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# Role of Tephra in Dating Polynesian Settlement and Impact, New Zealand

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## Introduction

Tephrochronology in its original sense is the use of tephra layers as time-stratigraphic marker beds to establish numerical or relative ages (Lowe and Hunt, 2001). Tephra layers have been described and studied in New Zealand for more than 160 years (the German naturalist and surgeon Ernst Dieffenbach described 'recognizable' tephra sections in his 1843 book *Travels in New Zealand*), and the first isopach map, showing fallout from the deadly plinian basaltic eruption of Mt Tarawera on 10 June 1886, was published in 1888 (Lowe, 1990; Lowe *et al.*, 2002). More recently, a wide range of tephra-related paleoenvironmental research has been undertaken (*e.g.*, Lowe and Newnham, 1999; Newnham and Lowe, 1999; Newnham *et al.*, 1999, 2004; Shane, 2000), including new advances in the role of tephra in linking and dating sites containing evidence for abrupt climatic change (*e.g.*, Newnham and Lowe, 2000; Newnham *et al.*, 2003). Here we focus on the use of tephrochronology in dating the arrival and impacts of the first humans in New Zealand, a difficult problem for which this technique has proven to be of critical importance.

## Heated debate

The timing of initial settlement of New Zealand has been the subject of heated debate. An early but transient contact *c.* AD 50 to 150, based on Pacific rat-bone (*Rattus exulans*) dates obtained from natural sites, was proposed by Holdaway (1996) on the premise that the rats, an introduced predator to New Zealand, accompanied the early Polynesians as a food source or as stowaways (Matisoo-Smith, 2002; Matisoo-Smith and Robins, 2004). This proposal seemingly supported Sutton (1987, 1994), who first suggested, on the basis of small-scale but short-lived disturbance evident in pollen records, that 'archaeologically invisible' Polynesian sailors may have reached New Zealand around this time. However, the reliability of the early rat-bone dates has been disputed, especially as aberrant rat-bone dates were reported from several archeological sites (Anderson, 1996, 2000, 2004; Higham and Petchey, 2000; Higham *et al.*, 2004), and dates on rat-nibbled land snail shells (*Placostylus ambagiosus*) and rat-nibbled seeds both suggested instead that the Pacific rat became established after *c*. AD 1250 (Brook, 2000; Wilmshurst and Higham, 2004). Moreover, the early rat-bone dates at one of Holdaway's (1996) sites in the South Island have not been duplicated (Holdaway *et al.*, 2002; Anderson and Higham, 2004).

## Using tephra layers to date archeological and paleoenvironmental sites

Because tephras provide essentially instantaneous chronostratigraphic marker horizons, or *isochrons*, that can be correlated between sites independently of radiometric dating, they provide a way of circumventing the various interpretative difficulties associated with radiocarbon dating very recent (last millennia) archeological and paleoenvironmental (natural) sites. Because tephra deposits are found in both archeological and natural sites, they have the capacity for linking such sites in an unambiguous manner unparalleled by other dating or correlative techniques (Lowe *et al.*, 2000).

Direct links between early Polynesians and their descendants (Maori) and tephras in New Zealand are associated with three different eruptive centres on North Island (Lowe *et al.*, 2002).

(1) Human footprints and other artifacts are buried beneath and within basaltic ash erupted from Rangitoto Island volcano, near Auckland, at *c*. AD 1400 (Fig. 1).

(2) The remains of Maori cooking stones (*umu*) aged *c*. AD 1450–1500 lie sandwiched between tephras on the slopes of the andesitic stratovolcano of Taranaki (Mt Egmont) in western North Island (Fig. 2).

(3) The key event for dating Polynesian settlement in New Zealand was the eruption of Kaharoa Tephra, a geochemically distinctive, rhyolitic tephra layer originating from Mt Tarawera volcano in central North Island near Rotorua (Lowe *et al.*, 2000). Widely dispersed over > 30,000 $km^2$ of northern and eastern North Island, Kaharoa Tephra provides a unique 'settlement layer' (*landnámslag*) (*cf.* Wastegard *et al.*, 2003; Sveinbjornsdottir *et al.*, 2004) in northern New Zealand. Difficult to date accurately by radiocarbon alone because of wiggles in the calibration curves (Lowe *et al.*, 1998), we derived a wiggle-match date of AD 1314 ± 12 for the Kaharoa Tephra eruption—the main plinian, tephra-fall-producing phase of which occurred in the austral winter (Hogg *et al.*, 2003)—using a carbonized log of *Phyllocladus* spp.. We used the Southern Hemisphere calibration curves of Hogg *et al.* (2002), thus avoiding the interhemispheric offset problem, and confirmed our date's likelihood using Bayesian statistics (Buck *et al.*, 2003).

