The following three papers formed a symposium on "Vulcanicity and Vegetation in the Rotorua District" at the 1962 Conference.

GEOLOGY OF THE ROTORUA DISTRICT

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INTRODUCTION

The Rotorua district is 3500 square miles in area, extending north from Maroa and Murupara to the Bay of Plenty coast between Matata and Tauranga. The Taupo Volcanic Zone, which lies as a belt north-east from Ruapehu to White Island, passes through the centre of the area. In this account the rocks have been divided into a number of groups on a lithologic basis, and their distribution and approximate age range are shown in Figure 1. These groups do not include late Quaternary volcanic ash, which mantles the entire area superficially and in places is more than 40 ft thick.

PHYSIOGRAPHY

Broadly speaking, the district consists of two extensive ignimbrite plateaux between which the Taupo Volcanic Zone extends as a 20-mile wide belt between Maroa and the Whakatane Graben. On the extreme east are the ranges reaching from Te Whaiti to the sea at Whakatane. They reach altitudes up to 3500 ft. but fall gradually towards the north. They are bounded by fault scarps of two intersecting systems — a north-south set of dextral transcurrent faults, and a set of north-east faults of normal type, down-thrown to the north-west and parallel to the Taupo Volcanic Zone. Both systems form prominent high fault scarps along the eastern side of the Galatea and Waiohau basins.

The Kaingaroa Plateau has a remarkably flat surface 1800 ft. above sea level at Kaingaroa. To the north there is a 200 ft. scarp around the erosional margin of the topmost ignimbrite sheet, and the remainder of the plateau is more dissected and falls gradually towards Te Teko, where it ends against the lower Rangitaiki Plains. The youthful volcanic cone of Edgecumbe rises from the western side of the plateau, which has a sharp descent into the Whakatane Graben and Reporoa lowlands, but on the east it slopes gently down to the Rangitaiki River. This flows along the fault angle between plateau and ranges, flowing in ignimbrite gorges between the tectonic basins of Galatea, Waiohau and Te Mahoe.

North-west of the Taupo Volcanic Zone the Patetere Plateau is gently arched along a north-south axis at an elevation of 2000 ft., but terminates on the north against the Kaimai Ranges and Whakamarama Plateau, also an ignimbrite plateau. On the west it descends towards the Tokoroa Plateau, and on the east it gives way to the Kaharoa Plateau, which north of Lake Rotorua is a little over 1500 ft. above sea level but falls to 1200 ft. north of Rotoma and 1000 ft. at Matata. On the north this plateau descends gradually to sea level in Maketu Basin. Tauranga Basin is a tectonic feature in which the post-gracial rise of sea-level produced a drowned valley system which is now Tauranga Harbour, cut off from the sea by large sand spits and bars. Maketu Basin is occupied by swamp, and Whakatane Graben has been filled by Holocene volcanic detrital material. A remnant of the Kaharoa Plateau remains between Rotorua and Okataina, Rotorua Caldera being a basin within the plateau.

The Taupo Volcanic Zone contains varied structural and volcanic relief. Maroa Volcanic Centre is a cluster of rhyolite domes and flows, 10 miles in diameter, from which the slopes fall to north-west and south-east into Atiamuri and Reporoa valleys respectively. Both valleys extend north-east for 15 miles at the feet of the flanking ignimbrite plateaux, and between them are a series of north-east ranges. These are fault blocks tilted away from Ngakura valley, which is a central graben.

Farther north-east are the huge volcanic piles of Tarawera and Haroharo. These are

