Sequence stratigraphy and architectural elements of the Giant Foresets Formation, northern Taranaki Basin, New Zealand

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Abstract

The modern continental margin in northern Taranaki Basin is underlain by a thick, mud-dominated, Pliocene and Pleistocene succession (Giant Foresets Formation, GFF) clearly imaged in seismic reflection datasets. A study focusing on the geometry and internal reflection character of the GFF has revealed structural, sedimentological, and eustatic controls on its accumulation.

Isopach maps prepared for northern Taranaki Basin show shifts through time in the main loci of sediment accumulation of the Mangaa Formation and Giant Foresets Formation. During the Early Pliocene (Opoitian Stage) deposition was focused in the southern part of the Northern Graben. The progradational front moved into the vicinity of Arawa-1 and Taimana-1 on the Western Platform during the early-Late Pliocene (Waipipian and Mangapanian Stages), forming large mounded slope fans. Through the latest Pliocene (Mangapanian - lower Nukumaruan Stages) the progradational front moved rapidly to the north and west through and across the Northern Graben to form a distinct shelf-slope depositional front. During the Pleistocene (upper Nukumaruan Stage – Recent), the progradational front straightened out, reaching the present position of the shelf-slope break. Even during the Pleistocene, broad subsidence persisted in the Northern Graben, trapping a proportion of the sediment flux being delivered to this part of the basin.

The Late Pliocene part of the GFF, particularly where it prograded on to the Western Platform, displays classic clinoform profiles, with over steepening having resulted in mass-failure of paleoslopes. Major degradation of the shelf edge and slope occurred during the Early Pleistocene, reflecting a change in the calibre and flux of sediment sourced to the continental margin.

Detailed examination of part of the GFF not significantly affected by mass-failure indicates that small-scale channel levee and overbank deposits dominate slope deposition, while basin floor deposits are characterised by slope-disconnected muddy and silty basin floor fans, with little lateral continuity between systems. In a sequence stratigraphic context, many of the dominant components of each seismic unit (slumps, fans, and channel-levee complexes) were deposited during the falling (RST) and low (LST) sea level parts of a relative sea level cycle, resulting in highly asymmetric sequences. While the GFF is considered to have minor reservoir potential in terms of containing sandstone-dominated stratigraphic traps, it does afford the opportunity to study in detail how deep-water clastic systems evolved in response to the various factors that control depositional architectures, particularly in a rapidly prograding muddy continental margin system.

1. Introduction

Analysis of the internal architecture of the progradational Giant Foresets Formation, northern Taranaki Basin, affords the opportunity to study how a slope to basin clastic depositional system evolved in response to the various factors that control depositional architectures. This setting may contribute to the development of reservoir architectural models for rapidly prograding margins.

This investigation of the Giant Foresets Formation has focussed on the context of architectural (stratigraphic) elements in a shelf-slope-basin succession (e.g., Galloway, 1998; Stow and Mayall, 2000). Thus we address several fundamental building blocks of the deposits in northern Taranaki Basin, including hiatuses, mass-wasting features and their products, fan mounds, and channel incision. The depositional characteristics of the Giant Foresets Formation, imaged on seismic reflection profiles, have been variously affected by sediment flux, basin structure and local subsidence, and eustatic sea level change, giving rise to a variety of slope morphologies and deeper water depositional elements.
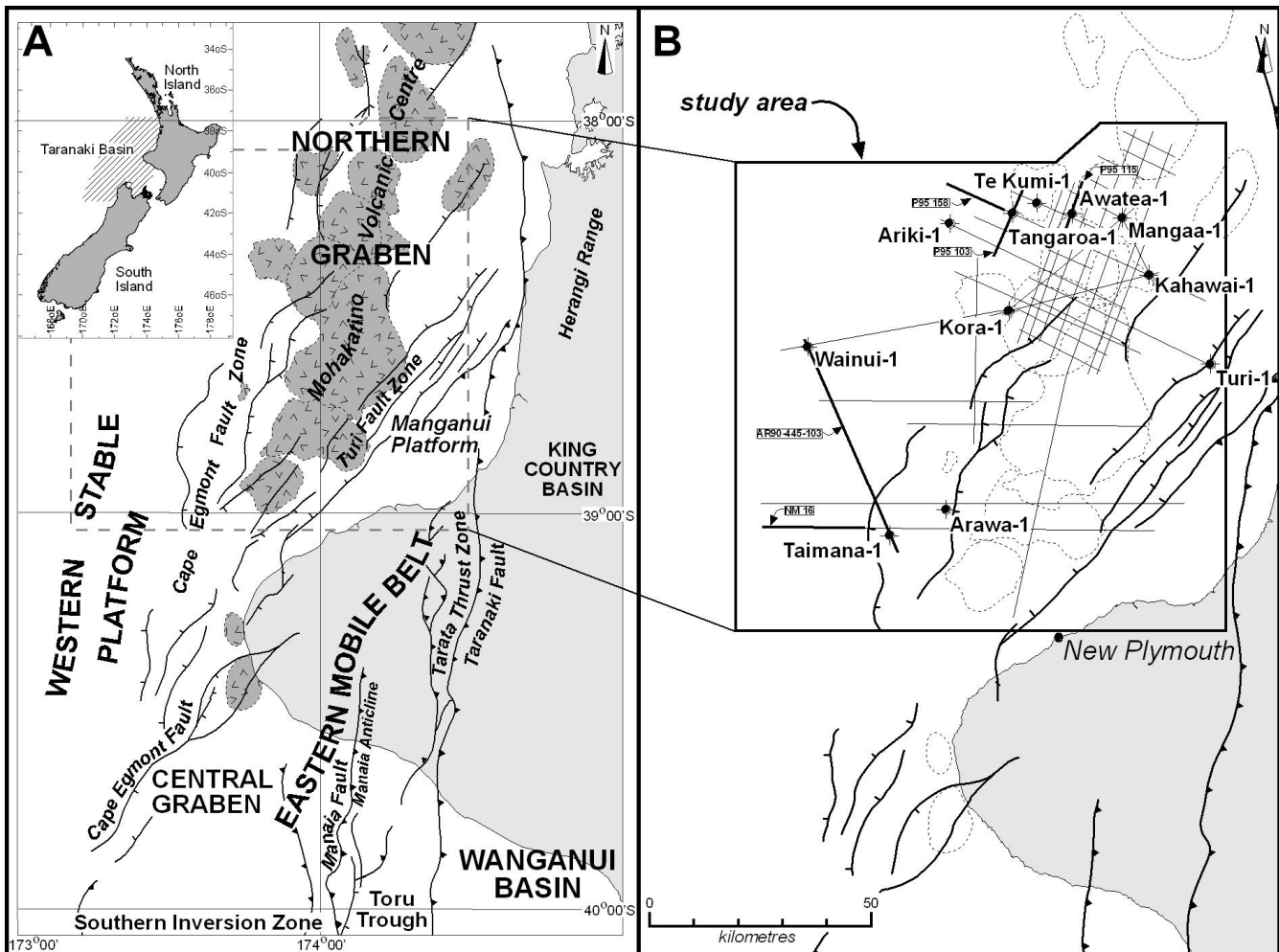
Figure 1: A. *Structural domains and principal tectonic and volcanic features, Taranaki Basin. Figure after King et al. (1993), King and Thrasher (1996) and Thrasher et al. (2002). King Country Basin after Kamp et al. (2002).*
Figure 1: B. *Location map illustrating the approximate extent of the area covered by this study, key wells sections used, and grid of seismic reflection data used in this study. Seismic reflection profiles used in subsequent figures are high-lighted.*

