of deforestation is similar to dates obtained from the oldest-known archeological sites (e.g., Wairau Bar), implies that the onset of forest burning was more-or-less contemporaneous with initial settlement (Lowe et al., in press). It remains feasible that earlier settlement sites still await discovery beyond the fall-out zone of macroscopic Kaharoa Tephra and that there might have been an earlier transient contact. If such transient contact occurred, it currently remains invisible in the archeological record and is indistinguishable from natural background events in the palynological record (Lowe et al., in press).

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Fig. 5: Archeological excavation of an early Maori village (kainga) site on dunes at Papamoa, coastal Bay of Plenty, eastern North Island, with the Kaharoa Tephra (dated at AD 1314±12 by Hogg et al., 2003) forming a prominent white marker layer in peat. Photo: David Lowe.

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Onshore-Offshore Correlation of Pleistocene Rhyolitic Eruptions from New Zealand: Implications for TVZ Eruptive History and Paleoenvironmental Construction

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Taupo Volcanic Zone (TVZ), in the North Island, New Zealand, is arguably the most active Quaternary rhyolitic system in the world. Numerous and widespread rhyolitic tephra layers, sourced from the TVZ, form valuable chronostratigraphic markers in onshore and offshore sedimentary sequences. In deep-sea cores from Ocean Drilling Program (ODP) Leg 181 Sites 1125, 1124, 1123 and 1122, located east of New Zealand (McCave & Carter, 1997; Hall et al., 2001; Fig. 1), 100 tephra beds have been recognized, post-dating the Plio-Pleistocene boundary at 1.81 Ma. These tephras have been dated by a combination of magnetostratigraphy, orbitally tuned stable-isotope data and isothermal plateau fission track ages. The widespread occurrence of ash offshore to the east of New Zealand is brought about by the small size of New Zealand, the explosivity of the mainly plinian and ignimbritic eruptions and the prevailing westerly wind field (Carter et al., 2003).

Although some tephras can be directly attributed to known TVZ eruptions, there are many more tephras represented within ODP cores that have yet to be recognized in near-source on-land sequences. This is due to proximal source area erosion and/or deep burial, as well as the adverse effect of vapor phase alteration and devitrification within near-source welded ignimbrites. Despite these difficulties, a number of key deep-sea tephras can be reliably correlated to equivalent-aged tephra exposed in uplifted marine back-arc successions of Wanganui Basin (Fig. 1), where an excellent chronology has been developed based on magnetostratigraphy, orbitally calibrated sedimentary cycles and isothermal plateau fission track ages. Significant Pleistocene tephra markers include: the Kawakawa, Omataroa, Rangitawa/Onepuhi, Kaukatea, Kidnappers-B, Potaka, Unit D/Ahuroa, Ongatiti, Rewa, Sub-Rewa, Pakihikura, Ototoka and Table Flat Tephras. Six other tephra layers are correlated between ODP-core sites but have yet to be recognized within onshore records.

The occurrence of fewer than expected equivalent marker beds that can be correlated between Wanganui Basin and the ODP cores is problematic and might be attributed to one or more factors. There is the possibility of narrow and highly directed tephra plumes that restrict the spatial distribution of fallout so that key tephra marker beds might be preserved in one or two cores but not necessarily in cores ideally located downwind from the TVZ and further eastward. Another explanation for the lack of tephras associated with voluminous and widespread eruptive events (e.g., Ongatiti eruption, 1.21 Ma) in Wanganui Basin might be the paleogeographical restriction of riverine sediment distribution systems, which periodically may have favored delivery to the East Coast Basin. Conversely, the products from a number of apparently less-voluminous eruptive events, not identified in the offshore cores, have made their way via fluvial systems to Wanganui Basin.

