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Short Paper

Timing of the late-glacial climate reversal in the Southern Hemisphere using high-resolution radiocarbon chronology for Kaipo bog, New Zealand

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Abstract

The pattern of climate change in the Southern Hemisphere during the Younger Dryas (YD) chronozone provides essential constraint on mechanisms of abrupt climate change only if accurate, high-precision chronologies are obtained. A climate reversal reported previously at Kaipo bog, New Zealand, had been dated between 13,600 and 12,600 cal yr B.P. and appeared to asynchronously overlap the YD chron, but the chronology, based on conventionally radiocarbon-dated bulk sediment samples, left the precise timing questionable. We report a new high-resolution AMS ^{14}C chronology for the Kaipo record that confirms the original chronology and provides further evidence for a mid-latitude Southern Ocean cooling event dated between 13,800 and 12,400 cal yr B.P. (2σ range), roughly equivalent to the Antarctic Cold Reversal.
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Keywords: Late-glacial; Climate reversal; Abrupt climate change; Younger Dryas; Antarctic Cold Reversal; Interhemispheric asynchrony; Radiocarbon dating; Tephrochronology; Wiggle matching; High-resolution palynology; Kaipo bog; New Zealand

Introduction

The Younger Dryas (YD) chronozone, a millennium-long cooling event ca. 12,700–11,500 cal yr B.P. that interrupted the transition from the last glacial to present interglacial (Holocene) period, is perhaps the best-documented example of abrupt climate change during the Quaternary. Two conflicting hypotheses have been proposed to explain such events. One invokes re-organisation of the ocean's thermohaline circulation, caused by catastrophic release of glacial meltwater into the North Atlantic Ocean (Broecker, 1998). This model predicts that patterns of climatic change in much of the Southern Hemisphere should be out of phase or asynchronous with abrupt climate events in the Northern Hemisphere, as appears to be shown by most Antarctic ice core records (Blunier et al., 1998). The other model proposes that changes in the dynamics of the tropical atmosphere–ocean system should result in essentially instantaneous climate response around the globe (Cane and Clement, 1999) and has been invoked to explain reported synchronous in-phase YD cooling in the Southern Hemisphere (Andres et al., 2003; Denton and Hendy, 1994; Lowell et al., 1995; Morigi et al., 2003).

Kaipo bog tephropalynological record

The pollen record at Kaipo bog from ~1000-m elevation near treeline in northeastern New Zealand was unusual in depicting an early, ~1000 year-long cooling event that interrupted deglacial warming in the region (Newnham and Lowe, 2000). Previously, terrestrial records from New Zealand had shown either no deglacial cooling event (Singer et al., 1998) or one that seemed essentially synchronous with the YD cooling of the Northern Hemisphere (Denton and Hendy, 1994). At Kaipo, the cooling overlapped the latter part of the Antarctic Cold Reversal (ACR, ca. 14,500–12,500 cal yr B.P.) and the early part of the YD chron. Based on the original chronology (Newnham and Lowe, 2000), the late-glacial climate reversal, detected as a decline in tree and shrub pollen

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relative to grass pollen and a concomitant decline in carbon content, occurred at 11,600 ^{14}C yr B.P. (ca. 13,600 cal yr B.P.), about 200 years after deposition of Waiohau Tephra. This estimate was based on linear interpolation from the estimated age of the Waiohau Tephra at ca. 13,800 cal yr B.P. (Lowe et al., 1999). The end of the 1000-yr-long cold reversal, marked by resumption of peat accumulation at the site and sustained increase in the tree/shrub pollen relative to grass ratio, was dated at ca. 12,600 cal B.P., based on ^{14}C ages of 10,790 ± 70 ^{14}C yr B.P. (Wk-5162) and 10,600 ± 90 ^{14}C yr B.P. (Wk-263) and also constrained by independently dated tephra layers above the point of change (Newnham and Lowe, 2000).

