8 *Volcanism and early Maori society in New Zealand*

D.J. Lowe, R.M. Newnham and J.D. McCraw

This chapter is dedicated to the memory of Jeanette L. Gillespie, a respected colleague and student in the Department of Earth Sciences at the University of Waikato, who died after a short illness on 4 October 2000. Jeannette, a part-time assistant lecturer in this department, was working towards her Ph.D. on the volcanic histories of Mayor Island and White Island, which feature in this chapter, by documenting the tephra record preserved in marine cores in coastal Bay of Plenty. A meticulous and talented researcher and teacher, and a warm and loyal friend, Jeanette is greatly missed.

INTRODUCTION

There is much current interest in the impact of geohazards upon global cultural development. Such studies tend to rest upon broad assumptions as to scale of event and response, but before these can effectively be drawn, it is necessary to have a clear understanding of the interaction of hazards upon cultures through time. This chapter addresses this issue by exploring the interaction of volcanic activity and Maori culture in New Zealand.

New Zealand is a mid-latitude, temperate, partly volcanic archipelago lying isolated in the South Pacific Ocean nearly 2,000 km eastward of its nearest neighbour, Australia. It is unique because it was the last substantial landmass to be settled by humans (Sutton, 1994a; Newnham *et al.*, 1999a). A consequence of the exceptionally short prehistory is that the record of interactions between volcanic activity and people is brief. The earliest known European contact with the Polynesian (Maori) inhabitants of New Zealand was by Dutchman Abel Tasman in AD 1642 followed, after a 127-year gap, by Englishman James Cook and Frenchman Jean de Surville, who both arrived in AD 1769. New Zealand's historical period is therefore restricted to barely the last two hundred years. The self-designated term '*Maori*', literally 'usual, ordinary', came into use only after European settlement in the nineteenth century AD and is applied to the descendants of the Polynesians who first settled New Zealand.

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In this chapter, the interactions between volcanism and early Maori society in New Zealand – both disastrous and beneficial – are examined. Due to the brevity of New Zealand's written history, our study relies largely on interpretations of volcanological, palaeoenvironmental, archaeological and oral history data, in turn constrained mainly by radiocarbon and other dating techniques including palaeomagnetism, obsidian hydration and thermoluminescence. For the purposes of the review, we have defined 'early' Maori society to date from 'earliest settlement' of New Zealand (*c.* AD 1250–1300) until the catastrophic Tarawera eruption on 10 June, AD 1886, the traumatic effects of which have been well described.

After discussing briefly the question of origin and timing of initial Polynesian settlement, we summarise in detail the record of volcanic activity in New Zealand's North Island since *c.* AD 200, and record the types of volcanic hazards associated with this activity. We next use one of the main products of volcanism – tephra – to date and correlate the palaeoenvironmental impacts of early Maori people with archaeological records via tephrochronology. Tephrochronology is defined as the use of tephra layers, the unconsolidated, primary, pyroclastic products of volcanic eruptions, as chronostratigraphic marker beds to establish numerical or relative ages (e.g. Froggatt and Lowe, 1990; Lowe and Hunt, 2001; Hunt and Lowe, in press). Following this section, the likely effects and impacts that volcanism and tephra deposition had on Maori society are examined. Turning to the other side of the coin, we describe the benefits and exploitation of volcanic features and products by early Maori. Finally, we discuss aspects of Maori mythology and spirituality associated with volcanism.

POLYNESIAN SETTLEMENT OF NEW ZEALAND

Current evidence indicates that the most likely 'homeland', or *Hawaiiki*, of the early Polynesian settlers of New Zealand was central Eastern Polynesia (Sutton, 1994b). The primary contenders within this tropical region include the Society Islands (encompassing Tahiti, Ra'iatea and Borabora, and others) and the islands of the Marquesan Archipelago. Additional possibilities include the Southern Cooks, Mangareva, Pitcairn and the islands of the Austral and Tuamotuan Archipelagos (Evans, 1998). Establishing the timing of settlement has been controversial. However, the most recent and reliable evidence, both from archaeological and natural sites, points consistently to initial settlement between *c.* AD 1250 and 1300 at the earliest (Anderson, 1991; Higham and Hogg, 1997; Newnham *et al.*, 1998a, 1998b; Ogden *et al.*, 1998; Higham *et al.*, 1999; McGlone and Wilmshurst, 1999; Lowe *et al.*, 2000, in press). 'Settlement' is used here to mean establishing a more-or-less permanent abode or place or way of life. An earlier, transient contact at *c.* AD 50–150, based on Pacific rat-bone (*Rattus exulans*) dates obtained from natural sites, was proposed by Holdaway (1996, 1999) on the premise that the rats, an introduced predator to New Zealand, accompanied the early Polynesian seafarers as a food source or stowaways. However, neither archaeological nor palaeoenvironmental (chiefly pollen, charcoal and phytolith) records currently provide any definitive support for settlement at this time (Newnham *et al.*, 1998a; McGlone and Wilmshurst, 1999; Brook, 2000; Lowe *et al.*, 2000), and the reliability of the early rat-bone dates is strongly disputed (Anderson, 1996, 2000). Short-lived, minor disturbances in the pollen record (e.g. small increases in bracken and other seral taxa) prior to *c.* AD 1250, although attributed to possible early human activities by Sutton (1987, 1994b), are indistinguishable from natural background events (e.g. lightning-induced fires, impacts from volcanic eruptions, storms or droughts) that occur throughout the Holocene and earlier (e.g. McGlone, 1989; Ogden *et al.*, 1998; Newnham *et al.*, 1998b, 1999a; McGlone and Wilmshurst, 1999). In this chapter we therefore adopt the date of *c.* AD 1250–1300 as the most likely beginning of Polynesian settlement of New Zealand.

VOLCANIC ACTIVITY AND HAZARDS IN NORTH ISLAND

Volcanism in New Zealand originates from its position astride an obliquely converging and active boundary between the Australian and Pacific lithospheric plates (Fig. 8.1, inset). The North Island's main locus of current volcanic activity is the Taupo Volcanic Zone (TVZ), which is a unique type of 'rifted arc' dating back to *c.* 2 MYA. The highly productive rhyolite caldera volcanoes of the Taupo and Okataina volcanic centres occupy the central TVZ, whereas andesitic stratovolcanoes, including those of Tongariro Volcanic Centre and White Island, occur at its southwest and northeast ends (Fig. 8.1; Wilson *et al.*, 1995). In addition to the TVZ centres, Mt Taranaki volcano (known also as Mt Egmont), the Auckland Volcanic Field, and the Tuhua Volcanic Centre (Mayor Island or Tuhua) are also regarded as active or recently active.

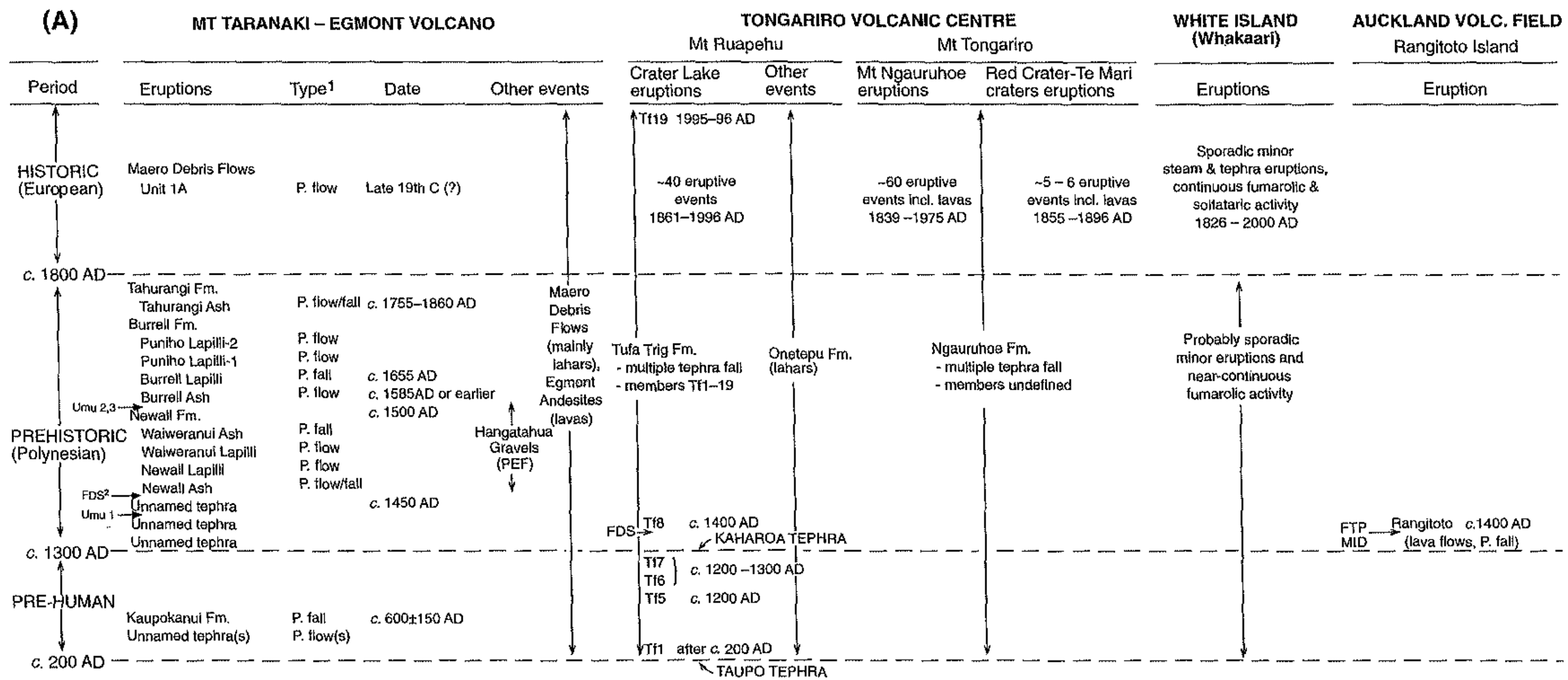
Fig. 8.2 summarises the history of known volcanic activity and some related events in North Island since *c.* AD 200. In this compilation we have divided the time-scale into three main periods: a pre-human (pre-settlement) period from *c.* AD 200 to 1300; a prehistoric (Polynesian) period from *c.* AD 1300 to 1800; and a historic (European) period since *c.* AD 1800. The benchmarks at *c.* AD 200 and *c.* AD 1300 are defined by two widespread rhyolitic tephra marker beds, the Taupo and Kaharoa tephras, respectively. Kaharoa Tephra, dated by radiocarbon to between *c.* AD 1300 and 1390 by Lowe *et al.* (1998), has most recently been dated more precisely at AD 1314 ± 12 by provisional dendrochronological 'wiggle-match' dating of a carbonized *Phyllocladus* spp. tree killed in the eruption (Hogg *et al.*, in press). This tephra represents the critical 'settlement layer' datum for prehistory in the North Island, as discussed below.