2. Geological setting and structural evolution

The major structural elements that have affected depositional architectures in the Giant Foresets Formation in northern Taranaki Basin are summarised in Fig. 1A. Taranaki Basin can be broadly divided into two tectonic regions: the tectonically active Eastern Mobile Belt, which includes the Northern Graben, and the tectonically quiescent and structurally simple Western Stable Platform (Pilaar and Wakefield, 1978; King and Thrasher, 1996) (Fig. 1A). A (now buried) Middle to Late Miocene andesitic volcanic arc is aligned in a north-northeast–south-southwest trend along the axis of the Northern Graben (King and Thrasher, 1996) (Fig. 1A).
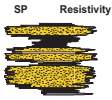
The area covered by this study takes in the Northern Graben and northern part of the Western Stable Platform (Fig. 1B). While the Northern Graben experienced subsidence during the Pliocene and

Pleistocene, its eastern flank (Turi Fault Zone) was concurrently tilted, uplifted and eroded, forming the Manganui Platform (King and Thrasher, 1996) (Fig. 1A). To the west, the Western Stable Platform was characterised by persistent subsidence through the Pliocene and Pleistocene (Hayward and Wood, 1989; Holt and Stern, 1991). The Mangaa Formation is the lowermost unit in the Northern Graben and accumulated as a series of basin floor fan deposits. The muddy Giant Foresets Formation that has built up most of the modern continental shelf and slope, in places attaining a thickness of about 2000 m. Rapid progradation together with active down-faulting resulted in active synsedimentary filling of the Northern Graben, and as a result the Giant Foresets Formation is over-thickened in this structure.

3. Architectural elements: characterisation and depositional mechanisms

Investigation of the Giant Foresets Formation,

Table 1: *Typical wireline facies, associated lithologies, and depositional environments found in Pliocene and Pleistocene sediments, northern Taranaki Basin. Equivalent seismic architectural elements are indicated in brackets below the relevant wireline facies.*

Wireline facies	Wireline motif	Wireline characteristics	Dominant lithology	Depositional environment and mechanisms	Occurrence (formation)
Basin floor fan facies (Type 1 fans)	SP / Resistivity	▪ blocky to tabular, abrupt upper and lower contacts; stacked packages become thinner upward ▪ high to moderate GR ▪ high negative SP ▪ resistivity mirrors SP	▪ medium to coarse-grained sandstone, subordinate siltstone	▪ basin floor fan - upward-thinning units indicate progradation of fan system	▪ Mangaa Formation
Slope fan facies — *Subfacies 1 (Sf1)* (Channel-levee complexes)	SP	▪ funnel or bell-shaped, often stacked in gross coarsening-upwards packets ▪ moderate to high GR ▪ high negative SP values	▪ siltstone to coarse sandstone	▪ overbank deposit, crevasse splay ▪ associated with fan progradation on lower slope to basin floor fan	▪ Mangaa Formation ▪ upper part of Giant Foresets Formation ▪ Mangaa Formation equivalent
Subfacies 2 (Sf2) (Type 2/3 fans)	GR	▪ funnel or bell-shaped, tend to be more fining-upwards than coarsening-upwards ▪ low to moderate GR ▪ suppressed SP and resistivity	▪ siltstone and mudstone	▪ ? distal or muddy turbidite deposition on slope and basin floor ▪ mud-dominated fan lobes	▪ lower part of Giant Foresets Formation
Subfacies 3 (Sf3)	GR	▪ funnel or bell-shaped, tend to be more fining-upward than coarsening-upward ▪ low to high GR ▪ high bulk density	▪ volcaniclastic mudstone to coarse sandstone	▪ turbidite deposition downslope of volcanic massifs (flanks)	▪ Mohakatino Formation ▪ Mohakatino/Manganui Formation
Subfacies 4 (Sf4)	GR	▪ barrel-shaped package, with upward-coarsening, followed by upward-fining units. ▪ high to moderate GR ▪ moderate negative SP ▪ 10's m thick	▪ variable mix of mudstone, siltstone, fine sandstone, and shell hash	▪ thin-bedded deposition, probably related to channel migration across the slope ▪ overbank deposits?	▪ Giant Foresets Formation
shelf facies — *Subfacies 1 (Shf1)*	GR	▪ dominantly upward-coarsening packages ▪ moderate to low GR, upwards increasingly negative SP and sonic (low) ▪ greater degree of separation between shallow and deep resistivity cf slope facies	▪ silty sandstone to sandy siltstone, occ. pebble bands, frequent layers of shell hash	▪ regressive shelf sandstone	▪ (upper) Giant Foresets Formation
Subfacies 2 (Shf2)	GR	▪ moderate to low GR, often serrate, slightly rounded shape ▪ greater degree of separation between shallow and deep resistivity logs, cf. finer grained facies	▪ silty sandstone to mod. fine sandstone	▪ trangressive shelf sands ▪ ?storm surge deposits on shelf and upper slope ▪ ?channel fill	▪ (upper) Giant Foresets Formation
Slumped facies	GR	▪ similar to Sf4, but occur in much thicker packages (100's m) ▪ high to moderate GR ▪ moderate negative SP ▪ highly variable density and sonic	▪ ?chaotic mix of mudstone, siltstone, fine sandstone, and shell hash	▪ mass failure of the shelf/slope break, possibly due to oversteepening during lowered sea level conditions	▪ Giant Foresets Formation

using established seismic interpretation criteria (e.g., Mitchum, 1985; Van Wagoner et al., 1988; Posamentier et al., 1991), has revealed a variety of internal configuration patterns, mapped on the basis of highly contrasting internal reflection configurations, packaged between bounding reflectors. The dominant architectural elements within Mangaa and Giant Foresets Formation strata are associated with basin floor and slope depositional environments (e.g., small-scale fans, channel-levee and overbank complexes), while external features (such as larger fans, mass-wasting features, channels, and hiatuses) are recognised using bounding seismic reflector characteristics. Four major wireline facies and six subfacies have been identified using wireline motif (Table 1). The equivalent seismically-identified architectural elements have been related to these where possible (Table 1).