Numerous archeological sites in eastern and northern North Island contain the Kaharoa Tephra datum (Fig. 3; Lowe *et al.*, 2000), and the absence of artifacts or cultural remains reported beneath it thus far indicates that these sites must be younger than *c*. AD 1314. In the same region, nearly 20 pollen profiles obtained from peat or lake deposits contain both Kaharoa Tephra and palynological indicators for the onset of significant deforestation, in the form of both marked and sustained rises in bracken (*Pteridium*) spores and charcoal, and a concomitant decline in tall forest trees (Newnham *et al.*, 1998; Horrocks *et al.*, 2001, 2004; McGlone and Jones, 2004). Unprecedented in the Holocene record, these palynological changes are inferred to be the result of initial and repeated firing by early Maori (Ogden *et al.*, 1998; McGlone and Wilmshurst, 1999; *cf.* Flenley and Todd, 2001). In a few profiles, the sustained rises in bracken and charcoal occur well after the Kaharoa Tephra datum but in the others, they occur close to the time of its deposition. In four pollen profiles, the earliest sustained rises are recorded in sediments just a few centimetres below the Kaharoa Tephra layer, probably ≤ 50 years before the eruption of *c*. AD 1314 (Lowe *et al.*, in press). A similar pattern is evident from independent opal phytolith data in tephra-soil sequences in the Bay of Plenty (Kondo *et al.*, 1994; Sase and Hosono, 1996). Thus, it is likely that the Kaharoa eruption was witnessed by a small number of very early Maori (an argument supported by oral tradition) and that archeological sites containing artifacts just beneath the Kaharoa Tephra may yet be found.

**Conclusions**

Taken together, both the archeological and palynological evidence, constrained by the *c*. AD 1314 Kaharoa Tephra datum, suggests that the earliest environmental impacts associated with initial Polynesian settlement in northern New Zealand (North Island) occurred between *c*. AD 1250 and 1300. This is coincident with the earliest-known settlement dates from archeological remains on both North and South islands, with dates obtained from rat-nibbled snail shells and seeds, and with reliably-dated deforestation signals (Figs. 4 & 5). The fact that the maximum date for the onset 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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**Captions to figures**

**Fig. 1:** Human footprint in basaltic Rangitoto Tephra, erupted *c.* AD 1400, Auckland, northern North Island (Nichol, 1982). The age of the eruption is derived from multiple radiocarbon, paleomagnetic, thermoluminescence, and obsidian hydration dates (Lowe *et al.*, 2000). Photo courtesy of Reg Nichol.

**Fig. 2:** Early Maori cooking stones (*umu*) sandwiched between andesitic tephra layers on Taranaki volcano, western North Island. At this site, the stones are overlain directly by Burrell Ash and underlain by Waiweranui Lapilli, dating the *umu* to *c.* AD 1500 or a little before (Alloway *et al.*, 1990; Lowe *et al.*, 2000). First recognized by Oliver (1931), the oldest *umu* on Taranaki is dated at *c.* AD 1450. Photo courtesy of Brent Alloway.

**Fig. 3:** Distal rhyolitic Kaharoa Tephra showing up as a prominent, 5-cm-thick marker layer in shallow peat deposits at Waihi Beach, western Bay of Plenty, eastern North Island. Taupo Tephra (erupted *c.* AD 232; Sparks *et al.* 1995; Lowe and de Lange, 2000) occurs also in the section, faintly visible as fine lapilli on the 'corner' in the middle of the photo, a few centimetres above the pale muds near the water table. The peat above Kaharoa datum is darker than below because it contains abundant charcoal from Polynesian burning, which is documented by pollen analysis in this area (Newnham *et al.*, 1995). Cutting tool handle is ~30 cm long. Photo: David Lowe.

**Fig. 4:** Summary of stratigraphy and ages of tephras, erupted from five volcanic centres since *c.* AD 232 (left side of diagram), and their relationship with archaeological and deforestation signals in northern and eastern North Island (right) (after Lowe *et al.*, 2000, 2002). The Kaharoa Tephra provides a settlement datum, or *landnámslag*, for inferred human-induced burning and deforestation

in much of northern and eastern North Island (*e.g.*, Newnham *et al.*, 1998; Horrocks *et al.*, 2001). It matches the earliest settlement dates of *c.* AD 1250–1300 from many sites containing archaeological remains (*e.g.*, Anderson, 1991; Higham and Hogg, 1997; McFadgen, 2003; Higham *et al.*, 2004), including the ancient Wairau Bar artifacts and skeletons (Higham *et al.*, 1999) and the tropical pearl lure at Tairua (Schmidt and Higham, 1998) (2 sigma error ranges), the oldest known rat-nibbled snail shells and seeds (Brook, 2000; Wilmshurst and Higham, 2004), and the earliest reliable dates for sustained deforestation elsewhere in the New Zealand archipelago (Ogden *et al.*, 1998; McGlone and Wilmshurst, 1999). The zone depicting possible early transient human contact is based on Holdaway (1996, 1999). Dutchman, Abel Tasman, was probably the first European to visit New Zealand (AD 1642).