Seven spatially separate volcanic centres or fields have been active in the North Island since *c.* AD 200 (Fig. 8.2). The andesitic centres (Taranaki, Tongariro, White Island) have all erupted very frequently; the basaltic Auckland field is characterised by a single eruptive episode (Rangitoto Island); and the rhyolitic centres (Taupo, Okataina, Tuhua) have each erupted just once or twice. The

Figure 8.1 North Island volcanoes (bold) that have erupted since *c.* AD 200 and other features or sites mentioned in the text

Note: Those volcanoes active since Polynesian settlement (*c.* AD 1250–1300) are marked with an asterisk (Tuhua uncertain). TVZ, Taupo Volcanic Zone; NLD, Northland; CMD, Coromandel Peninsula; BOP, Bay of Plenty; HKB, Hawke's Bay. Inset shows plate tectonic setting of New Zealand

Source: After Lowe *et al.* (2000)



(A)
MT TARANAKI – EGMONT VOLCANO
TONGARIRO VOLCANIC CENTRE
Mt Ruapehu
Mt Tongariro
WHITE ISLAND (Whakaari)
AUCKLAND VOLC. FIELD
Rangitoto Island
Period
Eruptions
Type1
Date
Other events
Crater Lake eruptions
Other events
Mt Ngauruhoe eruptions
Red Crater-Te Mari craters eruptions
Eruptions
Eruption
HISTORIC (European)
Maero Debris Flows
Unit 1A
P. flow
Late 19th C (?)
Tf19 1995–96 AD
~40 eruptive events 1861–1996 AD
~60 eruptive events incl. lavas 1839 – 1975 AD
~5 – 6 eruptive events incl. lavas 1855 – 1896 AD
Sporadic minor steam & tephra eruptions, continuous fumarolic & solfataric activity 1826 – 2000 AD
c. 1800 AD
Tahurangi Fm.
Tahurangi Ash
P. flow/fall
c. 1755–1860 AD
Burrell Fm.
Puniho Lapilli-2
P. flow
Puniho Lapilli-1
P. flow
Burrell Lapilli
P. fall
c. 1655 AD
Burrell Ash
P. flow
c. 1585AD or earlier
Umu 2,3
Newall Fm.
c. 1500 AD
Waiweranui Ash
P. fall
Waiweranui Lapilli
P. flow
Newall Lapilli
P. flow
Newall Ash
P. flow/fall
FDS2
Unnamed tephra
c. 1450 AD
Umu 1
Unnamed tephra
Unnamed tephra
PREHISTORIC (Polynesian)
Hangatahua Gravels (PEF)
Maero Debris Flows (mainly lahars), Egmont Andesites (lavas)
Tufa Trig Fm.
- multiple tephra fall
- members Tf1–19
Onetepu Fm. (lahars)
Ngauruhoe Fm.
- multiple tephra fall
- members undefined
Probably sporadic minor eruptions and near-continuous fumarolic activity
FDS
Tf8 c. 1400 AD
KAHAROA TEPHRA
FTP
MID
Rangitoto c.1400 AD (lava flows, P. fall)
c. 1300 AD
Tf7
Tf6
c. 1200 – 1300 AD
Tf5 c. 1200 AD
PRE-HUMAN
Kaupokanui Fm.
P. fall
c. 600±150 AD
Unnamed tephra(s)
P. flow(s)
Tf1 after c. 200 AD
c. 200 AD
TAUPO TEPHRA

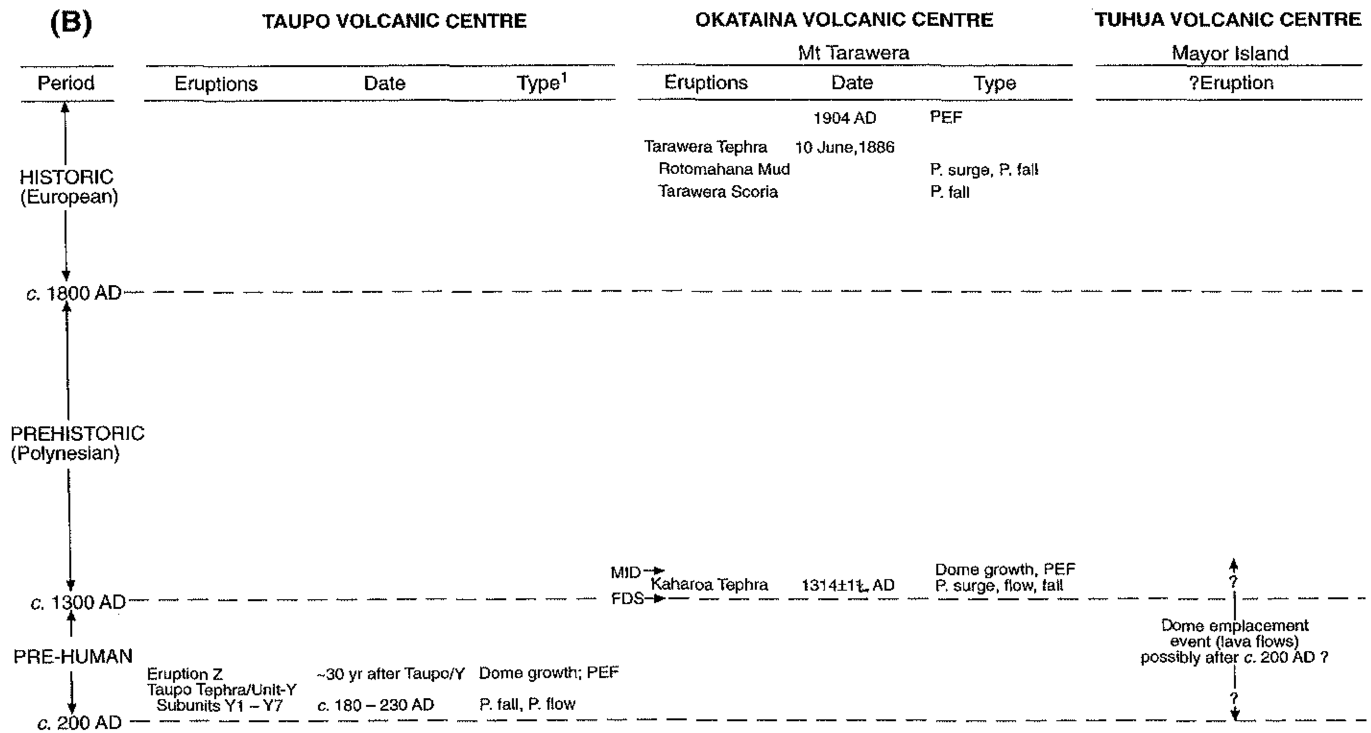


Figure 8.2 Summary of eruptions of North Island volcanic centres, and other events, since *c.* AD 200: (A) andesitic and basaltic volcanoes; (B) rhyolitic volcanoes. The latest Mayor Island lava dome eruption is undated but assumed to post-date *c.* AD 200

Sources: Data from Gregg (1960), Neall (1972, 1979), Cole and Nairn (1975), Nairn (1979, 1991), Walker *et al.* (1984), Houghton and Wilson (1986), Hackett and Houghton (1986), Cole *et al.* (1986), Houghton *et al.* (1992), Wilson (1993), Donoghue *et al.* (1995, 1997), Stevenson *et al.* (1996), Cronin *et al.* (1997), Hodgson *et al.* (1997), White *et al.* (1997), Lecointre *et al.* (1998), Gillespie *et al.* (1999), Manville *et al.* (1999), Lowe and de Lange (2000), Lowe *et al.* (2000), Price *et al.* (2000) and Nairn *et al.* (2001)

Notes: [1] Dominant style of eruption: P. flow, pyroclastic flows; P. fall, pyroclastic falls; PEF, post-eruptive flooding. Pyroclastic flows at Mt Taranaki were block-and-ash flows (V.E. Neall, pers. comm., 2000). See Table 8.1 and Sigurdsson (2000) for technical descriptions of eruption types

[2] FDS, first (sustained) deforestation signal (inferred to be human-induced); FTP, human and dog footprints; MID, middens. *Umu* are earth ovens.

latest eruption from the Okataina Volcanic Centre (Tarawera eruption) was a basaltic rather than rhyolitic event, as normally occurs at this centre. The uncertain timing of the latest (dome-building) eruption on Mayor Island/Tuhua precludes it from further discussion in this section because it may not have been active at all during the prehistoric period (Fig. 8.2).

The main types or styles of eruption, and associated volcano-related events including lahar emplacement and post-eruptive flooding, for each volcanic centre are given in Fig. 8.2. Based on these data, the types of volcanic hazards likely to have been experienced or witnessed by prehistoric Maori are listed in Table 8.1. Additional information on eruption types and historical impacts and fatalities are also reported there.

TEPHROCHRONOLOGY

The use of tephra layers to correlate and date archaeological remains and human-induced environmental impacts in New Zealand has been reviewed recently by Newnham *et al.* (1998a) and Lowe *et al.* (2000). Only the key findings are therefore reported here. Supporting information is provided by related studies on pollen and phytolith stratigraphy (e.g. Sase and Hosono, 1996; Wilmshurst, 1997; Ogden *et al.*, 1998; McGlone and Wilmshurst, 1999; Newnham *et al.*, 1999a; Wilmshurst *et al.*, 1999; Horrocks *et al.*, 2000), on the timing of prehistoric predator damage to landsnails (Brook, 2000), on isotopic analyses of speleothems (Hellstrom *et al.*, 1998), and on careful radiocarbon dating at archaeological sites (e.g. Anderson, 1991, 1995, 1996, 2000; McFadgen *et al.*, 1994; Higham and Hogg, 1997; Higham and Lowe, 1998; Petchey and Higham, 2000), including one of the oldest known at Wairau Bar (Fig. 8.1; Higham *et al.*, 1999). In comparison with many parts of the prehistoric world where chronologies are based largely on radiocarbon dating with its attendant imprecision and error sources, the suite of multi-sourced tephras in New Zealand provides valuable isochronous markers to help chart the course of prehistory.

Tephras derived from five North Island volcanic centres or volcanoes, together with exotic sea-rafted tephra deposits (Loisels pumice), are known to be relevant to archaeological studies (Lowe *et al.*, 2000). The locally distributed basaltic and andesitic tephras from Rangitoto Island and from Mt Taranaki overlie or contain cultural remains (including footprints and *umu*) and directly date human occupation to *c.* AD 1400 and *c.* AD 1450, respectively (Figs 8.2, 8.3). Distal andesitic tephras (Tufa Trig Formation members Tf5 and Tf8) from Mt Ruapehu help constrain the timing of onset of human impact signals in Hawke's Bay to *c.* AD 1400. The sea-rafted Loisels pumice, although of uncertain stratigraphic reliability in places, overlies cultural remains aged *c.* AD 1350 on coastlines of eastern North Island (Lowe *et al.*, 2000). It is the widespread Kaharoa Tephra, however, that provides the critical 'settlement layer' datum (equivalent to the *landnám* tephra layer in Iceland). This is because no cultural remains or artefacts are known to occur beneath it (e.g. Fig. 8.4), and because palynological evidence for earliest

Table 8.1 Volcanic hazards probably experienced or witnessed by prehistoric Maori

Hazard type	*Volcano or centre associated with event(s)* [1]
Pyroclastic fall[2]	Taranaki, Tongariro, White Is., Auckland, Okataina
Pyroclastic flows[3]	Taranaki, Tongariro, Okataina
Pyroclastic surges[3]	Okataina
Lava flows	Tongariro, Auckland, Okataina
Lava dome building	Taranaki, Tongariro, Okataina, ?Tuhua
Lahars[4]	Taranaki, Tongariro
Post-eruptive flooding[4]	Taranaki, Tongariro, Okataina
Debris avalanches[5]	Taranaki, Tongariro, ?White Is.
Volcanogenic earthquakes	Taranaki, Tongariro, Auckland, Okataina
Lightning, forest fires	Taranaki, Tongariro, Okataina
Hydrothermal eruptions[6]	High-temp. geothermal systems in TVZ (e.g. Ketetahi)
Volcanogenic tsunami[7]	?
Acidic rain/volcanic gases	?