3.1 Fans
Fans within northern Taranaki Basin display three distinct morphologies and aerial extents, related to their position in the paleogeographic setting, and dominant lithology (Table 2).

Type 1 fans are associated with the Mangaa Formation, and are restricted to the Northern Graben. They display features that conform to models of basin floor fans cited in the literature (e.g., Mitchum, 1985; Posamentier et al., 1991), including a low-mounded external geometry, and continuous, bright, high amplitude internal reflectors, suggesting a number of depositional lobes (Fig. 2A). They display a distinctive blocky to tabular GR and SP wireline motif (Basin floor fan facies, Table 1; Fig. 2A) indicating massive sandstone units separated by thinner mudstone beds. The lower part of Type 1 fans are characterised by a distinct funnel-shaped motif, (wireline facies Sf1, Table 2), and a lithological gradation from clay to silt to coarse sand. This coarsening-upward profile, in conjunction with the tabular nature of the stacked packets of the basin floor facies, is typical of a prograding submarine fan system (Cant, 1992).

Type 2 fans represent Giant Foresets Formation slope fan deposition, ahead of the advancing shelf margin, but landward of the basin floor, in the southern part of the study region (vicinity of Arawa-1 and Taimana-1). These fans have a pronounced mounded

geometry (Fig. 2B) and well-defined basal onlap. The dominantly muddy to silty lithology of these units suggest distal sources. These fans were deposited as a series of lobes in the western and southern part of the region of study (Soenander, 1992; Hansen, 2003), slightly earlier or contemporaneously with accumulation of Mangaa Formation Type 1 fans.

Type 3 (a and b) fans are smaller in scale than Type 1&2 fans (Table 2), generally show little relief, and sometimes appear disconnected from associated channel-levee complexes. Downdip, mounded packages grade into parallel-subparallel basin floor facies, and occasionally into more chaotic facies. Updip, reflectors become more concordant with slope complexes, or onlap younger reflectors along the edge of the fan complex. The external mounded forms of Type 3a fans (Fig. 2C) are characterised by numerous internal smaller, high-amplitude overlapping constructional mounds, typified by parallel reflector sets and bi-di-rectional downlap, and interspersed with zones that are almost acoustically transparent. Type 3b fans (Fig. 2D) display subdued seismic responses, being characterised by continuous, high-amplitude parallel reflector sets or reflection-free zones, and equally subdued wireline responses. These responses and fan geometries are indicative of muddy turbidite and hemipelagic accumulation.

3.2 Channel-levees
Channel-levee complexes and associated overbank deposits occur upslope of basin floor fans, and are the most dominant single architectural element observed slope deposits in northern Taranaki Basin. These often occur as low-amplitude single channel and levee couplets, or more seldomly, as smaller-scale nested channels and vertically stacked levees (Fig. 3). Channel-levee complexes are not well expressed on wireline logs, although coarsening-upward (funnel-shaped) or fining-upward (bell-shaped) wireline motifs are observed (e.g., wireline facies Sf1,2 and 4, Table 1).

Overbank deposits are delineated seismically by their moderate continuity and generally higher-amplitude subparallel-parallel reflectors. These correlate with slope fan subfacies 4 (Sf4). The barrel- or crescent-shaped motif of Sf4 may be indicative of several depositional elements, including channel-overbank deposits or multi-story intervals within the channel-levee complex (Mitchum et al. 1993). Channel fill is characterised by acoustic transparency, and is probably mud-dominated.

3.3 Mass wasting
Mass wasting features (slumps, slides and debris flows) are commonly associated with continental slopes (e.g., Coleman and Prior, 1988; McHugh et al. 2002), and occur on a number of different scales in northern Taranaki Basin. Slumping of the shelf-slope margin is the prevalent mass wasting mechanism within the Giant Foresets Formation. Two distinct periods of

	External geometry and bounding reflectors	Internal reflector configuration	Aerial extent	Example and representative figure
Type 1	Gently mounded, sheet-like to wedge shaped geometry. Continuous, bright, high amplitude reflectors.	Parallel to subparallel, moderate to high amplitude and continuous, becoming less so towards the outer fringe.	Moderate-large, several 10's of km's. Fault controlled, several lobes identified.	Mangaa Formation (Fig. 2A).
Type 2	Distinctly mounded geometry. Bold, moderate to high amplitude reflectors.	Numerous parallel-subparallel, moderate amplitude and continuous reflectors downlapping lower boundary.	Large, several 10's of km's. Roughly circular to elongate lobes.	Giant Foresets Formation (Fig. 2B).
Type 3	(a) Gently mounded. High to moderate amplitude reflectors.	(a) Low-relief mounds, and/or gull-wings, bi-directional downlap, often discontinuous, variable amplitude, occasionally acoustically transparent.	Restricted, several km's Elongate lobes.	Giant Foresets Formation (Fig. 2C).
	(b) Planar geometry.	(b) Parallel and continuous, moderate amplitude, or reflection free.	Grades laterally into pelagic/hemipelagic basinal facies. Extent uncertain.	Giant Foresets Formation (Fig. 2D).