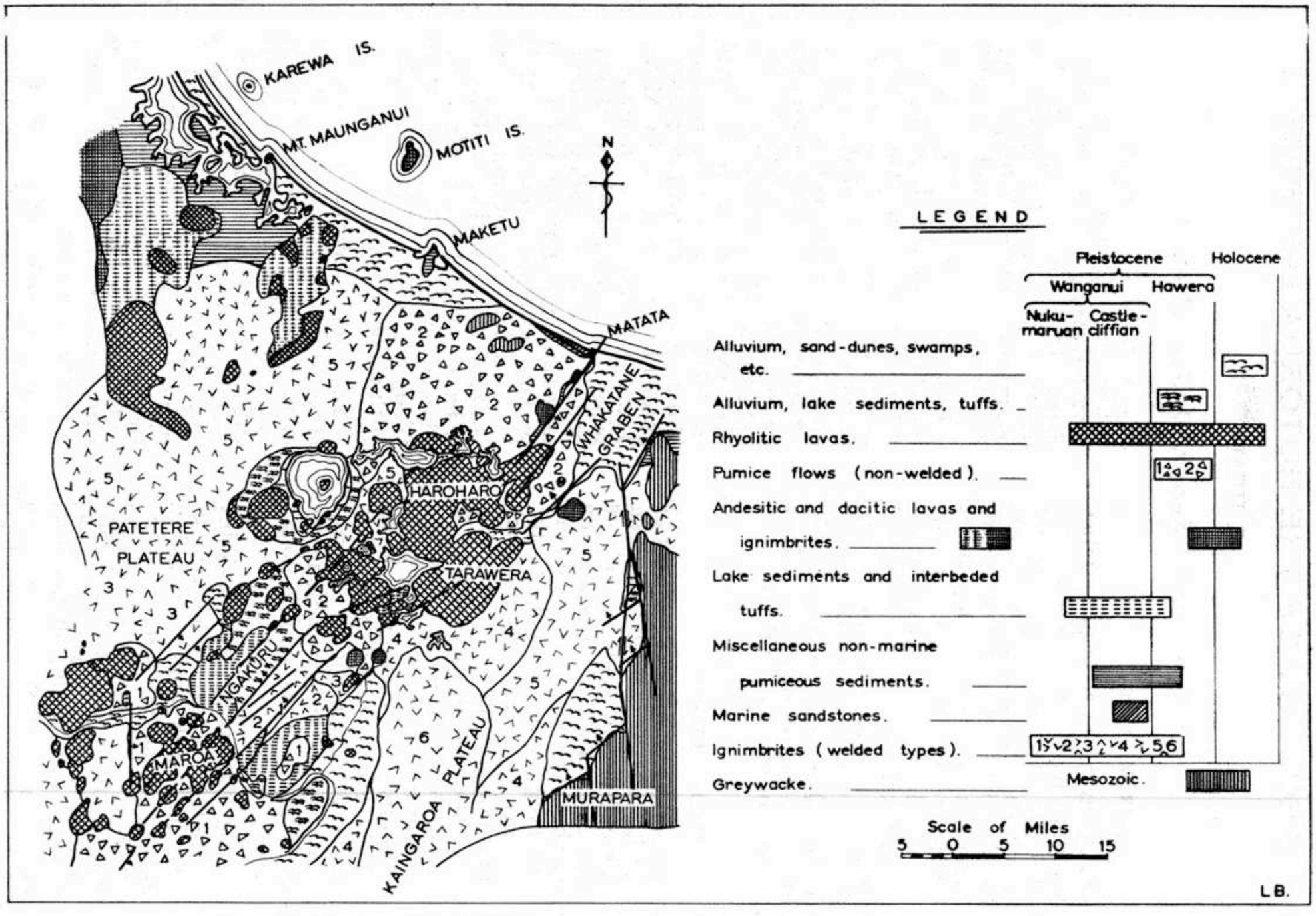

FIGURE 1. *Geological map of the Rotorua area*

rhyolite lavas of the Okataina Volcanic Centre, extruded on the floor of Haroharo Caldera, within which Rotokakahi, Tikitapu, Okareka, Okataina, the eastern end of Rotoiti, Rotoehu and Rotoma are marginal lakes dammed by the lavas, and Tarawera lake is a remaining part of the floor blocked off by coalescing flows from Tarawera and Haroharo. Two miles downstream from the outlet, the Tarawera River plunges over the margin of one of the flows, and enters the lower Tarawera Valley.

North-east of Tarawera volcano the Taupo Zone narrows abruptly and enters the Whakatane Graben. This is bounded by steep fault scarps south of Matata and at Awakeri. Seaward the graben probably enters White Island Trench (Fleming 1952).

