcareous to biosiliceous sedimentation in Hole 699A suggests a front was close to and/or migrated across the site, either the AAPF (Westall and Fenner, 1991), or more likely a proto-SAF (Fig. 4C). The earliest evidence of IRD, used to indicate proximity to the northern margin of the AAPFZ in Hole 699A, occurs at ca 23.5 Ma (Allen and Warnke, 1991) (Fig. 4E). The proto-SAF/SAF remained close to the site throughout the Neogene (Fig. 4F), with another pulse of IRD at 10.7 Ma (Allen and Warnke, 1991).

The oldest sediments cored in Hole 704B (middle Eocene) are calcareous and reflect relatively warm surface waters (Fig. 4A) (Leg 114 Shipboard Scientific Party, 1988b). Nannofossil assemblages indicate surface waters had cooled considerably by the early Oligocene, warmed slightly in the late Oligocene, and cooled again by the middle Miocene (Crux, 1991). During Zone P22-N4 (late Oligocene to early Miocene) South Atlantic planktic foraminiferal diversity increased along with the presence of low-latitude species, indicating an increase in SSPTs (Crux, 1991), but subsequent species changes were associated with cooling later in the early Miocene (Müller et al., 1991). Rare early Oligocene appearance of bolboforms at this site (Spiegler, 1991) coincides with cooler conditions and may reflect the close proximity of the proto-SAF (Fig. 4C).

Müller et al. (1991) reported Site 704 to be north of the SAF from 9.8 to 6.4 Ma (Fig. 4F). Prior to ca 9 Ma, the microfossil assemblages and calcareous-dominated sediments are consistent with a position in warm subantarctic surface waters between the SAF and STF (Müller et al., 1991). A large decrease in carbonate productivity between 8.45 and 8.2 Ma (324–318 mbsf), associated with an increase in diatomaceous sediment, is taken to indicate significant cooling of surface waters and close proximity of the high-silica productivity zone and the SAF (Müller et al., 1991). Upper Miocene bolboforms are found in Hole 704B sediments from 438 to 258 mbsf (D. Spiegler, unpublished data), coincident with a 1.6°C cooling (0.4‰ increase in benthic $\delta^{18}O$) in bottom-water temperatures (Müller et al., 1991) and indicative of further cooling and intensification of circum-Antarctic circulation. Bolboforms disappear just before planktic foraminiferal $\delta^{18}O$ values indicate significant warming of surface waters at ca 6.5 Ma, supported by the presence of temperate and low-latitude diatom and silicoflagellate assemblages (Froelich et al., 1991). This suggests that the STF migrated southward over Site 704 (Fig. 4F). Pujol and Bourrouilh (1991) reported that coiling direction changes in *Neogloboquadrina pachyderma* indicate Site 704 was closer to the STF in the late Miocene, but closer to the AAPFZ in the late Pliocene and Quaternary. The earliest IRD in Hole 704B occurs at ca 4.2 Ma, further indicating the site was close to the northern edge of the AAPFZ at this time (Fig. 4G) (Allen and Warnke, 1991).

Within the four Palaeogene *Bolboforma* zones in the South Atlantic holes (Fig. 3), up to 10 *Bolboforma* species are recorded (Spiegler, 1991). This compares with only five species in the three equivalent zones at Maud Rise (Kennett and Kennett, 1990). This may indicate more favourable palaeoceanographic conditions existed for bolboforms in the South Atlantic, and that the Maud Rise locality was close to the southern limit of their ecological range.

5.5. Region D – Central Kerguelen Plateau

The modern location of all Leg 120 sites is 500–900 km south of the AAPF (Schlich and Wise, 1992). To simplify palaeoceanographic reconstructions, details of the Palaeogene species reported from Holes 748B and 749B, and of the Neogene species from Hole 747B, are used here.

5.5.1. Palaeogene record

Lazarus and Caulet (1993) reported no provincialism of warm-water radiolarians in early Eocene sections from the southern Indian Ocean, but a dramatic change to subantarctic assemblages in the middle Eocene of Hole 748B, and to Antarctic assemblages by the Eocene–Oligocene boundary. Both planktic and benthic foraminiferal $\delta^{18}O$ records from the same hole exhibit significant enrichment (0.6–1.0‰ planktic and 1.2‰ benthic) in the uppermost Eocene to lowermost