The lesser number of tephra in the Wanganui Basin may simply reflect the depositional environment. Basinal sediments accumulated in shallow shelfal seas which, judging by the modern shelf off the western North Island, is a high energy setting where the preservation of macroscopic tephra units is not favored, as attested by the paucity of such units in shelf cores. Preservation would have been further disadvantaged by eustatic changes in sea level. Carter et al. (2004), through comparison of eruption history with the $\delta^{18}O$ curve from Site 1123, have shown that the majority of the large rhyolitic eruptions occurred at a time of lower sea level when sub-aerial exposure, fluvial base-level adjustment (downcutting) and subsequent marine transgressions would have eroded any tephra deposit.

An offshore-onshore TVZ eruptive record over the last 2 Ma is summarized in Fig. 2. Some ODP tephra can be attributed to known TVZ eruptions (e.g., the Kawakawa, Omataroa, Rangitawa, Potaka, Unit D/Ahuroa, and Ongatiti tephras). ODP tephra can also be correlated to equivalent-aged tephra beds occurring in marine to near-shore sequences of Wanganui Basin (e.g., the Kaukatea, Kidnappers-B, Pakihikura, Ototoka and Table Flat tephras). However, the source areas of these tephra have yet to be established. Numerous other tephra occurring in ODP cores and Wanganui Basin have yet to be identified in proximal source areas and remain uncorrelated.

Houghton et al. (1995) suggest that major rhyolitic eruptions from the TVZ were related to three main periods of caldera formation: 1.68-1.53 Ma, 1.21-0.68 Ma and 0.34 Ma to present (Fig. 2). However, the ODP records show that major eruptions also occurred outside those periods, a feature that is confirmed for 1.8-0.6 Ma using data from onshore sites (e.g., Wanganui Basin) distant from the TVZ. The presence of substantial tephra between known periods of caldera formation implies that the ocean received ash from inter-caldera volcanoes or unknown caldera in the TVZ, or from both sources. The ODP record (670-1080 km distance from source) points to more continuous volcanism during the Pleistocene and extending into the Holocene, with a frequency of 1 event per 35 ka (cf. 1 event per c. 50 ka in Wanganui Basin).