Subsequent work elsewhere in the Southern Hemisphere has shown a similar pattern to that in the Kaipo bog record such as the cold reversal recorded in Huelmo mire (Chile) and in Mascardi lake sediments (Argentina) (Hajdas et al., 2003), thus indicating that this event was more widespread than initially thought. New pollen records from two New Zealand sites (Kettlehole, Otamangakau), both at ~600 m elevation, also showed a similar "early" reversal (Turney et al., 2003; McGlone et al., 2004), the start of cooling at Otamangakau being marked approximately by the Waiohau Tephra isochron.

New chronology from Kaipo bog

Dating the Kaipo sequence

The original Kaipo bog chronology was considered to be sound, comprising 34 stratigraphically coherent tephrochronological (n = 14) and radiometric ages (n = 20) spanning the interval from Rerewhakaaitu Tephra (14,700 ^{14}C yr B.P.) to Waimihia Tephra (3230 ^{14}C yr B.P.). Comparatively large standard errors for the conventionally radiocarbon-dated bulk sediment samples (reported in Lowe et al., 1999), however, left assertions regarding the precise timing of events open to question. Consequently, we have obtained a further 20 AMS-derived radiocarbon ages from peat between Rerewhakaaitu Tephra and Opepe Tephra (9050 ^{14}C yr B.P.), thereby providing a high-precision, fine-resolution chronology for the interval 14,700 to 3000 ^{14}C yr B.P. in the Kaipo bog profile (Table 1). In total, therefore, this sequence comprises 51 independently dated points, approximately one point per 230 ^{14}C-years on average (Table 1). The younger sediments in this range were sampled to provide a longer overlap with the tree-ring based radiocarbon calibration curve, which extends to 12,400 cal yr B.P.

Bulk fine peat or peaty mud samples, free of visible roots, from between depths 80 and 252 cm (depths are reported on a tephra-free basis; Table 1) were prepared for radiocarbon dating at the ETH AMS facility, Zurich. Samples were replicates from the same set used to construct the high-resolution pollen diagrams of Newnham and Lowe (2000). After drying at 80°C for 2–3 days, samples were cooled in a desiccator, ground to <200 μm, cleaned using a modified ABA procedure with longer treatments than usual (12–24 h), and converted to graphite (Hajdas et al., 2004). Measured ^{14}C/^{12}C and ^{13}C/^{12}C ratios (Bonani et al., 1987) were used to calculate conventional (Libby) ^{14}C ages following Stuiver and Polach (1977) (Table 1).

All 51 age points for Kaipo bog (i.e., new, previous, and tephrochronological ages) were corrected for Southern–Northern Hemisphere offset of calibration curves (McCormac et al., 2002) and together wiggle-match fitted against the INTCAL04 calibration curve (Reimer et al., 2004) via the OxCal (version 3.10) sequence calibration (Bronk Ramsey, 2001) (Fig. 1). OxCal uses a Bayesian approach that incorporates known parameters into the fitting procedure (MCMC). In our case, the known stratigraphy—age superposition with depth—defined the fitting procedure. This procedure resulted in reduced errors for calibrated ages and gave a continuous sequence of calendar ages independent of ^{14}C age plateaux or wiggles. Several reversals in the conventional ^{14}C ages are not apparent in the calibrated ages obtained by this procedure, in particular in the sequence of ages at depths 231–230 cm and those at 223–213 cm, excluding the outlier at 227 cm (Wk-264) obtained previously (Table 1; Fig. 1). This calibration pattern suggests that the reversals of the conventional ^{14}C ages are a product of variations in atmospheric ^{14}C content that have been successfully accounted for by the calibration procedure. We cannot exclude an alternative explanation, however, that the ^{14}C age reversals reflect minor contamination by older carbon resulting, presumably, from reworking of soils in the catchment (cf. Newnham and Lowe, 2000).