Oligocene records (Zachos et al., 1992). Associated with this change in $\delta^{18}O$ is a dramatic increase in cold-water nannofossil species, a decrease in carbonate accumulation, an increase in biosiliceous sediment, a shift of 0.7‰ (from 0.7 to 1.4‰) in benthic $\delta^{13}C$ values, and the appearance of IRD at 117–115 mbsf (Zachos et al., 1992). Similar $\delta^{18}O$ enrichment is reported from Site 744, south of 748B (Salamy and Zachos, 1999), suggesting it was a regional phenomenon. Together these changes indicate there was significant cooling of both surface and intermediate waters through the later Eocene and into the Oligocene, compatible with initially the proto-STF and then the AAPF migrating northwards over the site (Fig. 4C). The increase noted in benthic $\delta^{13}C$ values is not evident in the planktic record, suggesting a change in chemistry at the source of the intermediate waters bathing the site. Specifically, this could indicate that the source of the intermediate waters was getting closer to Site 748, resulting in waters bathing the site being younger and more nutrient-depleted (Zachos et al., 1992). As the front generating SCIW/AAIW is the AAPF, this further suggests it migrated northwards at this time (Fig. 4C).

Bolboforma are reported in Hole 748B from 180.6 to 111.3 mbsf, in middle Eocene to lower Oligocene sediments (Mackensen and Spiegler, 1992). Their presence coincides with a cooling trend in the $\delta^{18}O$ record starting at around 170 mbsf, ca 46–44 Ma (Zachos et al., 1992). Prior to appearance of IRD (around 116 mbsf) and biosiliceous sedimentation in the earliest Oligocene, which are taken to indicate arrival of the proto-SAF, the site would have been located between the proto-STF and proto-SAF (Fig. 4C). The $\delta^{18}O$ values remain high after the isotope shift, indicating the site stayed within the cool subantarctic zone. The disappearance of bolboforms after the earliest Oligocene IRD, and their absence from the rest of the core, support the site being located south of the proto-SAF, and probably south of the AAPF, since that time (Fig. 4D).

5.5.2. Neogene record

Late Miocene to early Pliocene (ca 10–4 Ma) bolboforms are reported from Hole 747A on Central Kerguelen Plateau, north of Sites 748 and 749 (Mackensen and Spiegler, 1992). They occur from 66 to 29.5 mbsf, with the zonation extending from the *B. compressispinosa* Zone to the *B. intermedia* Zone (Fig. 3). This is the same zonation as in Leg 90 holes (Grützmacher, 1993; Crundwell et al., 1997) and in Hole 704B (D. Spiegler, unpublished data). The upper Miocene sediments of Hole 747A from 60 to 34.3 mbsf are foraminifera- and diatom-bearing nannofossil ooze, while the Plio–Pleistocene sediments through to the seabed change to foraminifera-bearing diatom ooze (Leg 120 Shipboard Scientific Party, 1989). As for other sites, the presence of diatom ooze is taken to indicate proximity of the SAF, marking the northern margin of the AAPFZ (Burckle and Cirilli, 1987). Upper Miocene nannofossil ooze suggests Hole 747A was at this time located north of the AAPFZ, with the change to diatom ooze representing northward migration of the SAF over the site (Fig. 4F). The overall surface-water temperatures derived from the radiolarian assemblage suggest the site has been south of the AAPF for much of the Neogene, but subantarctic radiolarian species are common in the uppermost Miocene to lowermost Pliocene sediments, indicating slightly warmer conditions (Leg 120 Shipboard Scientific Party, 1989). This slight warming of surface waters occurs at the same time as the bolboforms appear and is taken to reflect southward migration of the SAF over the site (Fig. 4F). Return of cooler surface waters during the middle Pliocene is indicated by minor amounts of IRD in the upper 20 m of the hole (Leg 120 Shipboard Scientific Party, 1989), which suggests that by this time the fronts had migrated northwards again.

As Site 747 is currently south of the AAPF, it may be possible to track the continued northward migration of the AAPF using the sediment compositional changes linked to oceanic fronts north of this site. The only site north of Site 747 with sufficient core recovery is Site 737 on Northern Kerguelen Plateau which sits within the modern AAPFZ (Baldauf and Barron, 1991), and with the AAPF located north of the site and Kerguelen Island (Belkin and Gordon, 1996). In Hole 737A the transition from upper Miocene nannofossil

ooze to diatom ooze occurs at 245 mbsf, at approximately 6.3 Ma (Baldauf and Barron, 1991; Bohrmann and Ehrmann, 1991). This probably marks migration of the SAF over Site 737 at this time (Fig. 4F). However, between 263 and 157 mbsf (150 mbsf = ca 5.8 Ma) the cool-water diatom assemblage also includes warm-temperate diatoms, typical of low- to mid-latitudes (Baldauf and Barron, 1991). Above this depth level the Pliocene assemblage is again representative of the Southern Ocean (Baldauf and Barron, 1991). Given the complicated nature of the modern AAPF structure in this part of the southern Indian Ocean (Belkin and Gordon, 1996), it would appear that the frontal structure did not reach something approaching the modern situation until the Pliocene (Fig. 4G).