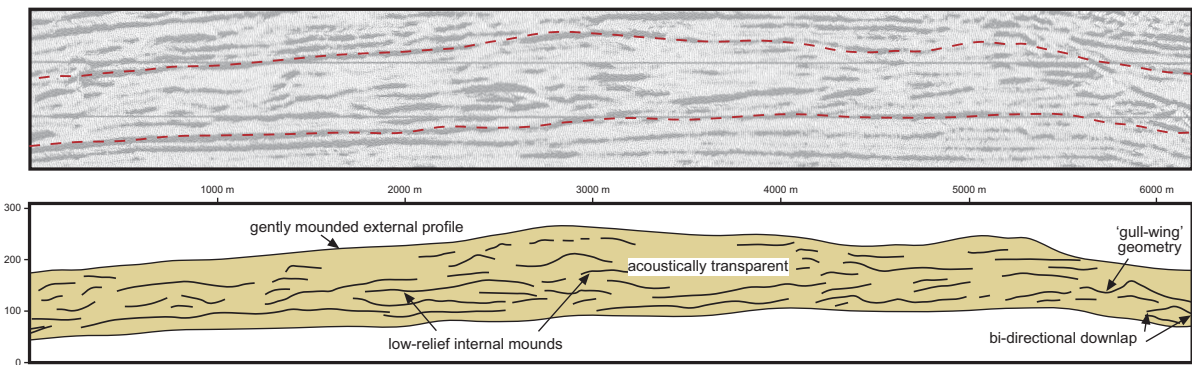**Table 2:** *Seismic characteristics of basin floor fans. See also Fig. 2(A-D).*
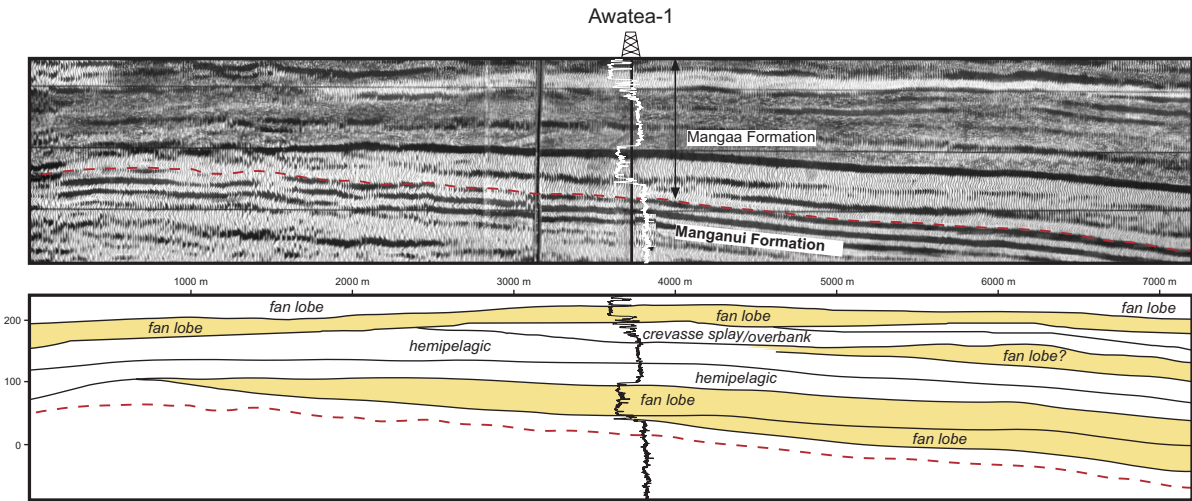
A. Type 1 (Mangaa Formation, seismic reflection profile P95-115; SP log overlay).
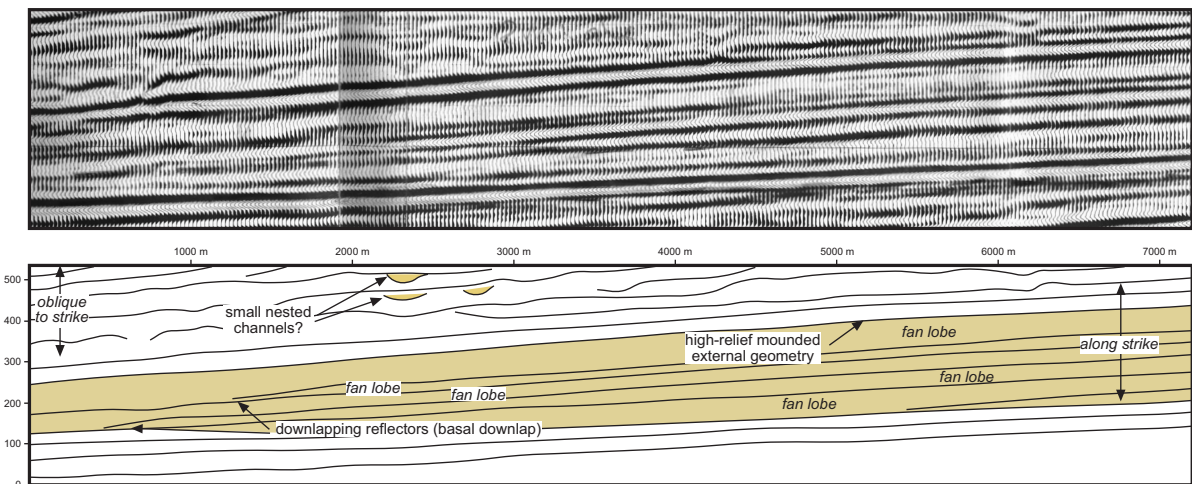
B. Type 2 (western end of seismic reflection profile NM16).

C. Type 3a (seismic reflection profile P95-158).
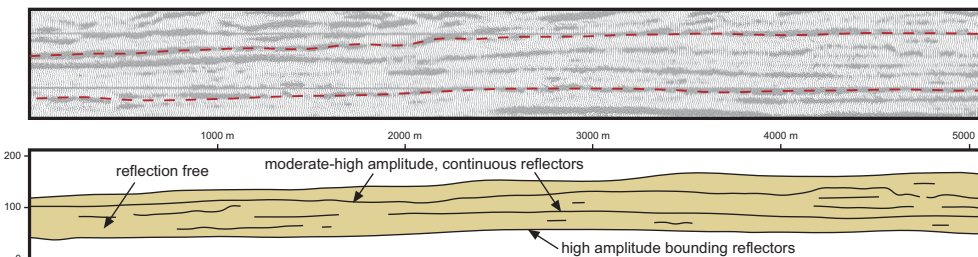
D. Type 3b (seismic reflection profile P95-158). *NB: aerial extent much greater than illustrated.*

Figure 2: *Three main depositional styles and seismic expression of basin floor fans within the northern Taranaki Basin. A. Type 1 fans; B. Type 2 fans; C. Type 3a fans; D. Type 3b fans. Vertical scale in msecs (TWT). Vertical exaggeration = 1.5x.*

Figure 3: *Channel-levee complexes, seismic reflection profile P95-103. Vertical exaggeration = 1.5x.*