[1] See Fig. 8.2 for examples of named eruptions or associated events. Some of the hazard types may have occurred at other volcanoes as well.

[2] Pyroclastic fall deposits are produced by the rain-out of clasts (which may be of any size or composition) through the atmosphere from an eruption jet and/or plume during an explosive eruption (Houghton *et al.*, 2000).

[3] Pyroclastic flow deposits are emplaced as hot, fast-moving, particulate gaseous flows of high particle concentration. They include (a) block-and-ash flow deposits, comprising dense to moderately vesicular blocks in an ash matrix, and of small volume and localised distribution; and (b) ignimbrites, comprising welded to non-welded, predominantly massive and poorly sorted, pumiceous, ash-rich deposits, and of potentially large volume and widespread distribution (Freundt *et al.*, 2000). Pyroclastic surge deposits are strongly bedded and emplaced by high-velocity, turbulent, gaseous flows ('hurricanes' or 'blasts') of low particle concentration (e.g. Valentine and Fisher, 2000).

[4] Lahar is a general (Indonesian) term used for describing gravitationally driven, rapidly moving mudflows of volcanic origin (e.g. Vallance, 2000). End-member types include (a) debris flows, which are mixtures of debris and water with a high sediment concentration (the deposits are termed diamictons); and (b) hyperconcentrated streamflows, which have a higher water concentration than in debris flows but less than in (normal) muddy streamflow. Hyperconcentrated streamflows possess fluvial characteristics yet carry very high sediment loads. Events described as post-eruptive flooding may be transitional to hyperconcentrated streamflows and include catastrophic 'breakout' flood events (e.g. White *et al.*, 1997; Manville *et al.*, 1999). In historic times, a lahar/breakout post-eruptive flood event in the Whangaehu River, Mt Ruapehu, resulted in 151 fatalities when the overnight train was derailed at the Tangiwai bridge in 1953. In 1904, a pyroclastic barrier emplaced at Lake Tarawera during the 1886 eruption was swept away, causing a flood that affected communities for 40 km downstream to the coast (White *et al.*, 1997).

[5] Debris avalanche deposits result from sectorial collapse of the flanks of a volcano. They differ from debris flows in that they are not water-saturated: the load is entirely supported by particle–particle interactions (Ui *et al.*, 2000). Debris avalanching/landsliding occurred at Waihi, a Maori village in the Waihi–Tokaanu geothermal field on the caldera fault-margin of southwestern Lake Taupo (Fig. 8.1) in AD 1834, AD 1846 (*c.*60 fatalities) and in 1910 (1 fatality). A similar event took place on the crater wall of White Is. in 1914 (11 fatalities).

[6] Geothermal fields occur throughout TVZ (Hedenquist, 1986), and some generated hydrothermal (steam) explosions during prehistoric times, e.g. at Waiotapu (Fig. 8.1), probably associated with the Kaharoa eruption. After the AD 1886 Tarawera eruption, hydrothermal explosions occurred at Waimangu (Fig. 8.6) in 1903 (4 fatalities), 1915, 1917 (2 fatalities), and in the 1970s–1980s.

[7] Numerical modelling has shown that White Is. is unlikely to have generated significant tsunamis at the coast (de Lange and Fraser, 1999). A meteorological tsunami (rissaga) resulting from atmospheric coupling during the powerful Krakatau (Indonesia) eruption of AD 1883 generated waves up to 2 m high around the New Zealand coast. The Taupo eruption of *c.*AD 200 probably generated a similar or larger rissaga (Lowe and de Lange, 2000). Tsunamis resulting from earthquakes, both local and overseas, have affected coastal settlements in New Zealand in historic times and it is probable that some prehistoric Maori communities were destroyed by such tsunamis and rapidly abandoned (Harada 1993a; Goff and McFadgen, 2000).

Figure 8.3 Earth oven (*umu*) on Mt Taranaki at *c.*850 m asl

Note: Undisturbed coarse Burrell Lapilli (top) and fine Burrell Ash directly overlie subrounded andesitic cobbles and pebbles, many of which show heat fractures. The cooking stones lie in an excavation into underlying Waiweranui Lapilli which is dated at *c.* AD 1500 ± 50 (Alloway *et al.*, 1990; Lowe *et al.*, 2000). Total thickness of Burrell Lapilli and Ash is *c.*40 cm. Lens cap (left) is *c.*5 cm in diameter

Photograph: B.V. Alloway

human-induced impact (start of the sustained rise in *Pteridium*) occurs stratigraphically just before its deposition (Fig. 8.5). The rise is inferred to start at *c.* AD 1280. This date matches the earliest reliable radiocarbon dates derived for both settlement and human impacts from archaeological and natural sites (*c.* AD 1250–1300), and implies that the onset of deforestation was essentially contemporaneous with initial settlement (Lowe *et al.*, 2000, in press). The widespread Taupo Tephra provides an isochronous benchmark well before earliest settlement, though it may coincide with the putative earlier transient contact in New Zealand, as noted in the introduction.

IMPACTS OF VOLCANISM ON EARLY MAORI SOCIETY

Since *c.* AD 1250–1300, early Maori have witnessed probably only one catastrophic rhyolitic eruption (Kaharoa), two basaltic eruptions (Rangitoto, Tarawera), and numerous andesitic eruptions from the frequently active volcanoes of Tongariro Volcanic Centre, White Island and, to a lesser extent, Mt Taranaki (Fig. 8.2). Apart from the historic AD 1886 Tarawera eruption, the degree of impact on early

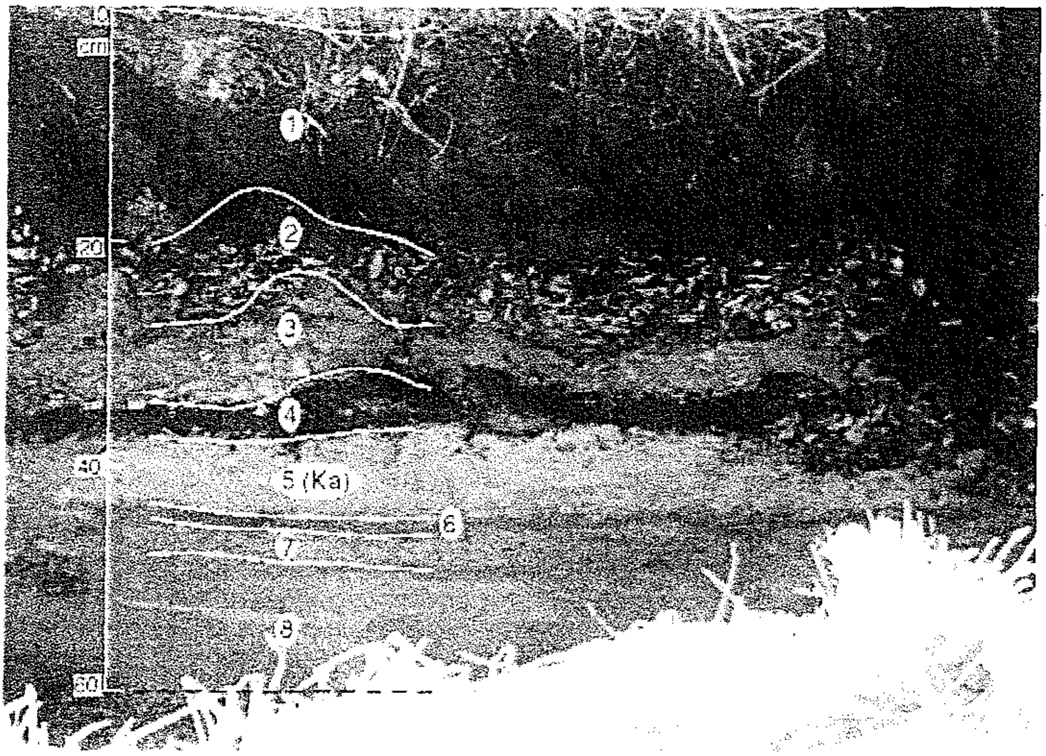


Figure 8.4 Archaeological section at Papamoa on the Bay of Plenty coast (Fig. 8.1) showing prehistoric Maori shell middens postdating the *c.* AD 1300 Kaharoa Tephra ('Ka'). (1) 'cultural' topsoil; (2) shell midden; (3) mixed sand/tephric material (with scattered shells); (4) black charcoal layer; (5) Kaharoa Tephra; (6) thin paleosol; (7) Taupo Tephra; (8) aeolian dune sand (to trench base at *c.*60 cm depth)

Note: Radiocarbon dates from the site show that it was occupied initially from *c.* AD 1450–1550 with a second occupation phase to *c.* AD 1650 at the latest (W. Gumbley, pers. comm., 2000)

Photograph: W. Gumbley

Maori society from these and related volcanic events is generally not known, but some potential or likely effects, which have been hypothesised on the basis of the different hazard types and tephra thicknesses, are listed in Table 8.2. We provide more specific comments relating to the eruptions and impacts for each volcano in the following sections.