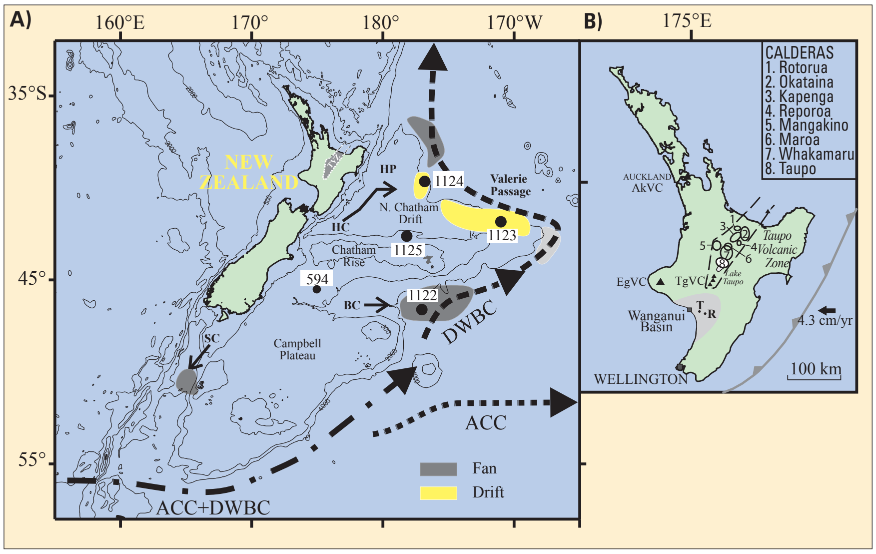

*Fig. 1: (**A**) Location of study area (modified from Hall et al., 2001). Shown is a generalized abyssal circulation scheme and sediment fan drifts, which together make up the major elements of the eastern New Zealand oceanic sedimentary system (Carter et al., 1996; ENZOSS). Contours are at depths of 500, 2000 and 4000 m. Sediment is supplied down the Solander (SC), Bounty (BC) and Hikurangi (HC) channels to abyssal depths and into the path of the deep western boundary current (DWBC), which transports the material along the margin of the Chatham Rise/Hikurangi Plateau, depositing sediment drifts where the flow slows down. The locations of ODP181 Sites 1125, 1124, 1123, 1122 are shown, as well as the location of DSDP-594. ACC, Antarctic Circumpolar Current; TVZ, Taupo Volcanic Zone; HP, Hikurangi Plateau. (**B**) Inset map of the North Island showing location of the Hikurangi Subduction Zone, Taupo Volcanic Zone (TVZ), Wanganui Basin (T, Turakina Section; R, Rangitikei Section) as well as other North Island Volcanic Centers (AkVC, Auckland Volcanic Centre; EgVC, Egmont Volcanic Centre; TgVC, Tongariro Volcanic Centre). TVZ Calderas are numbered 1 through 8.*

Interestingly, the chronology developed for most middle Pleistocene silicic tephra found in distal onshore sites in New Zealand is based on the glass-ITPFT and/or zircon-fission track (FT) techniques. While, FT-age has been pivotal to our understanding of the timing of silicic volcanism and the history of adjacent sedimentary basins, associated age errors range up to 10%. While Ar/Ar tephra ages typically have a lower analytical age error than FT-dates (< 5%), the application of this technique is more restricted due to the sparse occurrence of suitable minerals that can be reliably dated. Certainly, with high resolution records (e.g., tuned stable isotope and light reflectance data, together with paleomagnetic data) like those determined for Site 1123 that can then be graphically correlated to other core sites (e.g., Site 1124), it is possible to derive a tephra age with a precision that is hard to replicate for onshore equivalents dated by either the FT or Ar/Ar techniques.

The identification of previously unrecognized TVZ-sourced deposits in deep ocean records and their correlation to onshore uplifted marine successions (Wanganui Basin) represents a significant refinement of the eruptive record for the TVZ. However, by virtue of distance from the TVZ eruptive source, the Leg 181 ODP records are clearly biased towards macroscopic silicic tephra that represent moderate to large magnitude eruptive events. Tephra from smaller magnitude eruptions, especially those associated with onshore andesitic centers within the TVZ (e.g., Tongariro Volcanic Centre) and/or centers located further west (e.g., Egmont Volcanic Centre), were not noted in the ODP cores. It is un-