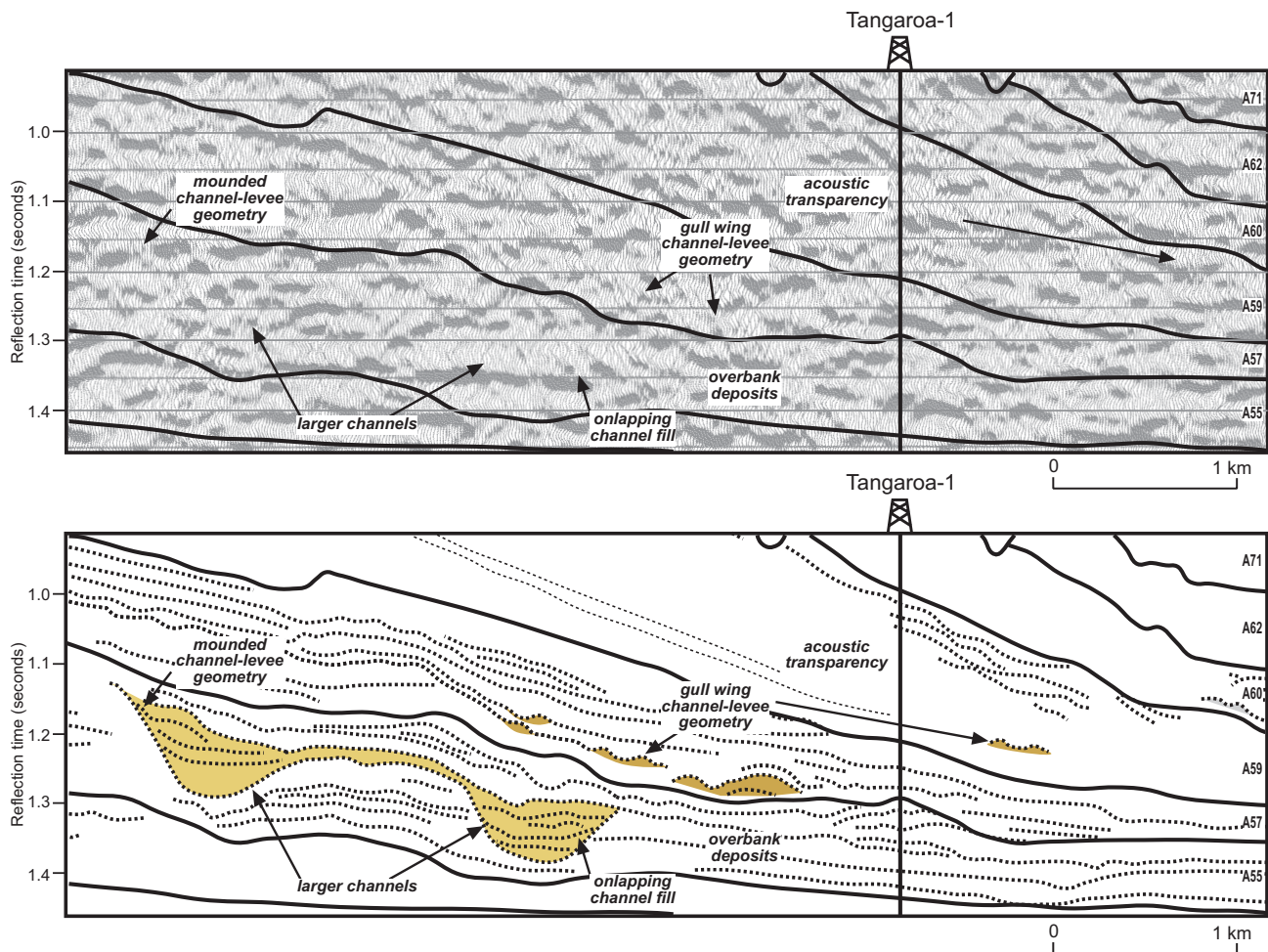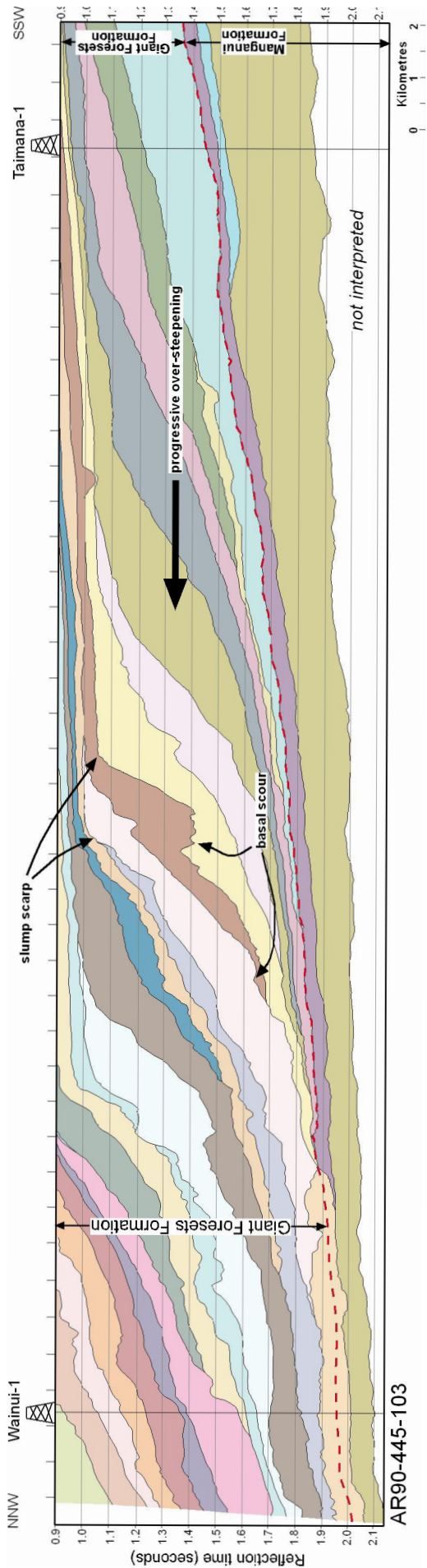slumping are observed in the seismic record. The first involves Late Pliocene (Waipipian to Mangapanian) strata (schematically illustrated in Fig. 4), is confined to a zone with a broad southwest-northeast oriented lineament across the study area, and corresponds to a change in morphology from Type 1 slope fans, to more classically sigmoid clinoform configurations. Within this slumped interval, seismic units progressively over-steepen, until failure at the shelf margin occurs, and slope inclinations re-equilibrate. The seismic units affected typically have variable internal characteristics, including acoustically transparent, chaotic and discontinuous, to subparallel and continuous, moderate amplitude reflector configurations in the mid to upper slope regions, which become more continuous and concordant in the lower slope. Bounding reflectors are often low amplitude and hummocky, and the lower boundary may display arcuate shear planes, indicative of rotational slumping.

A second period of mass wasting occurred during the Early Pleistocene (upper Nukumaruan to Castlecliffian). These slumps are very prominent in the seismic record and are a part of the Giant

Foresets Formation broadly termed 'degradational foresets' (by Beggs, 1990). These units display a range of configurations from reflection free or low amplitude discontinuous reflectors, to moderate or high amplitude, relatively continuous, parallel to subparallel reflectors. Bounding reflector characteristics are similarly variable, ranging from low to high amplitude, and discontinuous to relatively continuous. Occasionally, discrete and coherent blocks, retaining their original tramline reflector configurations, are evident, suggesting that these blocks are shelf-derived. Prominent scarps and basal gouges attest to the erosive nature of these units. Several wireline logs display a broadly barrel-shaped motif (Slumped facies, Table 1), although a general decrease in GR values upward through these degradational units reflects an increasing terrigenous component.