6. Discussion

6.1. Pulsed nature of bolboform records

The pulsed nature of the *Bolboforma* record in Hole 593 (Crundwell et al., 1997) and at Maud Rise (Kennett and Kennett, 1990) suggests an intermittent bloom or period of stable conditions followed by very rapid changes in environmental conditions within a few to several 1000 yr. Kennett and Kennett (1990) suggested that although there are only five *Bolboforma* species in some of the Maud Rise samples, the number of specimens (up to 55% by wt of the >63 μm size fraction) indicated there were large blooms, and that the low calculated flux rates in other samples was suggestive of intermittent rather than continuous productivity. Bolboforms in some Hole 593 samples make up to ca 10% of the >150 μm fraction. The occurrence of single species 'assemblages' in most upper Miocene samples from Hole 593 (Crundwell et al., 1997) may reflect some unknown environmental stress resulting in bolboform blooms which were subsequently transported away from the source population via a subsurface watermass. Single species assemblages are also reported from the North Atlantic (Poag and Karowe, 1986). This lack of species diversity with large numbers of specimens is characteristic of high-latitude marine ecology (Kennett and Kennett, 1990). The bolboform diversity appears to decline both towards the tropics (e.g. across Leg 90 sites from 12 to 4 species) and towards Antarctica, south of the AAPFZ.

6.2. Subsurface watermass emplacement of bolboforms at Southwest Pacific sites

In Southern Ocean sediments the presence of bolboforms generally coincides with indicators of subantarctic conditions. However, this is not always the case, as in the Southwest Pacific (Region A) Palaeogene sediments from Holes 277, 592, and 593, and the Neogene sediments from Holes 590B, 592, and 593.

Late Eocene sections in Hole 592 include bolboforms with some poorly preserved tropical radiolarians, whereas coeval bolboform-bearing deposits at Hole 593 to the south lack these radiolarians. Caulet (1986) postulated that the warm-water radiolarians at Site 592 possibly arrived via flow in a southern subtropical gyre (Fig. 4B), in which case their absence at Site 593 suggests the gyre cannot have directly influenced this site. Moreover, the presence of bolboforms at both sites indicates they did not arrive within any such warm-water gyre. Also, when early Oligocene SSPTs warmed slightly at Site 593 but cooled at Site 277 to the south (Murphy and Kennett, 1986), bolboforms disappear from the Site 593 Palaeogene record. We suggest below that the late Eocene to early Oligocene bolboforms at Sites 592 and 593 may have entered the relatively warm Tasman Sea in a cool subsurface watermass.

In Hole 590B the presence of very small numbers of bolboforms in upper Miocene sediments coincides with a ca 3°C cooling of surface waters, but with calculated SSPTs still around 20°C (Kennett, 1986). The cool subtropical/temperate foraminiferal assemblage in Hole 593 (Jenkins and Srinivasan, 1986) associated with the bolboforms indicates that this site (and Sites 592 and 590 to the north) remained north of the STF throughout the Neogene. Despite the bolboforms being associated with both subtropical SSPTs (Hole 590B) and temperate foraminiferal assemblages (Holes

592 and 593), they are always associated with some evidence for cooling of surface waters in the Southwest Pacific.

If bolboforms are pelagic and lived to the south of the STF in subantarctic surface waters, as appears to be the case at the other Southern Ocean sites, what might account for their apparent cool subtropical association in the Tasman Sea? There are several possibilities, including: (a) bolboforms in this region are not restricted to subantarctic surface waters; or (b) dead/dormant bolboform tests have arrived in the region via a subsurface watermass well below the photic zone, likely the SCMW (Southern Component Mode Water) or SCIW (Southern Component Intermediate Water); or (c) other regions north of the STF have not been sampled at sufficient resolution to show up detailed palaeoceanographic conditions associated with the bolboforms; or (d) there is a lack of suitable sites above the CCD, north of the STF in regions away from the Tasman Sea where carbonate sediments can accumulate.