The model indicated low probabilities of fit for three ages, which are described as outliers (Table 1). One of the outliers is that for Waiohau Tephra, erupted several centuries prior to the onset of cooling (Newnham and Lowe, 2000). Originally reported by Froggatt and Lowe (1990), the error-weighted mean age for Waiohau Tephra is 11,850 ± 60 ^{14}C yr B.P. (n = 12). Based on Wk-5403, which immediately overlies Waiohau Tephra, it is possible that this error-weighted mean age is too young. Low probabilities of fit were also obtained for Wk-264 and ETH-27743. The latter was obtained on a small sample (~0.5 mg) that had a very low carbon content (~0.8%). Even if these three points were included in the calendar-age model derived in Table 1, they would fall within the dating errors for the sequence and so have little effect on the whole chronology.

Revised calendar dates for Kaipo palynological cooling event

The cooling event observed in the pollen record began at around depth 228 cm (tephra-free basis), immediately above 'peaty mud layer A' near the base of the grey mud unit of Newnham and Lowe (2000). Based on our new chronology (Figs. 1 and 2; Table 1), this point is dated (2σ range) between 13,820 and 13,590 cal yr B.P. (12,030 ± 90 ^{14}C yr B.P., ETH-27740, 230 cm depth). The cooling event ended ~1000 years later at around 182 cm depth at the top of the grey mud unit, this point being dated (2σ range) between 12,780 and 12,390 cal yr B.P. (10,790 ± ^{14}C yr 70 B.P., Wk-5162) or 12,800 to 12,430 cal yr B.P. (10,600 ± 90 ^{14}C yr 70 B.P., Wk-263). We recognise that the calibration of records from the Southern Hemisphere has additional sources of error arising from

Table 1
Complete set of conventional radiocarbon ages (±1σ)[a] and their sampling depths (tephra-free basis) in Kaipo bog sequence, and corresponding calendar ages (2σ range)[b] derived from wiggle-matching using OxCal with the INTCAL04 calibration curve (see text)