3.4 Other significant architectural elements
Large channel systems, faults, topographic features, and condensed horizons have also impacted significantly on the depositional geometry of the Giant Foresets Formation. Most channel systems occur within the earliest Early Pleistocene (upper

Figure 4: *Schematic interpretation of seismic reflection profile AR90-445-103. Vertical exaggeration = 4x*

Nukumaruan) interval, and are invariably incised into shelf sediment. They display a meandering nature, indicative of the low gradient associated with the shelf (Pickering et al., 1995), and tend to be relatively small-scale, with widths in the order of ten's to hundred's of metres, and less than 100 msecs in depth. They are delineated by truncation of underlying strata, and by distinctive channel-fill configurations.

Faults are prominent on seismic reflection profiles that strike across the Northern Graben and Turi and Cape Egmont Fault Zones. Graben-bounding faults have experienced continued displacement throughout the Pliocene and into the Pleistocene, exerting significant control on the depositional patterns of strata, particularly the distribution of the Mangaa Formation, and later on the thickness and distribution of the Giant Foresets Formation across this zone.

Volcanic complexes (Fig. 1A, after Thrasher et al., 2002) are characterised by low-amplitude, bright, chaotic and discontinuous reflectors on seismic reflection profiles, as well as a clearly mounded profile and onlapping reflector configuration. While volcanism had ceased in northern Taranaki Basin by the Late Miocene, parts of larger complexes were emergent throughout much of the Opoitian, continuing to exert a physical presence into the Pleistocene by restricting or influencing sediment distribution pathways.

Unconformities (hiatuses) are important architectural elements, representing intervals of erosion and/or non-deposition. The Giant Foresets Formation is underlain in many parts across northern Taranaki Basin by a significant condensed section that formed as a result of sediment starvation during the latest Miocene and Early Pliocene (the Ariki Formation). The Ariki Formation and equivalent units are recognised by a distinct arcuate wireline motif and bold, high-amplitude reflectors, and obtains a maximum thickness of 109 m (Ariki-1). Much thinner (a few metres only) condensed intervals occur throughout the Giant Foresets Formation, and are interpreted as representing horizons of partial lithification. These horizons may be associated with changing sedimentary depo-centres, switching fan lobes, or may be due to a rise in

relative sea level (Hansen and Kamp, 2004).

4. Variability in foreset geometry and internal architecture; a changing sedimentary regime

While local tectonism controlled to some extent the depositional patterns and early seismic architecture within northern Taranaki Basin, particularly within the Northern Graben, the change in slope morphology, from the Early Pliocene mounded (Type 2) slope fans in the vicinity of Arawa-1 and Taimana-1, to the classic sigmoidal clinoforms characteristic of the Mangapanian and lower Nukumaruan, and finally the upper Nukumaruan to Recent degradational foreset morphology, can be related in great part to a change in the sedimentary regime thorugh time. The Early Pliocene mounded Type 2 fans were dominated by siltstone and mudstone lithologies, with several coarser intervals in lower parts of the succession, suggesting a mixed mud/sand-rich depositional system (after Reading and Richards, 1994), possibly fed by a single point source feeder system (Fig. 5A). Type 1 fans associated with the Mangaa Formation are likewise typical of a single point source feeder system.

The gradual traslation to a more mud-rich system, with progressive oversteepening of Late Pliocene (Waipipian and Mangapanian; Fig. 5B) foreset strata, is possibly related to a widening shelf and the consequent capture of coarse siliciclastic sediment closer to shore, or by high efficiency (after Mutti and Normark, 1987) muddy turbidity currents and flows transporting any available sand significant distances away from the base of the slope. Chaotic- to reflection-free internal configurations consistent with slumping and the predominance of slump scarps are similarly suggestive of a mud-rich line-source slope apron system with an increasing sediment supply.

A predominance of finer-grained lithologies is associated with sigmoidal clinoforms. This dominance of muddy lithologies is typical of passive margin basins with wide shelves and high sediment flux. Sediment bypassing rather than prograding fan construction, and the absence of significant vertical aggradation associated with progradational clinoforms, similarly implies high rates of sedimentation (Adams et al. 1998; Bouma, 2000). Channel-levee complexes become more common in mud-rich systems (Emery and Myers, 1996). Distribution patterns also change with a change in external morphology, from the lobate pattern of the large mounded Type 1 and 2 fans, to an elongate prism of slope sediment (slope apron;

Galloway, 1998) oriented parallel to depositional strike (Fig. 5C,D), indicating that sediment was efficiently distributed along strike. This also reflects the decreasing influence of local tectonics.

Several channel systems are also associated with Pleistocene (upper Nukumaruan to Castlecliffian) degradational strata which, coupled with the coarser lithologies associated with these units, reflects a change back from the mud-rich system of underlying units to a mixed mud/sand-dominated system. However, this latter change may indicate that the paleo-shoreline migrated much closer to the shelf edge during Pleistocene low sea level conditions, and possibly even reached it, with a greater influence of relative sea level change on the shelf break due to regional shallowing. It also in part reflects higher energy shelfal conditions (water depths shallowed considerably through the Nukumaruan), and a higher proportion of coarse siliciclastic sediment delivered to the shelf edge.

5. Depositional architecture and implications for sequence stratigraphy

Detailed examination of part of a single seismic reflection profile (P95-103; Fig. 6A) allows examination of the depositional architecture of the Giant Foresets Formation, and interpretation of part of the Pliocene and Pleistocene succession to be considered in terms of classic Exxon-type sequence stratigraphic concepts.

5.1 Sequence boundaries
Squence boundaries are identified on the basis of several criteria:
(a) occurrence of bold, high amplitude reflectors that are relatively continuous from shelf to basin floor;
(b) onlap of strata onto the lower sequence boundary;
(c) erosional trucation of strata;
(d) the identification of slumps and/or basin floor fans (which most frequently occur during lowstand sea level conditions, and are often underlain by the lower sequence boundary).