Outside the Tasman Sea region, bolboforms are only associated with subantarctic conditions. The only site which has good evidence for the STF migrating across it is Hole 704B in the South Atlantic. Here bolboforms disappear from sediments when cool subtropical surface waters bathe the site, and return when the STF migrates northwards and reintroduces subantarctic surface waters over the site (Westall and Fenner, 1991). This strongly suggests that the bolboforms are restricted to warm subantarctic surface waters and consequently, that of the options given above, subsurface transport best explains their presence at sites north of the STF. The modern STF is a very effective barrier to surface-water transfer across it (Chiswell, 1994), effectively necessitating a subsurface mechanism for transfer.

In the southern hemisphere, regions where calcareous sediments can accumulate above the CCD and north of the STF appear to be limited to Lord Howe Rise in the Tasman Sea, Campbell Plateau, the northern margin of the South Australia Basin (Leg 182), and parts of the South Atlantic (e.g. Site 704). So areas which might record SCIW (Southern Component Intermediate Water) *Bolboforma* transport away from the Southern Ocean are limited. One possibility could be ODP cores along the ocean ridges as they are occasionally shallow enough to accumulate calcareous sediments. Two areas in the Southwest Pacific which are bathed by modern AAIW (Antarctic Intermediate Water) and probably have been through at least the Neogene, and from which *Bolboforma* have recently been reported are Campbell Plateau (Site 1123; Leg 181 Shipboard Scientific Party, 1999; M. Crundwell, unpublished data) and South Tasman Rise (Leg 189 sites; J. Kennett, 2000, personal communication). Previous investigations in these areas (Leg 90 and Leg 29) did not recognise *Bolboforma* in the sediments, and that could well reflect a lack of awareness of this microfossil group rather than their absence.

6.3. *Bipolar nature of bolboform distribution*

Bolboforms are reported in Tertiary sediments from the North Atlantic and in northern hemisphere onshore drill sites where they exhibit a similar biozonation to that of the Southern Ocean cores (Fig. 3). The oldest known bolboforms occur in Hole 277, south of New Zealand. This suggests there must have been some mechanism to disperse the bolboforms into northern hemisphere high latitudes from high southern latitudes. The tropical oceans are formidable barriers to cool-water microfossils and transport across the ocean fronts is unlikely (Darling et al., 2000). However, using the bipolar distribution of planktic foraminifera, Darling et al. (2000) demonstrated that it was possible for cool-water genotypes to reach the opposite polar region via upwelling systems and cool subsurface boundary currents. It is possible that a similar scenario could apply to the bolboforms, especially if the transport mechanism is the SCIW, the forerunner of the modern AAIW. This watermass travels northwards along the western margin of the Atlantic and into the Caribbean Sea where it gets mixed into the regional watermasses (Tomczak and Godfrey, 1994). This certainly mirrors the *Bolboforma* distribution as it is presently known, with both Palaeogene and Neogene sites occurring along the east coast of North America (Spiegler and von Daniels, 1991). In the

South Atlantic there are few areas where carbonate sediments are preserved, hence sites with bolboforms are somewhat limited. The eastern Atlantic distribution is less clearly defined, with mostly Neogene sites in the central and eastern North Atlantic and onshore Europe (Spiegler and von Daniels, 1991). The global distribution of bolboforms between the SAF and its northern hemisphere equivalent may reflect the pathways of AAIW or its equivalent predecessor, but further investigation is beyond the scope of this paper.

6.4. *Neogene oceanic gateways and Tasman Sea palaeoceanography*

Both the Indonesian and Panama gateways were open to deep-water flow during the early middle Miocene (Hamilton, 1979; Duque-Caro, 1990; Burton et al., 1997), resulting in largely uninterrupted westward-flowing equatorial surface currents, equivalent to the modern Southern and Northern Equatorial Currents (Kennett et al., 1985). Any return flow as an Equatorial Undercurrent would have been weaker due to the lower equator-to-pole thermal gradients, with a resultant reduction in strength of both the trade winds and the westerlies.