Mt Taranaki

Mt Taranaki volcano has erupted at least a dozen times since *c.* AD 1300 (Fig. 8.2). Most eruptions have been pyroclastic in nature, both fall and flow deposits being recorded, but some lavas were erupted near the summit as well (e.g. Egmont Andesites, subunit eg_2: Neall, 1979). Many of the eruptions were relatively minor in scale but the Newall and Burrell groups of eruption episodes, dated at *c.* AD 1500 and *c.* AD 1600–1650, respectively, were substantial events that destroyed forest or disrupted forest canopies on parts of Mt Taranaki and beyond (Topping, 1972; McGlone *et al.*, 1988; Lees and Neall, 1993). The Newall eruptions were directed mainly to the northwest and the Burrell Lapilli towards the east. If Maori

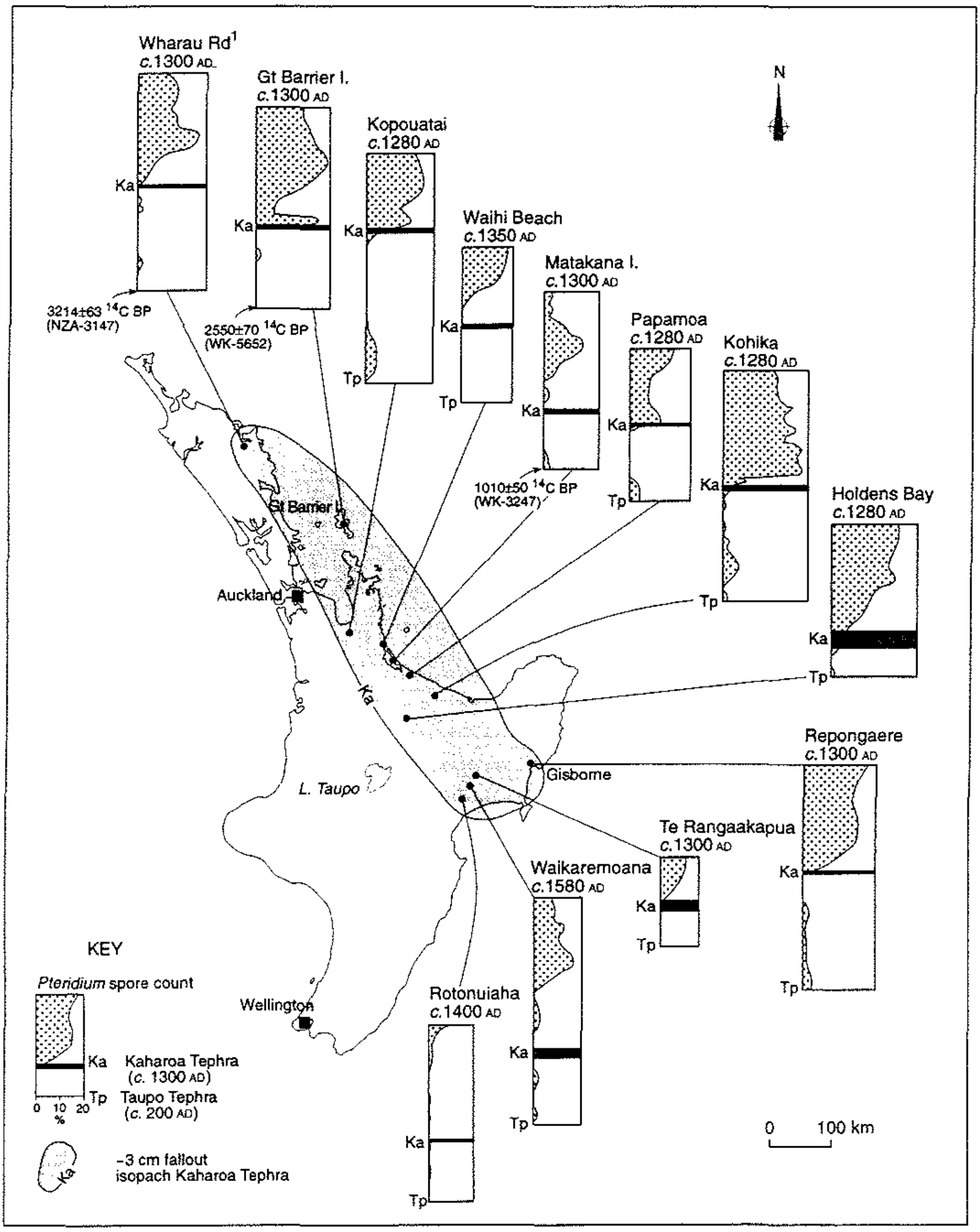


Figure 8.5 *Pteridium* (bracken) spore profiles from North Island containing the *c.* AD 1300 Kaharoa Tephra

Notes: Dates shown at the top of each profile are estimates of the timing of earliest human-induced deforestation impacts based on major changes in *Pteridium* spore counts and pollen spectra with respect to the Kaharoa datum. The earliest inferred deforestation signal occurs just before Kaharoa Tephra, at *c.* AD 1280. The *c.* AD 200 Taupo Tephra provides a pre-impact datum in all but three profiles where underlying materials have been dated by radiocarbon

[1] Stratigraphic position of Kaharoa Tephra is inferred from an adjacent core at the Wharau Rd swamp site

Sources: After Newnham *et al.* (1998a) with additional data from Elliot *et al.* (1997) and Horrocks *et al.* (1999, 2000)

Table 8.2 Potential effects and extent of impact of the main volcanic hazards[1] on prehistoric Maori society

Hazard	*Threat to life*	*Threat to property*	*Areas affected*
Pyroclastic fall	Generally low, except close to vent[2]	Variable, depends on thickness[2]	Local to regional
Pyroclastic flow/surge	Extremely high	Extremely high	Local to regional
Lava flows	Low	Extremely high	Local
Lahars/flooding	Moderate	High	Local to regional[3]
Gases/acid rain	Low	Low	Local to regional
Forest fires	Low	Low to moderate	Local to regional

[1] After Scott *et al.* (1995). See also Ansell and Taber (1996).

[2] Possible physical effects arising from the accumulation of critical thicknesses of pyroclastic material (after Newnham *et al.*, 1999b):

1 mm	Little or no effect on people apart from possible minor, short-lived respiratory problems; rapid recovery.
10 mm	Fish and insects killed; little or no visibility; infections of respiratory tract, inflamed eyes; crops possibly damaged or rendered unpalatable; possible animal poisoning, e.g. by fluorine.
100 mm	Serious respiratory problems, some human fatalities possible; bird life killed; crops destroyed or severely damaged, trees stripped, branches broken; roof collapse likely for dwellings and other buildings, especially with rain; water supplies temporarily contaminated.
1 m	Fatalities and injuries from building collapse; bush fires; trees, hunting areas destroyed; many waterways blocked; hunting/fishing gear and canoes and other property destroyed or damaged; animals killed directly or by starvation.
10 m	Substantial loss of life through building collapse and burns; widespread building and other property destruction; some waterways permanently altered; long-term loss of land use; resettlement of survivors.

[3] These processes may result in prolonged devastation, at times well after the initial eruption impacts, and well away from the volcano (e.g. Vallance, 2000).

had been encamped on or near the volcano, these events would have caused significant impacts both directly from pyroclastic flows or from tephra fallout, since at distances up to *c.* 15 km from source, the tephra deposits from each eruption range in thickness from *c.* 5–15 cm (Tonkin, 1970; Neall, 1976). Beyond a radius of about 15 km from source, the tephras are generally <5 cm thick but ash fall of the order of millimetres in thickness would have been blown over much of central North Island, depending on wind strength and direction (Neall and Alloway, 1991). For example, distal ash from one of the Burrell eruptions has been detected in Hawke's Bay (Eden and Froggatt, 1996). In addition, fires were generated near the volcano by many of the eruptions, including both the Newall Ash and Lapilli events and the Puniho Lapilli events (Neall and Alloway, 1986; McGlone *et al.*, 1988). Soon after the Newall eruptions, and with forest cover removed, much debris (e.g. from landsliding) was reworked down river valleys in a substantial post-eruptive flood event that resulted in extensive alluvial deposition (Hangatahua Gravels) in the Okato district (Figs 8.1, 8.2). The Maori name *Okato* means 'place of a great tidal wave', a description which may relate to this catastrophic flooding (Pearce, 1977; Neall *et al.*, 1986). Several dozen debris flows or lahars, originating largely from lava flow collapses around the Taranaki summit (especially the western crater rim) or from deep gorges in the middle part of the cone, have been emplaced since *c.* AD 1450 (Neall, 1979), and these may also have had delayed (and therefore unexpected) impacts on any Maori communities within stream valleys which acted as channel ways.

There are few Maori oral accounts of specific volcanic activity on Taranaki, apart from reference to a fortified village (*pa*) called Karaka-Tonga, believed to have been situated at about 600 m altitude on Waiwhakaiho River (near the Kokowai Springs) on the northern slopes of the mountain (Oliver, 1931). This village was evidently destroyed by an early (unknown) eruption. However, three *in situ* Maori earth ovens or *umu*, one dated at *c.* AD 1450 and the others at *c.* AD 1500 (Fig. 8.2), have been excavated on the volcano, and their occurrence within tephra layers (Fig. 8.3) means that eruptions such as the Newall and Burrell episodes must have been observed. Although most narratives indicate that later Maori regarded the Taranaki volcano with reverence, and that the higher slopes beyond the forest margin, rocky and barren, were sacred (*tapu*), it has been suggested that the *umu*, despite being at *c.* 850 m and *c.* 1075 m altitude, represent substantial rather than casual camp sites (Alloway *et al.*, 1990). One inference is that the inhabitants of these sites either did not feel unduly threatened by the consequences of a renewal in volcanic activity, or that the activities associated with the sites (e.g. catching birds, collecting ochre, collecting fine-grained andesite for making axes, interment of the dead, or use as a remote retreat in times of political need) were seen to be worth the risk (Topping, 1974; Alloway *et al.*, 1990). It is possible that the designation of the upper slopes as a 'sacred area' (*wahi tapu*), perhaps after initially being declared 'out-of-bounds' (*rahui*), was a deliberate societal response to reduce the impacts of future eruptions. Such responses to natural disasters elsewhere are known for early Maori, and have possible parallels in other societies (e.g. for Japan cf. Harada, 1993b, 1999 and below). For example, the fatal debris avalanching in AD 1846 at the Maori village at Waihi, southern Lake Taupo (see Table 8.1, footnotes), resulted in a *tapu* being placed on the devastated site to avoid a recurrence of the disaster. Unfortunately a 'transgressor' paid with his life in the 1910 landslide (Harada, 1993b).

Tongariro Volcanic Centre

The Tongariro Volcanic Centre is dominated by two large and very active strato-volcanoes, Mts Ruapehu and Tongariro. Since *c.* AD 1250–1300, activity on Ruapehu has been centred on Crater Lake (in South Crater) and was probably wholly pyroclastic. On Tongariro eruptive activity, which has been centred on the parasitic cone of Mt Ngauruhoe and on Red Crater and the upper and lower Te Maari craters (Figs 8.1, 8.2), has generated both tephra deposits and lavas (e.g. Nairn and Self, 1978). Thus, prehistoric Maori would potentially have witnessed or been aware of dozens of explosive, tephra-generating eruptions, typically plinian–subplinian or smaller and of low magnitude and volume, and possibly a number of local lava flows: at least one occurred at *c.* AD 1500 (Hobden *et al.*, 1999). However, the likelihood of significant impact on early Maori (other than minor damage or temporary respiratory-related problems arising from the downwind deposition of several millimetres or so of distal ashfall in Hawke's Bay for example (Froggatt and Rogers, 1990; Eden and Froggatt, 1996) is slight because apparently the whole area was regarded as *tapu* (Grace, 1959; Pearce, 1977; cf. below). It is doubtful if any Maori lived in close proximity to the volcanoes which, in any event, would generally be windswept, cold and inhospitable much of the time. In some accounts, the eruptions of Ngauruhoe were regarded as a sign of war by prehistoric Maori (R. Taylor in Gregg, 1960). Lahars were generated during and following larger Crater Lake-derived eruptions on Ruapehu in prehistoric times (Fig. 8.2; Cronin and Neall, 1997; Cronin *et al.*, 1997; Lecointre *et al.*, 1998), and by non-eruptive mechanisms (Donoghue and Neall, 2001), and these and associated post-eruptive flooding may have impacted on Maori communities in low-lying beds of river valleys draining away from the volcanoes (e.g. possibly at Turangi, Tongariro River in Fig. 8.1). Three lahars have been dated at between *c.* AD 1400 and 1650, and another since *c.* AD 1650 (Lecointre *et al.*, 1998; Donoghue and Neall, 2001). There are no known Maori cultural remains associated with eruptives or laharic deposits from the Tongariro Volcanic Centre.