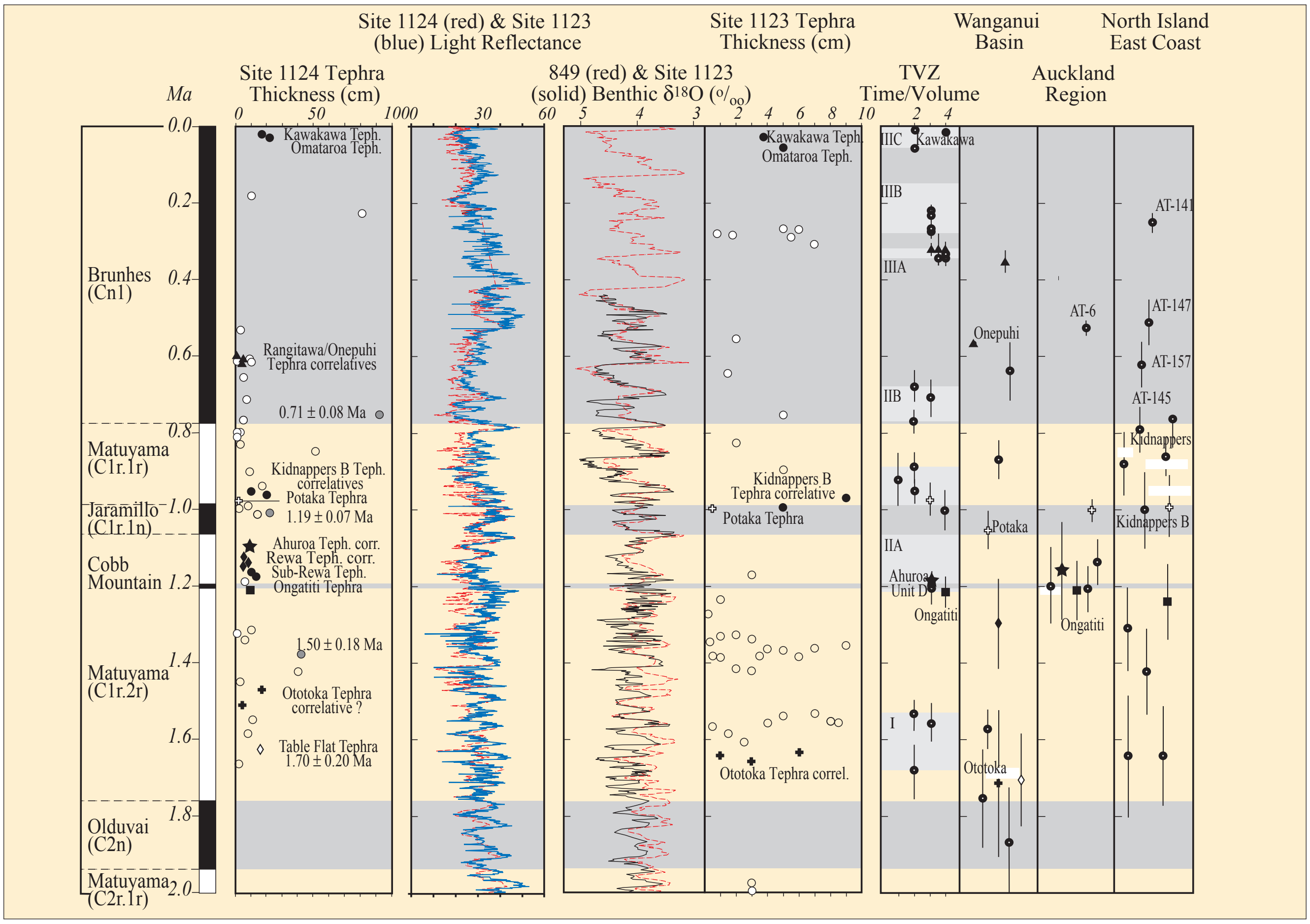

Fig. 2: Summary of 2 Ma record from Sites 1124 and 1123 based on tephra thickness/depth, paleomagnetic polarity, light reflectance and benthic $\delta^{18}O$ data. Onshore TVZ record is annotated with periods I-III representing major caldera-related ignimbrite eruptions (shaded light grey). Ages (± 1 SD error) of TVZ eruptive deposits from Wanganui Basin, Auckland region and North Island east coast are also shown.

likely that such eruptives are absent from the marine sites since numerous, dominantly mm-thick (rarely cm-thick) andesitic tephras have been identified within lake sediments on the east coast of the North Island, and in a 35-m-long giant piston core (MD97-2121) retrieved 110 km east of the North Island. At site MD97-2121, the preservation of numerous andesitic tephra has been facilitated by unusually high terrigenous flux extending back to MIS 6 (B. Manighetti and B.V. Alloway, unpublished data). On this basis, it is highly likely that numerous silicic and andesitic *cryptotephra* representing small to moderate eruptive events also occur at ODP181 sites, but that the combined effects of distance and bioturbation in the deep-sea environment prevent their preservation as macroscopic layers. As yet, no direct analysis of cryptotephra has been conducted on the ODP181 cores, although their presence has been inferred from geochemical analysis by Weedon and Hall (in press), who show that anomalous Si/Al, K/Al and Ti/Al values at Site 1123 were associated with tephra-rich sediments.

The identification of Pleistocene TVZ-sourced tephras within the ODP record, and their correlation to Wanganui Basin and other onshore sites, is a significant advance as it provides: (1) an even more detailed history of the TVZ than can be currently achieved from the near-source record, (2) a high-resolution tephrochronologic framework for future onshore-offshore paleoenviromental reconstructions, and (3) an opportunity to critically evaluate the chronostratigraphic framework for onshore Plio-Pleistocene sedimentary sequences through well-dated tephra beds correlated from the offshore ODP sites with astronomically-tuned timescales (e.g., Wanganui Basin, Naish et al., 1998).

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