ROCKS OF THE DISTRICT

The oldest rocks, usually known as "greywackes", are sandstones, argillites and conglomerates, which form the ranges east of the Rangitaiki River, and two small ranges near Otamarakau. Jurassic fossils have been found at Awakeri and east of Taneatua, though the rocks may locally be Lower Cretaceous elsewhere. These are the basement rocks of the region. Beneath the Kaingaroa Plateau they are believed on geophysical evidence to lie above sea level (Beck & Robertson 1955), but in the Taupo Volcanic Zone are faulted down to much greater depths (Modriniak & Studt 1959).

The most widely distributed rocks are ignimbrites. These are believed to be the products of large scale fissure eruptions, probably from ring fractures (Healy 1962). The material, of ash, lapilli and block grade, spread as pyroclastic pumice flows and settled by compaction after coming to rest hot enough to retain plasticity and to become welded in the lower parts. One sheet, the Matahina Ignimbrite (5 on the eastern side), flowed at least 70 miles, and individual sheets had volumes which in some cases exceeded 50 cubic miles.

The ignimbrites vary in colour from pink and mauve to grey and even black. They may contain abundant phenocrysts of plagioclase and quartz, or very few; and generally the upper and softer zones contain a greater amount of pumice, sometimes completely recrystallized during the cooling process, which weather to give the rock a honey-combed appearance. The oldest one is the Te Kopia Ignimbrite (1), a dark glassy, crystal-rich type which forms the base of the Paeroa Fault scarp. The Paeroa Ignimbrite (2), which forms the highest part of the Paeroa Range and the block west of it, is a light grey quartz-rich type similar to the Rangitaiki Ignimbrite but differing in containing abundant biotite. The Rangitaiki Ignimbrites form the base of the Kaingaroa Plateau and outcrop on both flanks. On top of the plateau are the Kaingaroa Ignimbrites (6), including an upper hard, fine-grained type with minor plagioclase and no quartz, and a lower dark grey to black, glassy type containing lumps of white and grey-streaked pumice.

The Waiotapu Ignimbrite (3) is red to pink in colour, contains no quartz, and at Waiotapu contains abundant coarse flattened lenticles. On the Patetere Plateau and farther west it is generally pink and finer grained. The Matahina and Mamaku ignimbrites (5) were spread in the shape of a huge circle centred on Rotorua Caldera and Okataina Volcanic Centre, from which they were probably erupted. The upper parts of these two ignimbrites are soft and pumiceous and the lower parts dense and welded, and both contain quartz.

Those described above are rhyolitic to dacitic in composition, but ignimbrites of the Whakamarama and Kaimai area are dacite and those of the Papamoa Ranges west of Te Puke are andesitic. They are older than the ignimbrites erupted from the Taupo Volcanic Zone.

Some ignimbrites are extremely pumiceous and are not welded, though they may be well compacted, and some, erupted into water, were interbedded with lake sediments. Rocks of this type form the southern half of the Paeroa Range (oldest formation of the Huka Group — Grindley 1959), and older ones form the block west of the Ngakura Graben (Ohakuri Formation of Grindley). Still younger, loosely compacted pumice breccias formed by pyroclastic flows from the Maroa Volcanic Centre (1) and from vents in and around the Okataina

Volcanic Centre (2) are the youngest beds of this type with any extent. These include the Waitahanui Breccias of Grange (1937) and Haparangi Rhyolite Pumice and Mihi Breccia of Grindley (1959).

The final stage of the volcanism at the two centres was the eruption of rhyolite lavas in the form of domes, and there are notable accumulations of rhyolite at Maroa and Okataina. In general the rhyolites of the outer rings west of both centres are older than those within the centres, and are considered to have been erupted from surrounding ring fractures. In Rotorua Caldera the central domes are similarly younger than those of the north and west rim. All are included in the Haparangi and Patetere rhyolites of Grange (1937). The oldest rhyolites are those of the Tauranga, Papamoa and Kaimai district, west of the Taupo Volcanic Zone. The oldest rhyolites are usually lithic and spherulitic, whereas the younger ones have undergone little erosion and still retain their glassy obsidianitic and pumiceous outer skins. The youngest dome at Maroa is Puketarata, which may be about 10,000 years old. At Tarawera the youngest domes are about 900 years old.