White Island

The island is unlikely to have been occupied for any period of time. Its continual volcanic activity was clearly well known because this has an important place in Maori oral legends (e.g. Luke, 1959; Pearce, 1977; Orbell, 1995). Sporadic eruptions of low volume and magnitude during prehistory probably had little or no impact on nearby coastal settlements in eastern Bay of Plenty and towards East Cape (Fig. 8.1), apart from that resulting from occasional wind-blown ash fall which probably amounted to a few millimetres at most. Furthermore, since it lies in deep water beyond the continental shelf and has a history of only minor eruptions, White Island is unlikely to have generated significant tsunami at the coast (de Lange and Fraser, 1999). There are no known Maori cultural remains associated with White Island eruptives.

Rangitoto Island (Auckland Volcanic Field)

Rangitoto Island, a small shield volcano comprising basalt lava fields capped by a steep-sided scoria cone, is the youngest and by far the largest volcano in the Auckland Volcanic Field (Fig. 8.1; Kermode, 1992; Nichol, 1992; Allen and Smith, 1994; Cassidy *et al.*, 1999). Its spectacular emergence from the sea in *c.* AD 1400 (Lowe *et al.*, 2000) was the result of effusive eruptions of lava and explosive fire-fountaining of scoriaceous pyroclasts. Alongside Rangitoto, Motutapu Island was blanketed with basaltic ash-fall deposits from the eruption (Fig. 8.1). At the Sunde site on West Point, Motutapu Island, human (both adult and juvenile) and Maori dog (*kuri*) footprints, together with other cultural remains, have been preserved beneath and within the ash layers derived from early phases of the eruption (Fig. 8.1; Nichol, 1981, 1982).

According to Nichol (1981, 1988), the local Maori were apparently undeterred by the nearby Rangitoto eruption, and sanguinely engaged in horticultural activities by digging and gardening the freshly fallen ash deposits. Nevertheless, a tephra-fall deposit in excess of *c.* 0.6 m thickness on the western third of the island (Nichol, 1988) must have engulfed and damaged or destroyed many Maori dwellings and other items there, as well as having other impacts (Table 8.2) within and beyond this part of the island (Cameron *et al.*, 1997). There would have been only minor effects on Maori communities on nearby islands (e.g. Rakino, Waiheke, Motuihe and Motukorea) or the Auckland isthmus (mainland) that were within range of wind-blown ash. Subsequently, Motutapu Island may have attracted increased numbers of Maori settlers because the new cover of fine-grained and easily worked tephra deposits was more suitable for gardening than the pre-existing clayey and enleached soils, which had formerly supported hunting, fishing and stone artefact manufacture (Davidson, 1978; Bulmer, 1996).

Mt Tarawera (Okataina Volcanic Centre)

The Tarawera Volcanic Complex, forming approximately the southern half of the Okataina Volcanic Centre (Fig. 8.1; Nairn, 1989), has erupted mainly rhyolitic material for most of its history. The *c.* AD 1300 Kaharoa eruption is the youngest rhyolitic eruption in New Zealand and the largest (volumetrically *c.* 7.5 km^3 as deposited, *c.* 5 km^3 as dense-rock-equivalent) since the powerful *c.* AD 200 Taupo event (Lowe *et al.*, 1998). The eruption, triggered by an injection of hot basalt (Leonard *et al.*, 2002), was a complex event that included initial vent-clearing blasts, the generation of at least 12 plinian to subplinian pyroclastic fall units and pyroclastic flow deposits, and the slow effusion of three large lava domes. The partial collapse of several domes produced extensive block-and-ash flows around Mt Tarawera (Nairn *et al.*, 2001). The most widely dispersed tephra-fall deposits ('Kaharoa Tephra') were distributed in a northwest–southeast oriented lobate pattern, with the 3 cm isopach covering an area of *c.* 30,000 km^2 in eastern and northern North Island including Northland, Coromandel, Bay of Plenty and Hawke's Bay (Fig. 8.5; Lowe *et al.*, 1998). These cataclysmic phases were followed by 'breakout' post-eruptive flooding down the Tarawera River (fed by breaches of water from Lake Tarawera) towards the Bay of Plenty coast and attained an extremely high peak discharge estimated at *c.* 10^5 m^3/s (Hodgson *et al.*, 1997; White *et al.*, 1997; Manville *et al.*, 1999). Based on similar types of large-scale rhyolitic eruptions elsewhere (e.g. Machida, 1990; Rodolfo, 2000), there would have been little or no warning of this flooding. Some landsliding and probably debris avalanching triggered by aftershocks or rainstorms may have occurred as well. Thus, it is likely that the eruption and subsequent events would have had enormous impacts on any early Maori living in eastern North Island, including probable annihilation for those (if any) who had been close to the Mt Tarawera massif, or within or adjacent to the Tarawera River channel and flood-plain downstream from the volcano. Around one quarter of the eastern North Island was affected by tephra fallout of 3 cm or more in thickness, and it is likely that little of the North Island escaped some fallout from the eruption (Newnham *et al.*, 1998a). Even a few centimetres of distal, acid-coated ash fall would have been sufficient to damage forest vegetation for some decades (e.g. Giles *et al.*, 1999).

Newnham *et al.* (1998a) and Lowe *et al.* (2000, in press) have inferred from pollen records that the earliest Maori settlers may have arrived in New Zealand just prior to the Kaharoa eruption. If so, it is possible that only a tiny population saw or experienced the eruption and its consequences. Several oral legends that seemingly refer to an 'ancient' eruption of Tarawera (i.e. before AD 1886) support the suggestion that early Maori were witnesses to the event (Lowe *et al.*, 2000).

Tarawera eruption

The Tarawera eruption of 10 June 1886 was the biggest and most destructive eruption in New Zealand during the historical (European) period. It was a basaltic rather than rhyolitic event, but was nevertheless very explosive: the resulting scoria fall ('Tarawera Scoria') has a dispersal similar in extent to that of the Vesuvius AD 79 pumice fall and is one of the few known examples of a basaltic deposit of plinian type from a fissure source (Walker *et al.*, 1984). The eruption cored out a series of craters in a 7 km long fissure through the antecedent rhyolite domes (including those emplaced during the Kaharoa event) of Mt Tarawera, and then generated more craters along an 8 km long southwest extension of the fissure across the Rotomahana basin (which contained two shallow lakes and large silica sinter aprons, the 'Pink' and the 'White' terraces, asssociated with extensive hydrothermal activity) to Waimangu (Fig. 8.6; Walker *et al.*, 1984). Narratives (summarized by Keam, 1988) indicate that after a series of precursory earthquakes from *c.* 12.30 am, the eruption began at Ruawahia Dome (Fig. 8.6) at *c.* 2.00 am on 10 June 1886, and then gradually extended both northeastward and southwestward. At *c.* 2.10 am the eruption intensified with the ascent of a tephra plume from the vicinity of Ruawahia Dome up to *c.* 9.5 km (Walker *et al.*, 1984; Keam, 1988). By 2.30 am craters along the whole length of the fissure were erupting, with the Rotomahana extension beginning to erupt possibly at *c.* 3.20 am. By 3.30 am, craters along the entire 17 km length of the fissure from Wahanga to Waimangu were in eruption. This paroxysmal stage of the eruption was over by 6.00 am, when most activity ceased.

The erupted products were exclusively pyroclastic (no lava flows were generated, although basalt dikes were emplaced). The total volume (as deposited) of Tarawera Scoria is *c.* 2 km^3 (Walker *et al.*, 1984). The eruption along the Rotomahana and Waimangu extension was mainly phreatomagmatic (the result of interaction between basalt magma and hydrothermal water) and phreatic. The explosive expansion of superheated water fragmented the country rock containing the hydrothermal system, plus subordinate lake sediment, to produce surge beds and fall deposits ('Rotomahana Mud') that rained out over much of the Bay of Plenty and beyond (*c.* 0.5 km^3 as deposited) (Fig. 8.6, inset). Near Rotomahana, the surge beds were emplaced violently by hot and fast-moving turbulent pyroclastic surges or density currents up to *c.* 6 km from source (Figure 8.6; Nairn, 1979; Keam, 1988). Lightning during the eruption set fire to a house in Te Wairoa and to the forest on the north shore of Lake Tarawera; strong winds flattened many trees at Lake Tikitapu; and suffocating gases and falling mud and ash made breathing difficult at Te Wairoa (Fig. 8.6), where most buildings were buried or collapsed under the weight of *c.* 1 m of mudfall (Fig. 8.7).

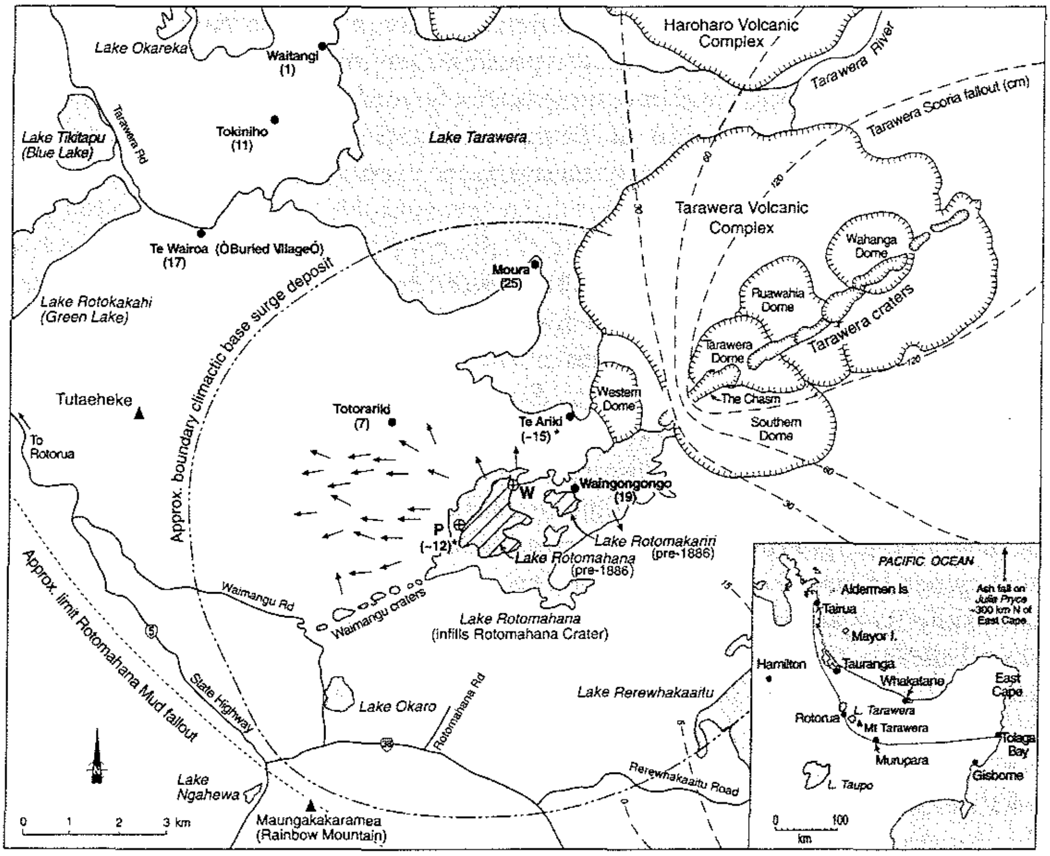


Figure 8.6 Map of the Tarawera area showing locations of the main craters of the 10 June 1886 fissure eruption across the Tarawera Volcanic Complex, Rotomahana Crater (including pre-eruption lakes Rotomahana and Rotomakariri) and Waimangu craters