**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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Fig.1

Fig.2

Fig.3

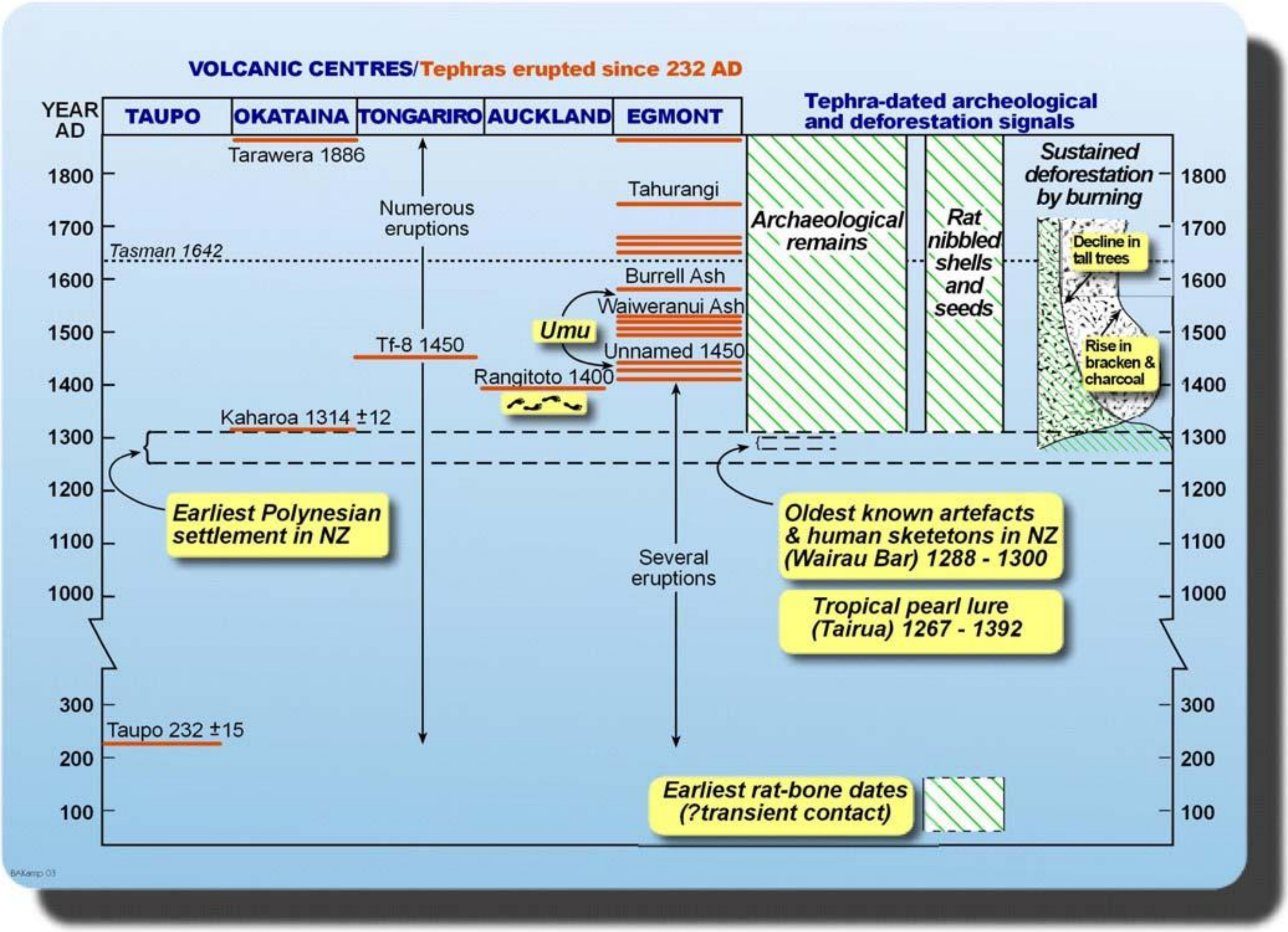
VOLCANIC CENTRES/Tephras erupted since 232 AD
YEAR AD
TAUPO
OKATAINA
TONGARIRO
AUCKLAND
EGMONT
Tephra-dated archeological and deforestation signals
Tarawera 1886
Numerous eruptions
Tahurangi
Tasman 1642
Burrell Ash
Waiweranui Ash
Umu
Tf-8 1450
Unnamed 1450
Rangitoto 1400
Kaharoa 1314 ±12
Archaeological remains
Rat nibbled shells and seeds
Sustained deforestation by burning
Decline in tall trees
Rise in bracken & charcoal
Earliest Polynesian settlement in NZ
Oldest known artefacts & human sketetons in NZ (Wairau Bar) 1288 - 1300
Tropical pearl lure (Tairua) 1267 - 1392
Several eruptions
Taupo 232 ±15
Earliest rat-bone dates (?transient contact)
1800
1700
1600
1500
1400
1300
1200
1100
1000
300
200
100

Fig.4

Fig. 5