At Manawahe and near Matata are andesites which possibly form part of a large volcanic complex almost entirely buried by later sediments and ignimbrites. Together with andesite near Te Puke and north of the Kaimai Ranges these could possible be correlated with andesites of the Coromandel Range which are of Miocene age. They are hornblende andesites, whereas Edgecumbe is a young hypersthene andesite similar in composition to the rocks of White Island and Whale Island. It may be little older than 1000 years, being covered only by Kaharoa Ash about 900 years old. Maungaongaonga and Maungakakaramea are young hornblende dacite volcanoes of late Pleistocene age at Waiotapu.

The only dated sediments younger than the Mesozoic basement rocks are marine sandstones and conglomerates at Matata. There are several hundred feet of well compacted sandstones containing fossils of upper Castlecliffian age. Younger conglomerates containing pebbles of greywacke and ignimbrites pass up into pumiceous tuffs over which lies the Matahina Ignimbrite, taken to be of Hawera age. Siltstones and sandstones with lignites and interbedded pumiceous tuffs border the Tauranga Harbour, and include the Tauranga beds of Henderson and Bartrum (1913). Included also are sands, conglomerates and tuffs at Maketu, Matata and Awakeri. They range in age from Castlecliffian to Hawera. Younger Hawera siltstones, sandstones and tuffs were laid down in lakes in the Ngakuru, Horohoro and Rotorua areas. The bulk of the Holocene sediments is alluvial pumice.

LATE QUATERNARY VOLCANIC ASH

Late Quaternary volcanic ash mantles the entire district. In the south this consists almost entirely of pumice ash erupted from near Taupo (Baumgart 1954, Baumgart & Healy 1956, Healy *in press*), but it also contains ash erupted from Puketarata and elsewhere in the Maroa Volcanic Centre. The remaining part of the district is covered by ash erupted from vents either in or around the Okataina Volcanic Centre. The uppermost beds consist of a series of brown pumice ash and lapilli layers (Grange 1937, Vucetich & Pullar 1962). Beneath these are two thick pumice lapilli and blocks beds which aggregate 60 ft. at Rotoehu, 12 ft. at Te Puke, 40 ft. at Pukehina and 25 ft. at Awakeri. These breccias do not appear to rest on the Haroharo rhyolites within the Okataina Centre. Elsewhere they are underlain by older ash members and breccias, a good section of which is exposed in the cliffs east of Otamarakau. The ash beds pass down here into pumice flows mentioned earlier. The latter were probably erupted during the last interglacial stage, because valleys were cut in them during the last glaciation. Younger terraces within the valleys can be distinguished by the presence or absence of some of the ash formations.

GEOLOGICAL HISTORY

During the latter part of the Tertiary, the Taupo Volcanic Zone was elevated and stripped of any marine Tertiary cover it had received. There is no clear evidence of the date of the beginning of volcanism, but

pumice outwash is first noted in Opoitian sediments (Pliocene). Subsequent ignimbrite eruptions were accompanied by subsidence within the Taupo Volcanic Zone, but the early history is complex and not yet understood. In the surrounding plateaux there is evidence that periods of erosion intervened between major ignimbrite outpourings, but within the Zone sedimentation may have continued in depressions and lakes formed as a result of the subsidence.

Within the large circular area between Mokai and Waiotapu sedimentation took place in one or more lakes intermittently during the latter part of the Pleistocene, following cauldron subsidence on a large scale. Subsequently intrusion appears to have arched up the central part along a north-east axis, probably reaching its greatest elevation where the Maroa Centre is now located. Lacustrine deposits were laid down, but eruptions at intervals deposited also bands of tuff, and ocasional pyroclastic flows laid down pumice breccias. The deposits were repeatedly tilted and dislocated because of the uparching, then faulted down along the crest as a result of the withdrawal of magma at the time of eruptions.

Finally the eruption of pumice flows (1) produced marked subsidence in the Maroa area, followed by the extrusion of rhyolite domes accompanied by pumice explosive eruptions. The youngest domes are on the eastern side associated with branches of the Paeroa Fault, which has the youngest and highest scarp of the faults east of Ngakuru Graben, indicating that the intrusive and eruptive processes, although concentrated along a north-east axis through Maroa, had a progressive tendency towards the south-east. This has also been suggested by Grindley (1959).