Notes: The approximate boundary of the base surge deposit resulting from the initial cataclysmic Rotomahana explosion is based on data in Smith (1886) and Keam (1988); bold arrows represent current directions inferred from cross-bedding of proximal surge deposits (Nairn, 1979). The southwestern fallout limit for Rotomahana Mud and the isopachs (cm) for Tarawera Scoria, both members of Tarawera Tephra Formation (Froggatt and Lowe, 1990), are from Thomas (1888) and Cole (1970), respectively. The location of villages and associated fatalities (numbers in parentheses) are based on Keam (1988). There was an additional death at an unknown locality. The fatalities were all Maori apart from six Europeans at Te Wairoa and one European and three part-Maori at Waingongongo. W, White Terrace (Te Tarata); P, Pink Terrace (Otukapuarangi)

* On the night of the eruption nearly half of Te Ariki's 27 residents were encamped at Pink Terrace at Lake Rotomahana (Keam, 1988)

Inset shows eastern North Island and the documented limits (stippled) of tephra fallout from the AD 1886 Tarawera eruption (Thomas, 1888). Ash fell on a number of ships at sea, the farthest being c.300 km (*Julia Pryce*) and c.1000 km (S.S. *Waimea*) from North Island (Keam, 1988)

All but seven of the 108 known fatalities arising from the Tarawera eruption were Maori (the true number of deaths may have been *c.* 120: Lowe *et al.* 2001). The majority of deaths were the result of the Rotomahana explosions, especially the lethal, scorching pyroclastic surges and blasts (Fig. 8.6). Clearly the event had a profound impact on Maori (and others) in the Te Wairoa and Rotomahana area especially, but trauma was felt throughout the extensive fallout zone in the Bay of

Figure 8.7 Buried meeting house (*wharenui*) ('Hinemihi') and smaller houses (*whare*) at Te Wairoa (Fig. 8.6) after the AD 1886 Tarawera eruption

Note: The meeting house, although mud-covered, remained intact and provided shelter for many survivors

Photograph: A.A. Ryan (photo no.15), 13 June 1886, by permission of the Museum of New Zealand Te Papa Tongarewa, Burton Brothers Collection C.10706

Plenty and eastern North Island (Keam, 1988). For example, some groups of Maori in the region of the Rangitaiki and Tarawera rivers, north of Tarawera, became refugees at Matata (Fig. 8.6). Although they had escaped with their lives and without serious injury, their possessions were buried by *c.* 15–30 cm of tephra (some were retrievable by excavation), many potato pits were lost and those with livestock had no feed for them and so many starved (Keam, 1988). These people were eventually resettled in 1903–05.

The plight of these and other Maori seem minor in comparison with the difficulties of those from Te Wairoa-Rotomahana: apart from the lives lost, all possessions had been buried and many crushed. Among livestock, most smaller animals were killed, but dogs, pigs, cattle and horses that survived wandered loose and starving. The main livelihood of the region, tourism, had been destroyed, literally overnight. (Whilst Maori continued to participate in the tourist trade, its control effectively moved into European hands from 1894 with the opening of the railway line to Rotorua: McKinnon, 1997.) But perhaps the biggest societal impact, according to Keam (1988), was the loss of land. For 30 years, Maori groups in the region had been generally secure in possession of their land and property. In previous times, under the old order, the prospect had always existed that a group might lose homes and land through warfare, but by the time of the Tarawera eruption, the people, long-established traders with European settlers, had become accustomed to a new-found security. The eruption rather than warfare (against which there could at least be retaliatory or conciliatory action to make-good losses) had destroyed that security and dispossessed the people of the land which they had prized most. Offers of resettlement for the surviving group, mainly the Tuhourangi subtribe or clan (*hapu*), were received from various parts of central and eastern North Island and beyond, but most settled at Whakarewarewa and Ngapuna, both near Rotorua. Eventually gifts of land were formally ratified and provided a home for most of the Tuhourangi people (Keam, 1988). Other Tuhourangi settled for a time in the Bay of Plenty and Coromandel. After 30–50 years almost all the refugees or their descendants had returned to Whakarewarewa or Ngapuna and the gifted land was returned to the donors (Keam, 1988).

BENEFITS OF ERUPTIONS

The Tarawera eruption exemplifies the volcanic threat faced by early Maori, but numerous benefits were also provided by the wide range of volcanic features and products in much of the North Island (Table 8.3). Most benefits were practical and derived from physical resources. The use of certain 'sacred' soils and pigments also held spiritual significance (e.g. Gray, 1996). The exploitation of most of these features is generally well documented (e.g. Davidson, 1984; Jones, 1987; McKinnon, 1997; Stokes, 2000; cf. Table 8.3). Two examples of direct and indirect benefits of volcanism are described here.

One of the most important volcanic resources for early Maori was the glassy rock, obsidian (*tuhua*), which was used extensively for making tools and traded. Sources are found in central and northern North Island (McKinnon, 1997) but Mayor Island, or Tuhua, was by far the most important (Fig. 8.8). Innumerable archaeological sites throughout New Zealand contain obsidian from Major Island. Compositionally distinctive, it occurs also in fourteenth century AD archaeological sites in the Kermadec Islands (e.g. Raoul Island), which are about 1000 km northeast of New Zealand (Anderson and McFadgen, 1990; Higham and Johnson, 1996).

A benefit arising indirectly from volcanism is the formation of secondary iron oxide minerals, chiefly ferrihydrite, which occur typically as orange–brown volcanogenic seepages. Ferrihydrite occurs also in small quantities in many types of soils, but is most abundant in those formed from more basic materials such as scoria which are reddish in colour – *onerua*. Such seepages are the result of ferrous iron, derived ultimately from the dissolution of iron-bearing minerals (characteristic of volcanic and pyroclastic deposits and their derivatives) being oxidised and precipitated rapidly on contact with air and/or via bacterial action. The oxides provided very useful pigments for a range of functional and important ceremonial purposes (Table 8.3). Such deposits were also used for both practical

Table 8.3 Beneficial volcanic features and products exploited by prehistoric Maori

Features/products	*Benefits*
Volcanic cones, lahar mounds	Elevated sites for fortified villages (*pa*)[1]
Scoria and volcanic-ash-derived soils	Friable soils (e.g. *onetea* or *onemata*) dominated by allophane and/or ferrihydrite and used for horticulture (northern–central North Island)[2]
Tubes/caves/clefts in lava, ignimbrite	Interment of dead, storage (e.g. of fishing nets)[3]
Volcanic lakes	Water and food supply, transport route
Volcanic or pyroclastic edifices (bluffs, outcrops, etc.)	Mythological figures (e.g. 'giant stone warrior' ignimbrite inselbergs on Mamaku Plateau), petroglyphs[4]
Geothermal activity	Hot-water supply for cooking, bathing, medical treatment, etc.[5]
Volcanogenic iron oxides	
Ferrihydrite seepages	Yellowish–reddish pigments (*kokowai*) for functional and ceremonial purposes (e.g. facial or body decoration, paint for buildings/canoes, insect repellent)[6]
Red scoriaceous soils (haematite rich)	Pigments for facial decoration, especially on high-ranking chief, etc. (*one tapu, pito one, onerua, onekura*)[7]
Volcanic rock materials	
Boulders, cobbles	Stonefield (basalt) structures (e.g. dry stone walls dividing land or garden plots, retaining walls, shelters, *pa* defence walls), anchors, hammerstones, cooking stones (*umu*)[8]
Obsidian, basalt, fine-grained andesite	Tools (adzes, beaters, drill points, flake tools, e.g. knives, flax scrapers), weapons[9]
Pumice	Abrader, carved figurines/heads, fishing-net floats, bowls, gourd stoppers, children's toys, etc.[9]
Volcanogenic sediment	Additive to garden soils (e.g. for growing sweet potato), backfill[10]

[1] Davidson (1993), Bulmer (1996), Cameron *et al.* (1997).
[2] Best (1925), Bulmer (1996), McKinnon (1997), Gumbley *et al.* (in press). Allophane is a short-range order aluminosilicate clay mineral (e.g. Lowe, 1995).
[3] Davidson (1984).
[4] Stafford (1999).
[5] Stokes (2000).
[6] See Table 8.4 and text; Childs *et al.* (1986), Stafford (1999).
[7] *One tapu, pito one*: sacred soil; *onerua*: reddish soil; *onekura*: poor reddish soil. *Kokowai* would be used on the face of a deceased paramount chief, *onerua* on that of a lesser chief. Both were generally *tapu* (Gray, 1996).
[8] Davidson (1984), Cameron *et al.* (1997).
[9] Moore (1980), Davidson (1984), Jones (1987).
[10] Best (1925), McFadgen (1980), Gumbley *et al.* (in press).

and ritualistic purposes by Japanese cultures since *c.* 10,000 BC from the Jomon to Kofun periods (Kamijoh, 1997).

One of the most extensive ferrihydrite deposits in the North Island occurs at springs issuing beneath andesite lavas on the northern slopes of Mt Taranaki at Kokowai Springs (Fig. 8.1). The deposits were referred to as *kokowai*, meaning

Figure 8.8 Mayor Island or Tuhua, a rift-related peralkaline rhyolite caldera volcano located *c.*30 km off the western Bay of Plenty coast (Fig. 8.1), was the pre-eminent source of obsidian (*tuhua*) for prehistoric Maori

Photograph: White's Aviation

'earth from which red ochre is procured by burning' or simply 'red ochre', by early Maori (Childs *et al.*, 1986). The strong colour intensity and high surface area (200–400 m^2/g), and the powdery nature and chemical stability when dried, help make the ochre a good colouring agent (Table 8.4). The material reddens on heating, giving a range of colours, with maximum redness corresponding to the formation of the iron oxide mineral haematite by 750 °C (Childs *et al.*, 1986). The use of *kokowai* by Maori was recorded by Dr Ernst Dieffenbach in his account of his ascent of Mt Taranaki in 1839

> They used it for many purposes; when mixed with shark's oil, it forms a durable paint for their houses, canoes and burying places; it is also universally in request to rub into their faces and bodies . . . the custom of covering themselves with a thick coating of this substance at the death of a relation or friend may have a symbolic meaning, reminding them of the earth from which they have sprung . . . The New Zealander also regards this pigment as a good defence against the troublesome sandflies and musquitos [sic].
>
> (B. Wells in Childs *et al.*, 1986: 86–7)

Table 8.4 Physical and elemental properties of volcanogenic red ochre[1] (*kokowai*) from Kokowai Springs, Mt Taranaki

Sample[2]	*Density* *($g\ cm^{-3}$)*	*Surface area*[3] *($m^2 g^{-1}$)*	*Colour (Munsell)*[4] *(air dry)*
1	3.56	225	Reddish yellow (7.5YR 6/8)
2	3.29	n.d.	Reddish-brownish yellow (7.5YR 6/8–10 YR 6/6)
3	3.63	n.d.	Strong brown (7.5YR 5/8)
4	3.71	380	Reddish yellow (7.5YR 6/8)

Mean chemical analysis (N = 5)[5]

	Fe	Mn	Ti	Ca	K	P	Si	Al	Mg	Na	$H_2O(+)$*	$H_2O(-)$†	C
Mean wt %	49.5	0.16	0.03	0.35	0.07	0.23	6.51	0.39	0.08	0.13	12.21	20.15	1.10
1 sd	6.0	0.23	0.02	0.19	0.11	0.18	1.95	0.36	0.03	0.10	3.68	2.85	0.97

[1] Primarily ferrihydrite, a short-range order iron oxide (after Childs *et al.*, 1986). Similar deposits occur on Mt Ruapehu (Childs *et al.*, 1982) and elsewhere, especially in volcanogenic terrains (Lowe and Percival, 1993).