Lab number or tephra	Depth (cm)	Conventional age (^{14}C yr B.P.)	±1σ ^{14}C age	δ^{13}C	±1σ δ^{13}C	Calendar age ranges (cal yr B.P.)
Wk-499/500	23	3000[c]	33	−21.6[c]	0.2	3260–2870
Waimihia (n = 17)	24	3230	20			3450–3370
Wk-498	25	3250	70	−26.4	0.2	3620–3380
Unit-K (n = 13)	35	4510	42			5270–4970
Wk-496/497	36	4509[c]	20	−26.7[c]	0.2	5290–5040
Whakatane (n = 21)	38	4830	20			5590–5470
Wk-501	39	4860	70	−26.4	0.2	5720–5480
Tuhua (n = 10)	41	6130	30			7160–6850
Mamaku (n = 22)	44	7250	20			8050–7960
Wk-4413	45	7380	70	−26.4	0.2	8330–8010
Rotoma (n = 45)	56	8530	10			9530–9480
Wk-492	77	8710	80	−26.7	0.2	9900–9520
Opepe (n = 10)	78	9050	40			10,230–9920
ETH-27724	80	8990	70	−24.3	1.2	10,250–9970
ETH-27726	100	9510	70	−28.2	1.2	10,890–10,510
ETH-27727	119	9795	75	−27.6	1.2	11,150–10,760
Wk-491	125	9560	80	−27.0	0.2	11,180–10,840
Poronui (n = 3)	126	9840	60	−29.0	0.2	11,270–11,110
Wk-351/352	127	10,024[c]	93	−29.1[c]	0.2	11,350–11,180
ETH-27728	135	9840	75	−26.9	1.2	11,400–11,200
Karapiti (n = 2)	140	10,030	90			11,600–11,220
ETH-27729	148	10,290	70	−24.7	1.2	11,780–11,390
Okupata (n = 3)	155	10,080	60			11,810–11,430
Konini (n = 4)	161	10,150	50			11,940–11,500
Wk-5404/NZA7751[d]	163	10,146	76	−29.1	0.2	11,980–11,630
ETH-27731	176	10,140	75	−28.7	1.2	12,080–11,700
Wk-5162	181.5	10,790	70	−30.0	0.2	12,780–12,390
Wk-263	182	10,600	90	−29.6	0.2	12,800–12,430
ETH-27732	184	10,640	75	−27.8	1.2	12,840–12,600
ETH-27733	185	10,900	75	−27.1	1.2	12,940–12,780
ETH-27734	186	11,120	80	−26.8	1.2	13,130–12,880
ETH-27735	194	11,320	80	−25.5	1.2	13,290–13,030
ETH-27736	204	11,540	80	−24.3	1.2	13,430–13,190
Wk-5164	212	11,360	210	−31.8	0.2	13,530–13,240
ETH-27737	213	11,800	80	−29.9	1.2	13,610–13,380
ETH-27738	214	11,730	85	−30.0	1.2	13,660–13,430
ETH-27739	223	11,620	85	−31.2	1.2	13,710–13,470
Wk-264	227	11,500[g]	80	−29.1	0.2	13,470–13,150
ETH-27740	230	12,030	90	−30.1	1.2	13,820–13,590
ETH-27741	230.5	11,940	85	−29.1	1.2	13,870–13,640
ETH-27742	231	11,830	85	−31.0	1.2	13,930–13,680
Wk-5403	233	12,180	260	−31.1	0.2	14,300–13,750
Waiohau (n = 12)	235	11,850[g]	60			13,800–13,470
ETH-27743	236	11,660[g]	100	−21.1	1.2	13,710–13,270
Wk-4414	236.5	12,420	90	−28.4	0.2	14,550–13,950
ETH-27744	243	12,240	85	−27.8	1.2	14,700–14,000
ETH-27745	252	12,610	85	−26.4	1.2	15,150–14,300
Rotorua (n = 10)[e]	261	13,080	50			15,750–15,100
Wk-5163	269	13,420	80	−31.2	0.2	16,350–15,500
Wk-5165	278.5	14,700	160	−30.5	0.2	17,950–16,850
Rerewhakaaitu (n = 4)[f]	281	14,700	95			18,050–17,200

[a] These comprise new AMS ages (ETH series, this study), previous radiometric ages (Wk series), and the error-weighted mean ages (based on n determinations) for named tephras (Lowe et al., 1999; Newnham and Lowe, 2000). δ^{13}C (±1σ) values were used to correct for fractionation effects (Bonani et al., 1987; Hogg et al., 1987).
[b] Before calibration, ages were uniformly corrected for offsets of 41 ± 14 years between Northern and Southern hemispheres (McCormac et al., 2002).
[c] Mean value of two measurements (two dates from same sample).
[d] Dual numbers applying to single date.
[e] This tephra, mis-identified at Kaipo bog as Puketarata Tephra by Lowe et al. (1999), was re-identified as Rotorua Tephra by Shane et al. (2003).
[f] Error-weighted mean age from Newnham et al. (2003).
[g] Outlier, calendar age obtained from the calibration.