From the middle Miocene onwards flow through the Indonesian gateway became more and more restricted due to continental collision with the northwards-moving Australian plate (Hamilton, 1979). As a result, equatorial flow was no longer able to pass through the Indonesian archipelago in the same volume as before (Kennett et al., 1985). The equatorial water is likely to have 'backed up' north of Papua New Guinea to initiate the Western Pacific Warm Pool, to then be deflected in western boundary currents and as equatorial return flow (Kennett et al., 1985; Jenkins, 1992). Consequently, increased flow within the proto-East Australian Current (EAC) is inferred, as it is the western boundary current linked to the subtropical gyre (Tomczak and Godfrey, 1994). Given that flow along the Tasman Front is directly linked to the EAC (Heath, 1985), it is assumed that this front did not exist in anything like its modern form prior to this increase in flow when surface watermasses in the Tasman Sea would have been less partitioned. This may account for the reported difficulty in determining which planktic foraminiferal biozonation scheme, warm or cool subtropical, is most appropriate for use with Tasman Sea samples, as the Neogene microfossil assemblages in both the warm and cool regions lack certain characteristic species at this time (e.g. Jenkins and Srinivasan, 1986; Leg 90 Shipboard Scientific Party, 1986a,b).

In Hole 208 (equivalent to Site 588 – northern Lord Howe Rise) there is a significant change in the planktic foraminiferal population in the middle Miocene, where temperate species begin to dominate over tropical ones (Kennett and Srinivasan, 1984). In Hole 206 (equivalent to Sites 590 and 591) this also occurs as the assemblage becomes dominated by temperate species, but with some rare but persistent tropical elements (Kennett and Srinivasan, 1984). In the southern Tasman Sea any tropical elements in the planktic foraminiferal assemblage disappear from Hole 593 at the same time as the late Miocene last occurrence of bolboforms (Crundwell, in prep.). The changes in planktic foraminiferal assemblage dominance indicate a general cooling of the surface waters in the Tasman Sea. In addition, the latitudinal position of the changes is taken to reflect partitioning of the Tasman Sea by deflection of warmer waters along the Tasman Front due to invigorated EAC flow. As there is no evidence for radical changes in circulation in the southern Tasman Sea (no major unconformities or changes in sediment type) it is assumed that AAIW continued to flow into the Tasman Sea throughout the remaining Neogene, so the absence of bolboforms is more likely to be due to bolboform ecology than to a lack of preservation.

A few sites containing *Bolboforma* are reported west of the Panama region during the middle Miocene (Spiegler and von Daniels, 1991). Uplift in this region, starting ca 16 Ma, began to restrict the gateway but not actually close it (Duque-Caro, 1990). By ca 12 Ma the restriction was affecting the surface-water circulation (Mullins and Neumann, 1979; Lyle et al., 1995). These 'tropical' bolboforms either indicate this group is tolerant of warm surface waters, and appear to have

been able to cross oceanic fronts, or more likely they arrived via a subsurface watermass as postulated in Section 6.3.

6.5. Circum-Antarctic Palaeogene bolboform distribution

Similarity of the bolboform and other microfossil biostratigraphy throughout the Eocene and Oligocene at sites around Antarctica is suggestive of some sort of circum-Antarctic connection. There was a shallow opening of the Tasmanian gateway prior to ca 31 Ma (Jenkins, 1974, 1993a) allowing flow between the Indian and Pacific Oceans, and once the Drake gateway opened by the late Oligocene (Barker and Burrell, 1977; Lawver et al., 1992) full Antarctic Circumpolar Current circulation was possible. However, the bolboform distribution is 'circum-Antarctic' prior to both these gateways opening, and assuming this group is pelagic and restricted to subantarctic waters, the distribution needs consideration. One possible early connection between the Pacific, South Atlantic, and Indian Oceans might have been via a West Antarctic seaway (WAS). The development of the West Antarctic Ice Sheet is inferred to have occurred in the late Miocene (Kennett et al., 1975), so prior to this, the area now covered in sea ice was presumably ice-free, at least in summer (Fig. 6). Therefore surface-water flow through the archipelago could have been possible, providing a circum-Antarctic marine connection between the three oceans (Fig. 4B,C).

The recording by Cande et al. (2000) of rifting along the Balleny fracture zone to link the West Antarctic rift system with the Alpine Fault in New Zealand added impetus to the idea of the existence of a possible WAS. The rifting is linked to initiation of uplift along the Transantarctic Mountains after ca 55 Ma, and was terminated by ca 27 Ma (Cande et al., 2000). This suggests the WAS could have existed from early Eocene to late Oligocene and would have enabled circum-Antarctic-like connections to exist in the Southern Ocean. By the late Oligocene the main Southern Ocean gateways were opening as the WAS was closing. Large unconformities in the lower Oligocene of Hole 277 and in the Kerguelen Plateau holes might possibly be related to this pre-Antarctic Circumpolar Current. Once the Tasmanian gateway opened, a proto-circum-Antarctic flow would have been possible via the WAS rather than through Drake gateway. While such a flow is unlikely to have extended to the depths of the modern Antarctic Circumpolar Current, the forcing of large volumes of water through a shallow gap is likely to have generated swift currents and the potential for sediment erosion. The upper Oligocene unconformity in Bellinghausen Basin in Hole 325 (Leg 35 Shipboard Scientific Party, 1976) could reflect scour caused by the subsequent change in position of the proto-circum-Antarctic circulation from the WAS to the Drake gateway by the late Oligocene.