[2] Sample 1, thick, extensive deposits at main spring seepage vent beneath a lava flow; 2, thin coating (0.01 mm) on boulders downstream from vent; 3, deposit below a spring vent dry at time of sampling; 4, thick layer (>1 mm) in extensive seepage area.

[3] n.d., not determined.

[4] On heating to ≥750 °C, the ochre forms the crystalline iron oxide haematite and attains a maximum redness of 10R 4/8–2.5YR 4/8 (red).

[5] Analyses (by X-ray fluorescence, gravimetric analysis, CO_2 loss) of oven-dry material. Mean of analyses of samples 1–4 (Kokowai Springs) plus sample of thick ferrihydrite seepage in volcanogenic sediments at the 'Ferry Bank', Waikato River, Hamilton (Lowe and Percival, 1993).

* Weight loss on ignition at 1,000 °C for 1 h (loss of organic matter and structural hydroxyls).

† Weight loss between air-dry and oven-dry states (absorbed water).

MYTHOLOGICAL AND SPIRITUAL RELATIONSHIPS

Maori legends had an important role in communicating knowledge. The sources of some can be traced back for about 2,000 years to the time when Samoan explorers sailed out into the Pacific Ocean (Orbell, 1995) and hence many Maori legends are common to other peoples of Polynesia. The Maori have a large number unique to New Zealand, many relating to the natural environment (Reed, 1977; McCraw, 1990, 1993a, 1993b, 1994, 1995). This emphasis was closely tied to the religion of early Maori because nature, being outside their control,was part of the supernatural.

Scores of legends purport to explain how the physical features of the landscape came into being. It is likely, however, that some of these legends had additional, subtler purposes, as illustrated below, and so it is probably a mistake to try to interpret them too literally. Nevertheless, a few show a remarkable parallel to geoscientific explanations for some phenomena. For example, legend records that when the Waikato River was first formed, it followed the wrong course to the sea and so the Maori volcano god, Ruaumoko, was asked to rectify the situation. Ruaumoko caused a great convulsion that blocked the river's path at Piarere and forced it to follow the correct course (Fig. 8.9). A geoscientific explanation for the abrupt disjunction is nearly the same: the voluminous Kawakawa (Oruanui)

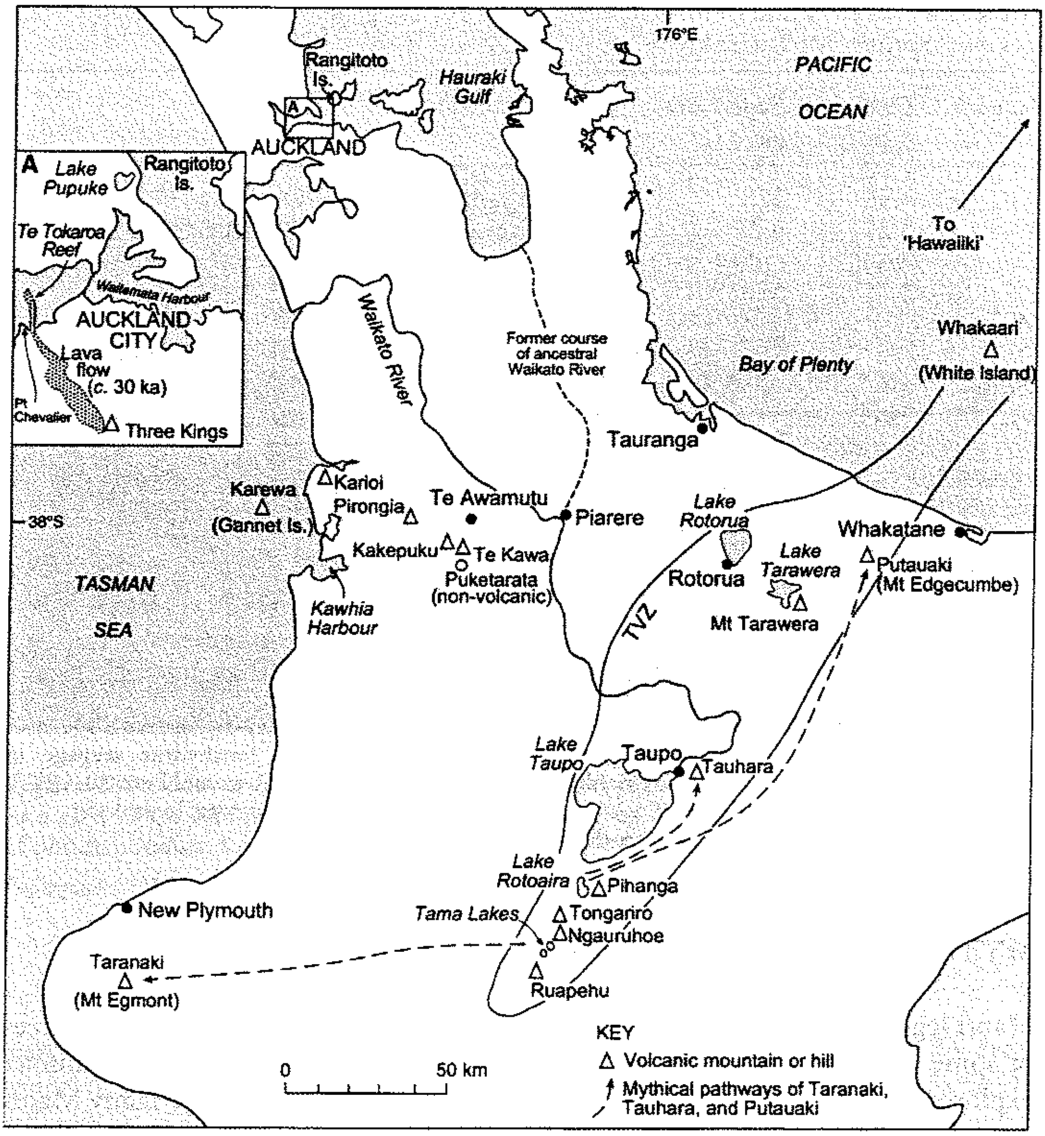


Figure 8.9 Locations of volcanic mountains and other features in North Island that are referred to in early Maori oral history

Note: TVZ, Taupo Volcanic Zone

eruption of Lake Taupo *c.* 26,500 calendar years ago (Wilson, 2001) so overloaded the river valley with volcanogenic debris that it overflowed its banks and adopted a new course (Selby and Lowe, 1992).

Legends relating to volcanic features

Each tribal group had its own sacred mountain, its size and prominence symbolising the importance of the tribe. Volcanic cones, if present in the tribal territory, were favourites for this role. Sacred mountains were regarded as ancestors and were given human attributes. Groups of mountains were often seen as an extended family and the legends tell how they squabbled, fell in love, had offspring and so on. For example, a legend about the northwest-trending line of isolated, eroded andesite-basalt cones near Te Awamutu (Fig. 8.9), which are members of the Plio-Pleistocene Alexandra Volcanics (Briggs *et al.*, 1989, 1997; Goles *et al.*, 1996), tells how in former times there were more members of this family group. Fighting between male rivals over the female, Te Kawa, lead to newcomer Kakepuku defeating Puketarata, who retreated south, and Karewa, who eventually fled west and out to sea (Reed, 1977). It has been suggested that the main purpose of this legend is to make it clear that Karewa (Gannet Island) was once on land and so continues to mark the limits of tribal territory.

Te Heuheu, chief of the Ngati Tuwharetoa tribe of Taupo district, explained to Dr Ferdinand von Hochstetter, an Austrian geologist visiting in 1859 during the *Novara* expedition, that fire was sent from *Hawaiiki* (the mythical Maori homeland) in response to a call from the high priest, Ngatoroirangi. The latter had been exploring the interior of the North Island and was now perishing from the cold on the summit of Tongariro (Fig. 8.9). The fire came under the sea to Whakaari and from there, according to Te Heuheu, travelled underground towards Tongariro. On the way it came to the surface in various places, giving rise to hot springs, geysers and other hydrothermal features. Finally, the fire burst out on the summit of Tongariro and saved Ngatoroirangi's life. Hochstetter was impressed by this explanation for the locus of hydrothermal activity in what is now called the TVZ (Figs 8.1, 8.9). He concluded that the Maori had grasped the connection between volcanism and hydrothermal activity (von Hochstetter, 1959; Gregg, 1960). The same legend also tells how Ngatoroirangi eliminated a rival by calling on Ruaumoko to direct clouds of ash on to him. This is possibly a reference to the frequent tephra eruptions (including pyroclastic flows) of Ngauruhoe.

Perhaps the best known of all Maori legends tells of a group of volcanoes that once stood in the centre of the North Island near Lake Taupo. They began fighting over the only female, Pihanga (Fig. 8.9), and a great battle ensued. According to the Tuwharetoa version, their sacred mountain, Tongariro, was victorious and at least three defeated volcanoes were put to flight, leaving Lake Rotoaira and the Tama Lakes where they had stood. According to folklore, mountains can move only at night, so when dawn came, and they became frozen in place, Taranaki had reached the west coast and Putauaki (Mt Edgecumbe) the Bay of Plenty region, but Tauhara, still besotted with Pihanga, had dawdled and was stranded near (present-day) Taupo township (Fig. 8.9). In this way early Maori explained the distribution of volcanoes (Grace, 1959). Perhaps an eruption from Tongariro, closely followed by one from Taranaki (Fig. 8.2), was interpreted as volcanic activity moving from one mountain to the other. In the manner of legends, it was but a short step to the mountain itself moving.

An informant from the Ngati Awa tribe of the Bay of Plenty added to this story by telling how Putauaki (that tribe's sacred mountain) had married Mt Tarawera but hankered for Whakaari (White Island). Tarawera became so jealous that she exploded and wept tears, forming Lake Tarawera (Fig. 8.9). Evidently this legend is much older than the historic Tarawera eruption of AD 1886. If so, it could be derived from the tribal memory of the Kaharoa eruption of *c.* AD 1300, as described earlier, and may explain Tarawera's strict *tapu* status. Pearce (1977) and Keam (1988) documented several other possible stories that may relate to the Kaharoa eruption, but these are open to various alternative interpretations.