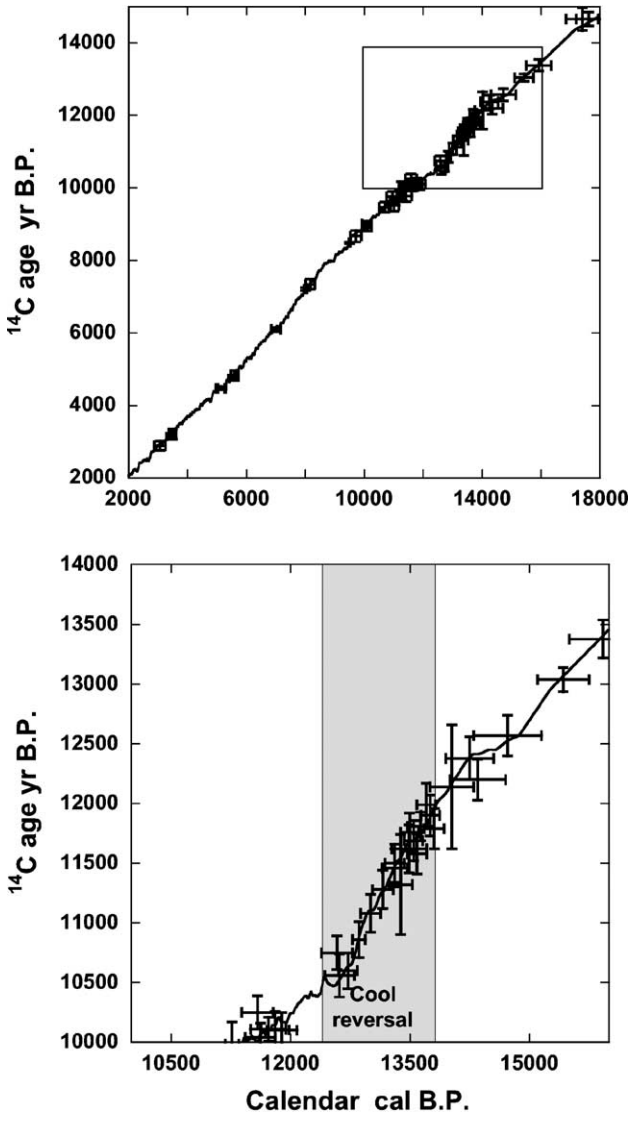

Figure 1. Combined age dataset (including independent tephrochronological ages) from Kaipo bog late-glacial and part-Holocene sequence wiggle-match fitted using OxCal to calibration curve INTCAL04 (minus outliers, Table 1). Radiocarbon ages are plotted with 2σ error, calendar ages correspond to 2σ ranges. Lower panel shows a close up of the late-glacial interval (rectangle). The cool reversal period, defined by palynology (see text and Fig. 2), is marked.

unknown variability in the offset between atmospheric ^{14}C content of hemispheres (McCormac et al., 2004) and from possible changes in reservoir ages of the Cariaco Basin calibration data set (Kromer et al., 2004). As well, additional high-resolution dating of the Kaipo peat section, and specifically of Waiohau Tephra, may reduce further the errors applying to the timing of cooling onset.

The close agreement between the ages of the independently-dated tephra layers (excluding Waiohau), the new ^{14}C AMS dates, and the previous radiometric dates shows that the sequence is free of any reservoir effect. Furthermore, because all samples were pretreated by prolonged ABA then any inorganic carbon, had it been present, would have been removed. The use of fine peat implies that few or no rootlets were present that might have led to contamination by younger carbon. In any event, an earlier study by Lowe and Hogg (1986) at Kaipo bog demonstrated that dates obtained on roots and residual fine peat fractions on two sample pairs (Wk-499, Wk-500; Wk-351, Wk-352) were identical and consistent with the tephrochronological ages, implying that no contamination had occurred. Also, our experience has shown us that thick tephra layers within peat prevent roots from penetrating through the profile (e.g., Newnham et al., 1995). Therefore, we are confident that our chronology reflects the atmospheric ^{14}C content during the late-glacial and part Holocene period and reliably constrains the timing of the Kaipo cold reversal to between 13,800 and 12,400 cal yr B.P. (2σ range).

Revised tephra isochron ages

The new wiggle-match age model derived for the Kaipo sequence allows new calendar ages to be assigned to the tephra layers. Previously, calendar ages had been estimated by simply calibrating the error-weighted mean ages associated with each tephra, as reported by Lowe et al. (1999). However, the new age model allows more robust calendar ages—reported using age ranges rather than error terms—to be interpolated from the wiggle-matched calibration curve via tephra depths. New calendar ages (cal yr B.P., 2σ ranges) assigned to the late-glacial and early Holocene tephras at Kaipo are as follows: Rerewhakaaitu 18,050–17,200, Rotorua 15,750–15,100, Waiohau 13,800–13,470, Konini 11,940–11,500, Okupata