Nearer Rotorua the general sequence of events was similar, but there the intrusion has not been associated with a large folded and faulted structure such as Ngakuru Graben and neighbouring fault blocks. The eruption of the Mamaku, Matahina and Kaingaroa Ignimbrites presumably produced calderas at Rotorura and Haroharo. Since then there have been further extrusions of rhyolite within Rotorua Caldera, and a number of benches indicate progressively lower lake levels. The topmost one, about 300 ft. above present lake level, does not occur on Mokoia Island which is younger.

In the Okataina Centre eruptive activity continued. During the last interglacial stage there were large eruptions of pumice as pyroclastic flows to the north and east. These were accompanied by caldera formation and the partial draining of Lake Rotorua. Presumably the drainage from the enlarged caldera flowed into the Whakatane Graben, though it was not then as deep as now. The digitate arms of Rotoehu are the result of headward erosion during this stage. Finally the eruption of rhyolite lavas and domes at Haroharo, Tarawera and other centres commenced, acompanied by intermittent ash eruptions. The coarse lapilli and block beds may have been an early product of this series. As the domes accumulated the centre of the caldera became filled and lakes formed in the remaining marginal hollows.

Sediments and water laid tuffs which overlie the coarse pumice lapilli and block beds along the north shores of Rotoiti, Rotoehu and Rotoma lakes probably postdate the rise of Haroharo volcano and indicate that the lakes rose in level and were connected to Lake Rotorua temporarily until the Kaituna River spilled over to the north and drained the lakes down to their present levels. However, some warping seems to have occurred, because the above young sediments and tuffs reach a higher level at the west end of Rotoiti than they do at the east. Also tectonic activity continued in the Whakatane Graben, the downward movement being offset by alluviation. About 900 years ago the three domes of Tarawera were extruded and there was a violent pumice eruption which showered Kaharoa Ash over the district. One or more pumice lahars swept down the Tarawera River and built a large fan on which Kaverau now stands, and which forms a well defined terrace up the river. In 1904 part of this was removed by a flood caused by the lowering of the outlet of Lake Tarawera, which had been raised by an unknown amount at the time of the 1886 eruption of Tarawera. The

1886 eruption also blocked the valley leading from Rotomahana to Tarawera lake and brought into existence a much larger and more elevated Rotomahana. The dome building and associated explosive eruptive phase of the Okataina Volcanic Centre activity presumably still continues.

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VULCANICITY AND INDIGENOUS VEGETATION IN THE ROTORUA DISTRICT:

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INTRODUCTION

Although most of the country round Rotorua is climatically and edaphically suitable for forest, only a third was covered by about the middle of last century. There was one major tract on high land between the coastal lowlands and the upper Thames (Waihou) and Waikato valleys; and a few outliers on high ground within inland valleys. The Kaingaroa plateau was nearly devoid of forest. Throughout the district there were small patches of forest in the gorges flanking the uplands, in folds of the hills in generally open country, and clumps of swamp forest on the plains. Apart from deep swamps, sand dunes, and the nearly bare summits of Mt. Tarawera, the rest was mainly scrub and fern, with heath and tussock in the south.

This pattern suggests that a nearly universal forest had been reduced by fire, probably by the Polynesians living in middle Waikato valley, along the Bay of Plenty, and about the Rotorua lakes. Fire was their only means of clearing land, but they could not control it. Frequent burning was necessary for a shifting cultivation, to retain fern land for the staple fern root, and to maintain communications. In recorded local traditions large fires are rarely mentioned, but early Europeans commented on them and on the natives' casual attitude towards them.

The recent dating of the last violent eruptions from the east Taupo volcanic centre at only 1,800 years ago suggested that the then forest had been devastated and had not since returned. But there is pedological evidence of former more widespread forests on soils of the Taupo suite (Vucetich, unpub.). Furthermore, forests now in this area are on southerly (the wetter) faces: the aspect expected from fires, but not from volcanic blasts from the direction of Taupo. A general "post-Taupo" forest would probably have been densely stocked with rimu, miro, matai, totara, and maires (*Dacrydium cupressinum, Podocarpus ferrugineus, P. spicatus, P. totara,* and *Gymnelaea* spp.); it would have grown largely on coarse soils