Legends associated with volcanic hazards

There are few legends about the hazards or disasters associated with volcanic activity. One example from Auckland explains the explosive formation of the Auckland Volcanic Field (Fig. 8.1), when powerful incantations from *tohunga* (priests) were called upon by one group to destroy an opposition war party (Simmons, 1987). It is intriguing, however, that although the *c.* AD 1400 eruption of Rangitoto Island was undoubtedly witnessed by early Maori, there are no legends clearly referring to this event. The name 'Rangitoto', which can be translated as 'blood sky', was formerly thought to refer to an eruption, but it is now accepted as referring to 'blood-stained rocks' through an injury received by a chief (Woolnough, 1984). Indeed, a legend explaining the formation of Rangitoto attributes it to a giant or a god lifting the mountain from the mainland where it was blocking the view of an important chief and dumping it in the Waitemata Harbour, leaving Lake Pupuke (a basaltic maar) to mark its original position (Fig. 8.9, inset A; Lowe and Green, 1992). There are several explanations for the lack of legends referring to this eruption. One is that the eruption, although a dramatic physical event, may not have affected the *mana* (prestige) of the tribe to any extent because no important chief was killed or injured, nor did such a person make comment that was worthy of preservation by a legend. Another reason is that the ancient people who witnessed the eruption were eliminated by later invaders and any memories of the eruption perished with them.

Despite many legends describing eruptions as angry mountains fighting each other with much rumbling, the ejection of boulders, and 'fiery glowing', none refers to flowing lava. This suggests that Maori were not familiar with the process or material. Apart from Rangitoto Island, the only other places where lava streams would be seen were close to the active vents on Mt Tongariro such as Ngauruhoe and near the summit of Mt Taranaki (Fig. 8.2). These areas came to be designated *tapu*, and so presumably visitors would not have been able to approach closely enough to recognise the slow-flowing andesitic lava for what it was. Alternatively, if Maori did venture to the upper slopes, as shown by the buried *umu* on Mt Taranaki (Fig. 8.3), their visits did not coincide with any eruption of lava. Similarly, a legend from Auckland about the formation of an old, 10 km long basalt lava flow derived from Three Kings volcano (Kermode, 1992) and extending part-way across Waitemata Harbour forming Te Tokaroa (Meola) Reef (Fig. 8.9, inset) gives no hint that this feature was once molten rock or that it came from a volcano.

The *c.* AD 200 Taupo eruption from Taupo caldera, Lake Taupo (Fig. 8.1), is the world's most powerful known eruption for the past 5,000 years (Walker, 1980; Wilson and Walker, 1985; Wilson, 1993; Smith and Houghton, 1995). It involved five phases of plinian (including 'ultraplinian') and phreatomagmatic fall activity, generating widespread tephra fallout, and a climactic sixth phase resulted in the violent emplacement of Taupo Ignimbrite over *c*.20,000 km^2 of central North Island (Wilson, 1985, 1993; Wilson and Walker, 1985). The extreme violence and energy release ($\geq$150 $\pm$ 50 megatons of explosive yield) of the ignimbrite-emplacement phase probably generated a global tsunami (Lowe and de Lange, 2000). However, the devastating eruption, which had enormous environmental impacts throughout North Island and beyond (e.g. Wilmshurst and McGlone, 1996), finds no mention in Maori legends.

To summarise, early Maori society maintained a strong physical and spiritual relationship with the land, which is reflected in the wealth of legends about natural phenomena including the origin of landforms. Maori readily took advantage of the benefits supplied by volcanic activity as described previously but were well aware of the dangers and took care to placate the volcano god (Simmons, 1987). Restrictions were placed on visiting the frequently active andesitic volcanic centres of Tongariro and Taranaki. There is, however, no strong evidence from their legends that early Maori had suffered catastrophically from volcanic eruptions and associated events until the Tarawera event of AD 1886.

DISCUSSION AND CONCLUSIONS

(1) The level and extent of the impacts of volcanism on early Maori in New Zealand are not well known. This is because New Zealand's prehistory in the pre-European period was exceptionally brief, beginning *c.* AD 1250–1300. In addition, the historical (written) period also has been very short, effectively covering barely the past 200 years. Consequently, our chapter has relied mainly on interpreting volcanological, palaeoenvironmental and archaeological data, which in turn have been constrained mainly by radiocarbon and other dating techniques and by tephrochronology.

(2) Since *c.* AD 1250–1300 it is likely that Maori would have witnessed only one rhyolitic eruption (Kaharoa, *c.* AD 1300), two basaltic eruptions (Rangitoto, *c.* AD 1400; Tarawera, AD 1886), and numerous andesitic eruptions from the very frequently active volcanoes of Tongariro Volcanic Centre, White Island, and Taranaki volcano (Fig. 8.2). Eruptions from Tongariro, Ngauruhoe and Ruapehu, and from White Island probably had relatively little direct impact because there few or no people living near them. In contrast, minor or short-lived impacts on more distant communities within range of tephra fallout, especially in eastern North Island (e.g. Hawke's Bay, Bay of Plenty), would have been relatively common. The human witnesses to the Rangitoto eruption who were undertaking gardening in the freshly fallen basaltic ash seem to have displayed a remarkable level of insouciance towards the event. Many small-scale, pre-European, basaltic eruptions in Taveuni, Fiji, similarly had apparently little impact on inhabitants because rapid resettlement or continued occupation occurred in nearby areas (Cronin and Neall, 2000). On the slopes of Mt Taranaki,

the existence of *umu* buried within tephra deposits indicates that those who used them did not feel unduly threatened, or they felt that the risk was worthwhile. Later Māori have come to regard the upper slopes of the mountain as *tapu* (meaning out-of-bounds, sacred) and the original designation of this status was possibly a response to minimise the risk for future generations.

(3) Several eruptions, notably the Kaharoa event, the largest eruption in prehistory, and some of the Mt Taranaki events, including the Newall and Burrell series of eruptions, potentially had devastating consequences for relatively few people. Impacts from these eruptions, especially from the blasts, pyroclastic flows and surges, would have been catastrophic near source, as has been observed during historic times in more populous volcanic terrains, such as in Japan or the West Indies (e.g. Machida, 1990; Soda, 1996; Nakada, 2000). Lesser effects, although tending to become minor in distant areas, would have been felt for considerable distances away from the vent areas, probably over most of the North Island in the case of the Kaharoa eruption. It is possible that post-eruptive events, such as landslides, debris avalanches, flooding or lahar emplacement, may have caused significant damage or resulted in fatalities, depending on population levels and geographic circumstances (e.g. proximity of people to drainage channels). Moreover, these sorts of destructive events may have been prolonged (months to years) or occurred decades after the initial eruptive episode and then impacted with little warning on distant areas far from the volcano (cf. Scott *et al.*, 1995; Soda, 1996; Scott and Nairn, 1998; Vallance, 2000). In Tables 8.1 and 8.2 we have summarised the different types of hazards seen or experienced by early Maori, and their potential effects and extent of impacts.

(4) The Tarawera eruption of 10 June 1886 provided an insight into the level of impact and trauma that even a very powerful basaltic eruption is capable of generating: at least 108 fatalities, total ruination of villages and other possessions, loss of the main livelihood, dispossession of land, and consequent need for resettlement. The societal impacts of this eruption on local Maori were perhaps worsened by its occurrence during a period when European settlement was exerting significant pressures on Maori land ownership and economic activity.

(5) Some secondary consequences of volcanism, such as the possible development of a 'disaster culture' by Maori society, may have occurred. Harada (1993b) suggested that, as in other prehistoric societies, early Maori may have developed a response mechanism to avoid the effects of future natural disasters initially by placement of a *rahui*, meaning 'prohibited access', on a devastated area. Subsequently, a more religious or superstitious restriction, or *tapu*, would be applied. Any violation of the *tapu* status, or sin (*hara*), was likely to bring upon a calamity. In contrast, other sacred areas were designated as accessible places of refuge or sanctuaries for all citizens (e.g. a *marae*, a ceremonial gathering place). This interpretation has some similarities with Japan, where Shinto shrines and their surrounds, which are sacred and inviolate areas, represent religious places

both of worship and refuge that may have been initially established in safe zones in response to earlier natural disasters (Harada, 1993b, 1999).

(6) Given the extent and frequency of volcanic activity in the North Island for the past *c.*2000 years (Fig. 8.2), it is notable that the disastrous consequences of volcanism do not figure more prominently in Maori culture, oral history and mythology. This contrasts with findings from Taveuni island in Fiji, for example, where local legends describing past eruptions have persisted since *c.* AD 120–320, and where such stories and relict place names can be readily related to independent volcanological and archaeological evidence (Cronin and Neall, 2000). Similar firm linkages between oral tradition and geoscientific evidence for volcanic impacts can be found in some other prehistoric societies (e.g. Blong, 1982; Chapters 9–11). The apparent incongruity for New Zealand, however, is reconcilable by the lateness of its settlement (and sparse population), which meant that there were fewer opportunities for substantial populations to witness very destructive eruptions, and probably because most of the frequent eruptions since settlement occurred in comparative isolation or generally had minor (i.e. forgettable) effects. The AD 1886 eruption of Mt Tarawera had catastrophic impacts on some Maori, yet this event was smaller by an order of magnitude than the previous eruption of Mt Tarawera (the Kaharoa event), which in turn is dwarfed in terms of magnitude and impacts by the *c.* AD 200 Taupo eruption. The *c.* AD 1300 Kaharoa eruption occurred very early in prehistory and the most hazardous areas close to Mt Tarawera are unlikely to have had dense occupation, if settled at all. At Lake Waikaremoana, situated in remote uplands (Fig. 8.5), the earliest unambiguous evidence for local human settlement in the pollen record occurs well after the 12 cm thick layer of Kaharoa Tephra was deposited (Newnham *et al.*, 1998b). However, those pollen records indicating that initial human settlement occurred just before the deposition of Kaharoa Tephra are obtained mostly from coastal sites where the Kaharoa Tephra layer is much thinner (Newnham *et al.*, 1998a; Fig. 8.9). As a consequence, populations at these sites are unlikely to have developed a disaster culture because they did not need one. The *c.* AD 200 Taupo eruption, however, obliterated a much more extensive area of the central North Island and would surely have forged an indelible cultural impression on any people who survived beyond the disaster zone, had they been there. That no cultural recognition of this eruption exists is consistent with the archaeological and palaeoenvironmental evidence, which demonstrates that no people were present in New Zealand at the time of the Taupo eruption.

(7) As well as bringing discomfort and some destruction to early Maori, volcanism also brought considerable physical and some spiritual benefits in many varied forms, as listed in Table 8.3.

(8) Volcanism in New Zealand, as in similar terrains elsewhere, has been a boon for archaeology and palaeoecology (Harris, 2000). Tephrochronologists have been able to use tephras to help establish reliable linkages between archaeological

and palaeoenvironmental studies, a bridging of disciplines favoured by Edwards and Sadler (1999) and emphasised by Lowe *et al.* (in press). The work has helped to determine the timing of earliest occupation of archaeological sites (*c.* AD 1250–1300) and to determine when the first environmental impacts of early Maori on the landscape were registered (*c.* AD 1280; Fig. 8.9). These findings, based around the critical 'settlement layer' datum represented by the *c.* AD 1300 Kaharoa Tephra, are in close agreement with other archaeological and palynological data in New Zealand (Newnham *et al.*, 1998a; Lowe *et al.*, 2000).

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