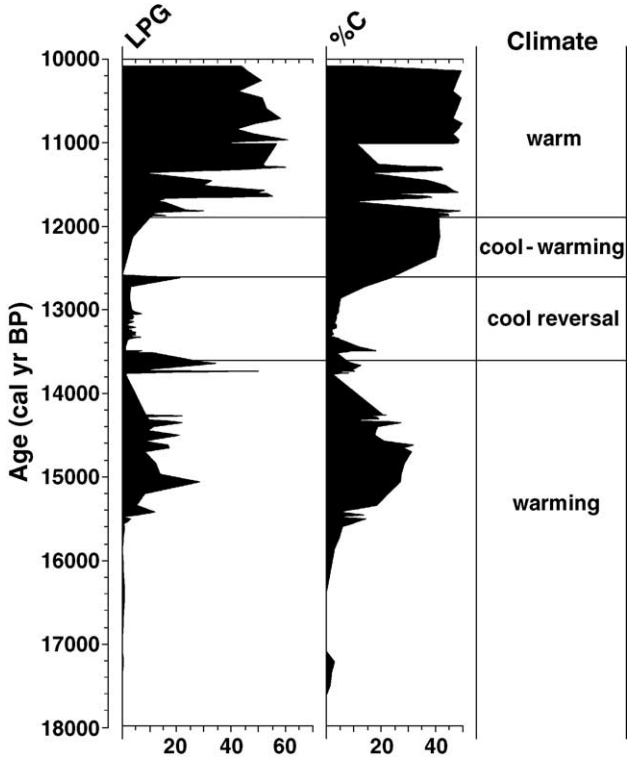

Figure 2. Ratio of lowland podocarp to grass pollen (LPG) and carbon abundance (C %) curves from Kaipo bog sequence plotted against the new chronology reported here. The cool reversal occurred from ca. 13,600 to 12,600 cal yr B.P. using midpoints of age ranges or from 13,800 to 12,400 cal yr B.P. using 2σ age ranges. Conditions remained cool but warming until ca. 11,900 cal yr B.P.

11,810–11,430, Karapiti 11,600–11,220, Poronui 11,270–11,110, and Opepe 10,230–9920. New calendar age estimates on the later Holocene tephras in the sequence, less well constrained because of fewer tie-points to the calibration curves, are provisionally as follows (cal yr B.P., 2σ ranges): Rotoma 9530–9480, Mamaku 8050–7960, Tuhua 7160–6850, Whakatane 5590–5470, Unit-K 5270–4970, and Waimihia 3450–3370.

Discussion and conclusion

The new chronology for the Kaipo bog sequence, based on a wiggle-match fit to the INTCAL04 calibration curve, differs little from the original chronology published by Newnham and Lowe (2000). The Kaipo cooling event as indicated by palynology occurred between 13,800 and 12,400 cal yr B.P. (2σ range), in agreement with the previous estimation. This timing corresponds closely to the coolest phase of the ACR from the Byrd and Law Dome ice cores (Blunier and Brook, 2001; Morgan et al., 2002), though the onset of the Kaipo reversal seems to postdate the onset of the ACR (ca. 14,500 cal yr B.P.) by ca. 700 cal years. The initiation of cooling matches that recorded for speleothems from the South Island of New Zealand at ca. 13,600 cal yr B.P., though the speleothem records indicate that cooling persisted to ca. 11,600 cal yr B.P. (Williams et al., 2005). This apparent difference in timing of the end of cooling may reflect spatial differences in climate response, variable sensitivity to climate response between the different proxies or, more simply, the subjective nature of choosing climatic boundaries between events.

The end of the cold reversal and resumption of warming at Kaipo bog coincides (within a few hundred years) with the onset of YD cooling in the Northern Hemisphere. These results provide further support for interhemispheric asynchrony in abrupt climate change and indicate that the antiphased relationship observed between polar ice-core records may extend to the southern mid-latitudes.