7. Conclusions

(1) *Bolboforma* represent an enigmatic group of marine microfossils which nevertheless have the potential to advance understanding of Cenozoic Southern Ocean biostratigraphy and palaeoceanography. Here the established mid–late Tertiary planktic foraminiferal and nannofossil Zones are correlated with the zonation scheme for bolboforms, and the evolution of surface watermasses and their oceanic fronts in the Southern Ocean is tracked using microfossil and sediment characteristics which in turn are linked to the stratigraphic and spatial distribution of the *Bolboforma*. Typically, in the Southern Ocean the appearance of bolboforms is associated with warm subantarctic surface waters bounded by the STF and SAF, or their predecessors.

(2) The oldest record of bolboforms is in the lower Eocene of Hole 277 on Campbell Plateau, south of New Zealand. They are not reported again until the middle Eocene in three areas: the Southwest Pacific, Maud Rise/South Atlantic, and Kerguelen Plateau. The Palaeogene circum-Antarctic distribution and biostratigraphy of the bolboforms suggest some connection existed between the South Atlantic, Indian, and Pacific Oceans at high latitudes prior to full opening of both the Tasmanian and Drake gateways by the latest Oligocene. We suggest this was via a West Antarctic

seaway linking Ross Sea with Weddell Sea during the early Eocene to late Oligocene. This early circum-Antarctic current may be the origin of certain early Oligocene unconformities in Southern Ocean sequences.

(3) The highest bolboform diversity at Maud Rise, Kerguelen Plateau, and Campbell Plateau occurs concurrently with significant cooling of late Eocene to early Oligocene sea-surface palaeotemperatures to values (8.5–6°C) similar to those characterising modern subantarctic surface waters south of the STF. However, the upper Eocene to lower Oligocene bolboforms from Southwest Pacific sediments are associated with cool subtropical palaeotemperatures and subtropical microfauna/flora, and we postulate their introduction into the Tasman Sea within a cool subsurface watermass.

(4) By middle Oligocene, surface-water conditions at both Maud Rise and southern South Atlantic sites had cooled sufficiently to force migration of bolboforms northwards, as indicated by the onset of diatomaceous sedimentation linked to a (proto-)SAF. There are presently no reports of upper Oligocene to uppermost lower Miocene bolboforms at any southern hemisphere sites, except in Bellinghausen Basin, where a few bolboforms are present that are possibly linked to latest early Miocene warming, after which the site cooled again to antarctic conditions and the bolboforms disappear.

(5) In the late Miocene the absence of bolboforms in northern Tasman Sea sediments, the limited numbers in central Tasman Sea sites, and the increased occurrence and numbers of species in more southern sites on Challenger Plateau reinforce the suggestion that they have a preference for cooler surface-water temperatures. However, as for the late Palaeogene Tasman Sea occurrences, and unlike those elsewhere in the Southern Ocean, these sites lie north of the STF and the bolboforms co-exist with temperate or cool-subtropical microfossil assemblages. We explain this apparently anomalous distribution by the bolboforms being subducted from subantarctic surface waters south of the STF into intermediate waters (SCIW), followed by subsurface transport northwards before pelagic settling onto Challenger Plateau.

(6) The bipolar distribution of bolboforms may also be linked to intermediate-depth transport in the SCIW from the Southern Ocean to the North Atlantic. Consequently, where palaeoenvironmental proxies indicate other than subantarctic conditions it is possible that subsurface transport of dead/dormant bolboforms may have occurred.

(7) The last occurrence of bolboforms was in the late Miocene (ca 8 Ma) at Southwest Pacific sites, in the early Pliocene on Kerguelen Plateau, and not until the late Pliocene in the North Atlantic. Reasons for this spatially diachronous disappearance are unclear, but may relate to tectonically controlled changes in oceanic circulation patterns consequent upon restriction of both the Indonesian and Panama gateways.

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