5.2 Sequence architecture
Modern sequence stratigraphy has moved on from the classic Vail (1987) sequence stratigraphic model, with more recent studies (e.g., Galloway, 1989; Posamentier and Allen, 1993) recognising that the variability in processes and depositional products of deep marine settings means that sequence stratigraphy must be viewed as a tool or approach rather than a rigid template. Particularly important in any sequence
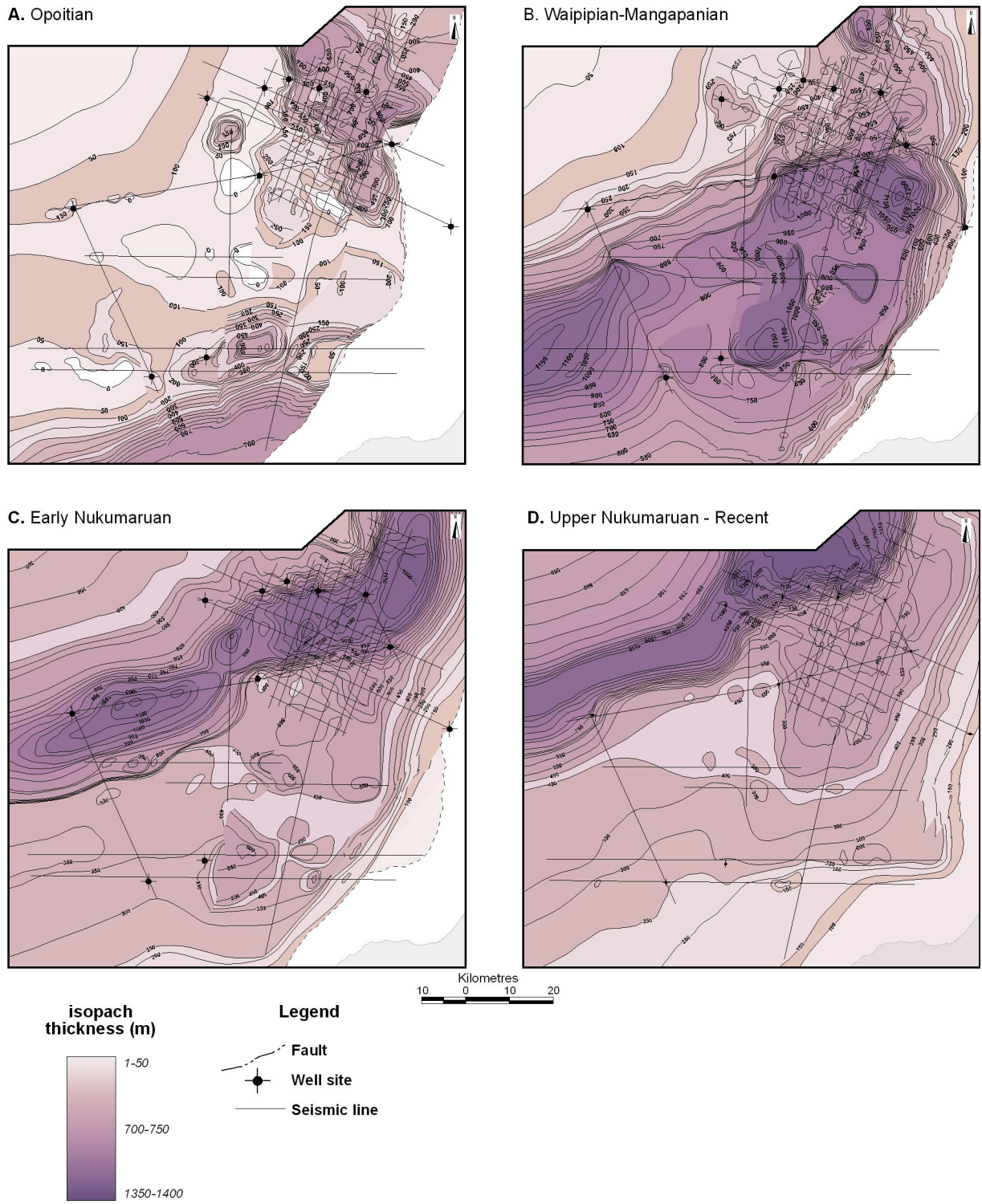
A. Opoitian

B. Waipipian-Mangapanian

C. Early Nukumaruan

D. Upper Nukumaruan - Recent

Kilometres

10   0   10   20

isopach thickness (m)

1-50

700-750

1350-1400

Legend

Fault

Well site

Seismic line

**Figure 5:** *Isopach maps for northern Taranaki Basin.*

stratigraphic model is local physiography, tectonics, frequency and magnitude of sea level fluctuations and the type and rate of sediment supply (Posamentier and James, 1993; Emery and Myers, 1996). Thus few depositional systems and stratal architectures conform entirely to the block diagrams presented in Posamentier et al. (1988).

Figure 6B illustrates several seismic sequences within latest Pliocene to Early Pleistocene (Nukumaruan) sigmoidal clinoforms. These sequences are delineated by concordant reflectors from shelf to slope, occasional onlap, but more notably, by the architectural elements contained within foreset strata. Often, the sequence boundary underlies Type 3a basin floor fans, which sometimes display bi-directional downlap onto the
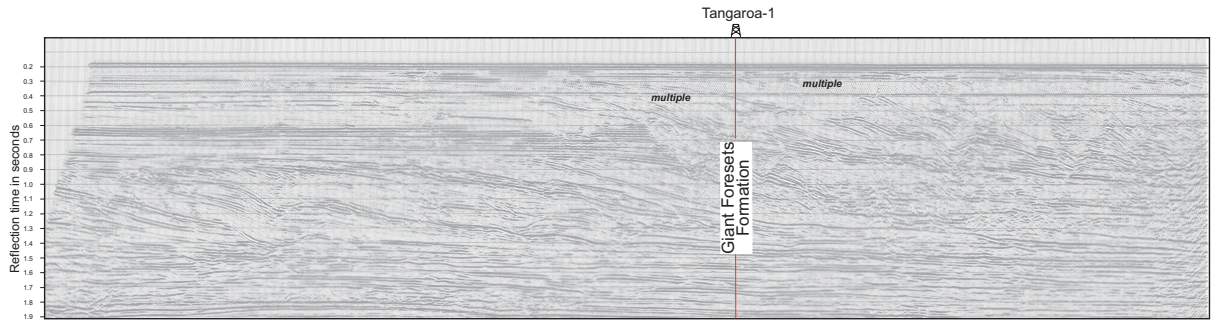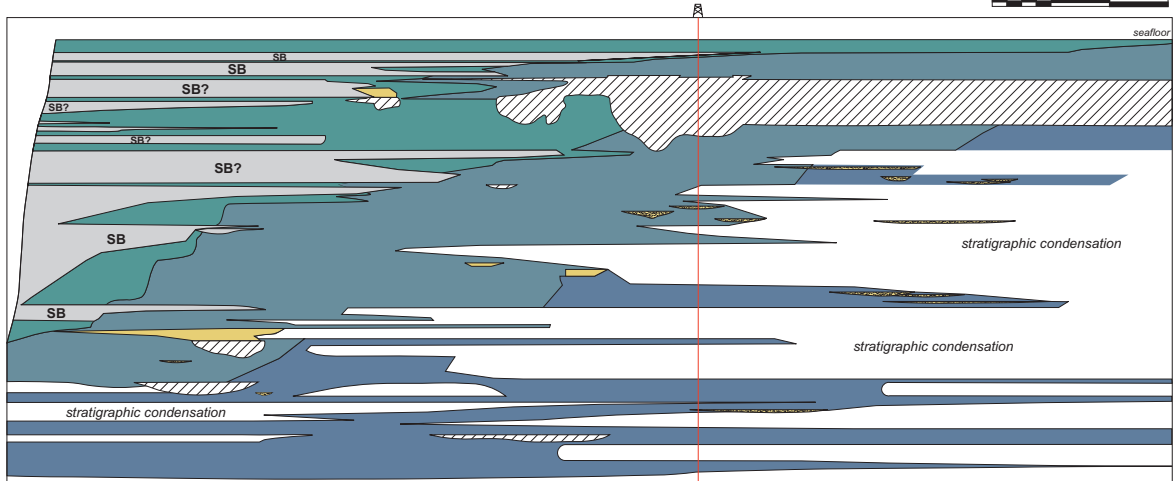
A. Seismic reflection profile P95-103, uninterpreted
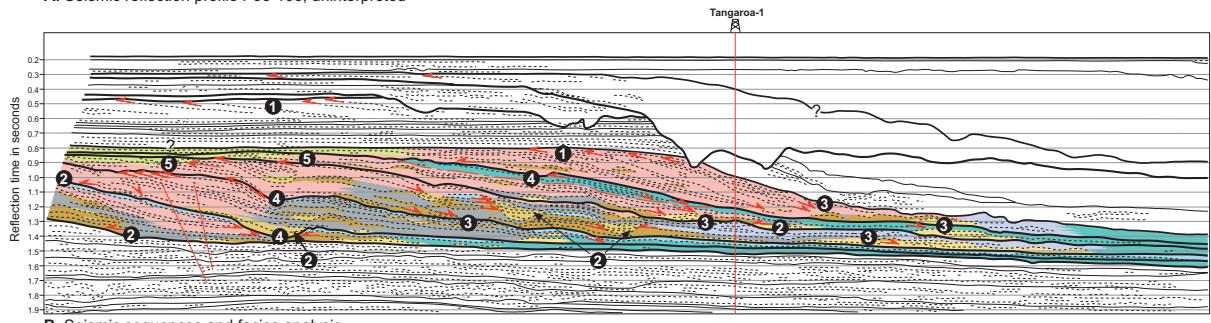
B. Seismic sequences and facies analysis.