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References

Andres, M.S., Bernasconi, S.M., McKenzie, J.A., Rohl, U., 2003. Southern Ocean deglacial record supports global Younger Dryas. Earth and Planetary Science Letters 216, 515–524.

Blunier, T., Brook, E.J., 2001. Timing of millennial-scale climate change in Antarctica and Greenland during the last glacial period. Science 291, 109–112.

Blunier, T., Chappellaz, J., Schwander, J., Dallenbach, A., Stauffer, B., Stocker, T.F., Raynaud, D., Jouzel, J., Clausen, H.B., Hammer, C.U., Johnsen, S.J., 1998. Asynchrony of Antarctic and Greenland climate change during the Last Glacial period. Nature 394, 739–743.

Bonani, G., Beer, J., Hofmann, H., Synal, H.A., Suter, M., Wölfli, W., Pfleiderer, C., Junghans, C., Münnich, K.O., 1987. Fractionation, precision and accuracy in ^{14}C and ^{13}C measurements. Nuclear Instruments and Methods in Physics Research B29, 87–90.

Broecker, W.S., 1998. Paleocean circulation during the last deglaciation: a bipolar seesaw? Paleoceanography 13, 119–121.

Bronk Ramsey, C., 2001. Development of the radiocarbon calibration program OxCal. Radiocarbon 43, 355–363.

Cane, M.A., Clement, A.C., 1999. A role for the tropical Pacific coupled ocean–atmosphere system on Milankovitch and millennial timescales: global impacts. In: Clark, P.U., Webb, R.S., Keigwin, L.D. (Eds.), Mechanisms of Global Climate Change at Millennial Time Scales. American Geophysical Union, Washington DC, pp. 373–383.

Denton, G., Hendy, C.H., 1994. Younger Dryas age advance of Franz Josef Glacier in the Southern Alps of New Zealand. Science 264, 1434–1437.

Froggatt, P.C., Lowe, D.J., 1990. A review of late Quaternary silicic and some other tephra formations from New Zealand: their stratigraphy, nomenclature, distribution, volume, and age. New Zealand Journal of Geology and Geophysics 33, 89–109.

Hajdas, I., Bonani, G., Moreno, P.I., Ariztegui, D., 2003. Precise radiocarbon dating of late-glacial cooling in mid-latitude South America. Quaternary Research 59, 70–78.

Hajdas, I., Bonani, G., Thut, J., Leone, G., Pfenninger, R., Maden, C., 2004. A report on sample preparation at the ETH/PSI AMS facility in Zurich. Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 223–224, 267–271.

Hogg, A.G., Lowe, D.J., Hendy, C.H., 1987. University of Waikato radiocarbon dates I. Radiocarbon 29, 263–301.

Kromer, B., Friedrich, M., Hughen, K.A., Kaiser, F., Remmele, S., Schaub, M., Talamo, S., 2004. Late glacial ^{14}C ages from a floating, 1382-ring pine chronology. Radiocarbon 46, 1203–1209.

Lowe, D.J., Hogg, A.G., 1986. Tephrostratigraphy and chronology of the Kaipo Lagoon, an 11,500-year-old montane peat bog in Urewera National Park, New Zealand. Journal of the Royal Society of New Zealand 16, 25–41.

Lowe, D.J., Newnham, R.M., Ward, C.M., 1999. Stratigraphy and chronology of a 15 ka sequence of multi-sourced silicic tephras in a montane peat bog, eastern North Island, New Zealand. New Zealand Journal of Geology and Geophysics 42, 565–579.

Lowell, T.V., Heusser, C.J., Andersen, B.G., Moreno, P.I., Hauser, A., Heusser, L.E., Schluchter, C., Marchant, D.R., Denton, G.H., 1995. Interhemispheric correlation of Late Pleistocene glacial events. Science 269, 1541–1549.

McCormac, F.G., Reimer, P.J., Hogg, A.G., Higham, T.F.G., Baillie, M.G.L., Palmer, J., Stuiver, M., 2002. Calibration of the radiocarbon time scale for the Southern Hemisphere: AD 1850–950. Radiocarbon 44, 641–651.

McCormac, F.G., Hogg, A.G., Blackwell, P.G., Buck, C.E., Higham, T.F.G., Reimer, P.J., 2004. SHCal04 Southern Hemisphere calibration, 0–11.0 cal kyr BP. Radiocarbon 46, 1087–1092.

McGlone, M.S., Turney, C.S.M., Wilmshurst, J.M., 2004. Late-glacial and Holocene vegetation and climatic history of the Cass Basin, central South Island, New Zealand. Quaternary Research 62, 267–279.

Morgan, V., Delmotte, M., van Ommen, T., Jouzel, J., Chappellaz, J., Woon, S., Masson-Delmotte, V., Raynaud, D., 2002. Relative timing of deglacial climate events in Antarctica and Greenland. Science 297, 1862–1864.

Morigi, C., Capotondi, L., Giglio, F., Langone, L., Brilli, M., Turi, B., Ravaioli, M., 2003. A possible record of the Younger Dryas event in deep-sea sediments of the Southern Ocean (Pacific sector). Palaeogeography, Palaeoclimatology, Palaeoecology 198, 265–278.

Newnham, R.M., Lowe, D.J., 2000. Fine-resolution pollen record of late-glacial climate reversal from New Zealand. Geology 28, 759–762.

Newnham, R.M., Lowe, D.J., Wigley, G.N.A., 1995. Late Holocene palynology and palaeovegetation of tephra-bearing mires at Papamoa and Waihi Beach, western Bay of Plenty, North Island, New Zealand. Journal of the Royal Society of New Zealand 25, 283–300.

Newnham, R.M., Eden, D.N., Lowe, D.J., Hendy, C.H., 2003. Rerewhakaaitu Tephra, a land–sea marker for the Last Termination in New Zealand, with implications for global climate change. Quaternary Science Reviews 22, 289–308.

Reimer, P.J., Baillie, M.G.L., Bard, E., Bayliss, A., Beck, J.W., Bertrand, C.J.H., Blackwell, P.G., Buck, C.E., Burr, G.S., Cutler, K.B., Damon, P.E., Edwards, R.L., Fairbanks, R.G., Friedrich, M., Guilderson, T.P., Hogg, A.G., Hughen, K.A., Kromer, B., McCormac, F.G., Manning, S., Bronk Ramsey, C., Reimer, R.W., Remmele, S., Southon, J.R., Stuiver, M., Talamo, S., Taylor, F.W., van der Plicht, J., Weyhenmeyer, C.E., 2004. IntCal04 terrestrial radiocarbon age calibration, 0-26 cal kyr BP. Radiocarbon 46, 1029–1058.

Shane, P.A.R., Smith, V.C., Lowe, D.J., Nairn, I.A., 2003. Re-identification of c. 15 700 cal yr BP tephra bed at Kaipo Bog, eastern North Island: implications for dispersal of Rotorua and Puketarata tephra beds. New Zealand Journal of Geology and Geophysics 46, 591–596.

Singer, C., Shulmeister, J., McLea, B., 1998. Evidence against a significant Younger Dryas cooling event in New Zealand. Science 281, 812–814.

Stuiver, M., Polach, H.A., 1977. Reporting of ^{14}C data. Radiocarbon 19, 355–363.

Turney, C.S.M., McGlone, M.S., Wilmshurst, J.M., 2003. Asynchronous climate change between New Zealand and the North Atlantic during the last deglaciation. Geology 31, 223–226.

Williams, P.W., King, D.N.T., Zhao, J.-X., Collerson, K.D., 2005. Late Pleistocene to Holocene composite speleothem ^{18}O and ^{13}C chronologies from South Island, New Zealand—Did a global Younger Dryas really exist? Earth and Planetary Science Letters 230, 301–317.