C. Chronostratigraphic interpretation (wheeler diagram) of line P95-103.

Legend for B

Sequence boundary configurations

toplap	❶
onlap (channel fill and SB)	❷
downlap	❸
erosional truncation	❹
concordance (slope roll-over)	❺
apparent truncation	
reflector terminations	
seismic unit	A70

internal configurations

basin floor fan facies	
channel-levee complexes	
- slope channels	
- channel-levees	RST/LST
- overbank deposits	
prograding wedge/slope delta fan	
mass emplaced units	
basin floor (bottomsets) facies	
shelf (topsets) facies	TST/HST
hemipelagic drape	

Legend for C

Unconformity - approximate position of sequence boundary	
Topsets (shelf facies)	
Foresets (clinoforms)	
Slope channel fill	
Bottomsets	
Basin floor fans	
Marine condensation	
Erosion due to truncation/channel incision	

Figure 6: *Interpretation of seismic reflection profile P95-103 (A), showing dominant architectural elements associated with sigmoidal clinoforms, and correlative systems tracts (B). A chronostratigraphic reconstruction (Wheeler diagram) highlights the asymmetry of the sequences.*

lower sequence boundary, or Type 3b fans which grade conformably into hemipelagic basinal facies. Stacked channel-levee complexes, separated by the subparallel reflectors of overbank deposits, are common in the mid to upper slope region. Only in a few sequences do we see prominent downlapping reflectors that are interpreted to represent the prograding wedge. The basin floor/slope fans and channel-levee complexes are inferred to comprise the RST/LST component of a relative sea level curve, while the prograding wedge is inferred to have been deposited during low sea level (LST) and the early part of subsequent sea level rise.

Foreset (slope) facies contain very thin deposits relating to rising and high sea level conditions. The transgressive systems tract component (TST) is unable to be separated from the highstand systems tract component (HST), and may be represented by a single reflector only, although on the shelf, the TST/HST may be up to 50 msecs thick. Consequently the HST (and TST?) are time-rich relative to the RST/LST. The thickness of the TST/HST on the shelf is a function of topset accommodation volume, which in turn is a function of the magnitude of (relative) sea level rise multiplied by the topset area (Milton and Bertram, 1995). The wide northern Taranaki Basin shelf, being widest during maximum sea level transgression, created enough space on the shelf to accommodate all transgressive and highstand sediment so that no sediment, or very little, reached the slope and basin floor during TSTs and HSTs. This has resulted in a highly asymmetric sequence architecture, which is further highlighted in Fig. 6C, being a chronostratigraphic interpretation of seismic reflection profile P95-103 (Fig. 6A). This analysis clearly shows a predominance of foreset (slope) facies, limited bottomset facies (although several small-scale basin floor fans are evident), and much stratigraphic condensation associated with sequence boundaries. It also illustrates the progradational nature of the foreset facies, and the degree of erosion associated with the degradational foreset facies.

6. Implications for reservoir architecture and characterisation

While the Giant Foresets Formation has never been the target of active hydrocarbon exploration in Taranaki Basin, some 15% of the worlds oil reserves occur in clastic-dominated hydrocarbon systems (Richards et al., 1998). It is useful therefore to identify the variability that exists within and between depositional basins. Comparison with the mud-dominated Mississippi Fan, Gulf of Mexico, suggests that possible reservoir facies may be contained within channel sands, unchannelised channel lobes, potentially sand-prone levees immediately adjacent to initial channels, and limited parts of mass transport (slumped) complexes (Weimer, 1990).

Although the Mississippi Fan is a large submarine delta-fan fed by a single point source (Mississippi River), and the Giant Foresets Formation is a progradational margin with a defined slope apron and probable linear feeder system, the similarity and dominance of architectural elements between the two systems, the shape of the clinoforms, and the amplitude and character of internal seismic reflections encountered, impart some degree of predictability as to the dominant lithology (i.e., mud, mixed mud/sand, sand) one might expect to encounter in a progradational system. The potential for hydrocarbon entrapment in these systems will thus rest predominantly on which type of architectural elements were present or dominant in the depositional system, at the right time (in terms of generation and charge), with reservoirs including such elements as (major) channel-fill sands, sands within slope channel or overbank deposits, and slope-disconnected basin floor fans.

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