MT TARAWERA: 1. VEGETATION TYPES AND SUCCESSIONAL TRENDS

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SUMMARY: Vegetation succession on Mt Tarawera, Rotorua, New Zealand, a recently erupted volcano, was studied. Field data from 70 plots were collected and analysed by a clustering algorithm. The plots formed an altitudinal and successional series which included bare scoria, herbfield, mixed hardwood, scrub, kamahi forest and tawa forest. Because of the differential effects of the 1886 eruption, different successional trends are being followed on the north-west and south-east faces of the mountain.

KEYWORDS: volcanic areas; plant establishment; plant succession; Mt. Tarawera.

INTRODUCTION

Mt Tarawera comprises a group of rhyolitic cumulodomes 24 km east-south-east of Rotorua in the Noith Island of New Zealand (Figs. 1, 2).

It was formed by the extrusion of successive rhyolitic domes and flows during the late Pleistocene period and has been known to erupt four times (Cole, 1976). During the Kaharoa eruption at about 1324 AD ± 56 years (Lawlor, 1980), the three central domes of the Mt Tarawera complex; Wahanga, Ruawahia and Tarawera were formed (Cole, 1965) (Fig. 3).

The most recent eruption occurred in 1886 and, although initially rhyolitic, the ejecta became predominantly basaltic ash and lapilli. Half a cubic kilometre of material was ejected from the mountain onto the surrounding landscape extending 16 km to both the north and south and about 24 km to the north-east. Comparatively little was deposited to the west (Thomas, 1888). The ejected material formed a layer overtopping the existing domes and reached its greatest thickness, 61 m, near the craters (Burke, 1964). Although the eruption resulted in little overall change to the form of the mountain, an impressive 7 km fissure opened up along the south-west-north-east axis of the complex. The events of the eruption are described in detail by Smith (1886), Hutton (1887), Thomas (1888) and others (see Cole, 1966).

The 1886 eruption of Mt Tarawera is the most significant to have taken place in New Zealand since European settlement. Records of the vegetation before, shortly afterwards and at intervals following the eruption offer the unique chance to study plant establishment and successions on a new volcanic surface.

VEGETATION HISTORY

Pre-eruption vegetation

Prior to the 1886 eruption, stands of forest, similar to extant virgin stands in the Rotorua Lakes district, grew on the lower slopes of the mountain reaching an altitude of about 610 m on the talus slopes at the bottom of the dome cliffs. These probably comprised rimu *(Dacrydium cupressinum),* rata

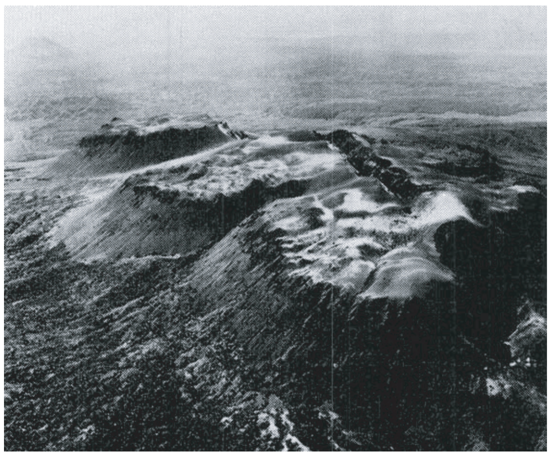

FIGURE 1. *Oblique aerial view across Mt Tarawera complex from above the southern arm of Lake Tarawera, looking north-east. From the left background to the right hand foreground the domes are: Wahanga, Ruawahia obscuring the lower Plateau, Tarawera. (photo: D. L. Homer, N.Z. Geological Survey).*

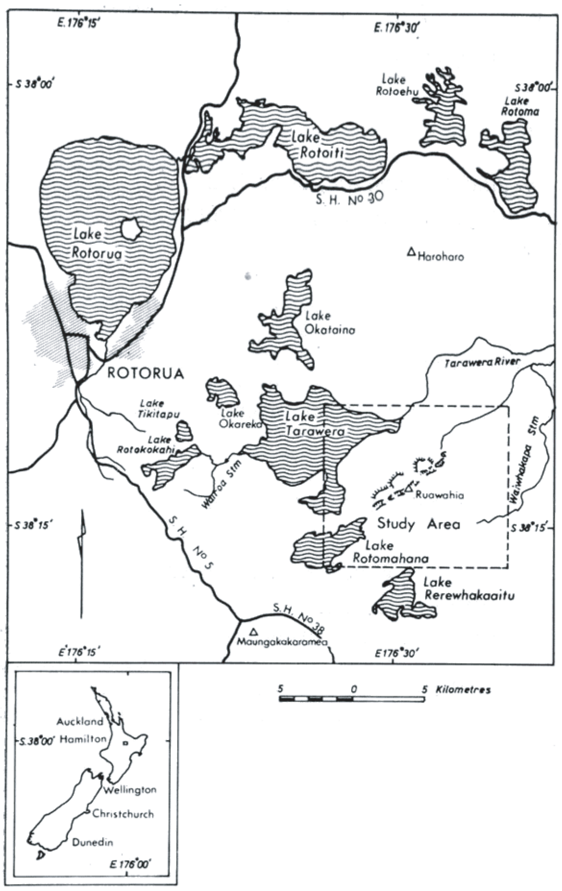

FIGURE 2. *Location of Mt Tarawera study area. (Source; Forest Service Map, series 65).*

(Metrosideros robusta), totara *(Podocarpus totara)* with Hall's totara *(Podocarpus hallii)* also common at higher altitudes, overshadowing a mixture of tawa *(Beilschmiedia tawa),* mangeao *(Litsea calicaris),* rewarewa *(Knightia excelsa),* hinau *(Elaeocarpus dentatus)* and kamahi *(Weinmannia racemosa)* (Nicholls, 1959). On the higher slopes of the mountain, Kirk (1872) found shrub community of manuka *(Leptospermum scoparium), kanuka (.Leptospermum ericoides)* and kohuhu *(Pittosporum tenuifolium)* in the deep ravines, and young growth of *Rytidosperma* sp. and *Deyeuxia* sp. on the open land that had been burnt over. On the summit (1092 m) he found dwarf shrubby vegetation in sheltered places but scanty, depauperate vegetation in the open and only 70 species were collected at about 914 m. Indeed, Smith (1886) described the plateau-like summit thus:

"The surface was formed by a confused mass of rhyolitic rocks, broken and jagged. Generally quite bare of vegetation, but here and there a little bracken or moss, or occasionally a weather beaten shrub, relieved the sombre grey of the rocks."

The immediate effects of the eruption on the Tarawera vegetation were described by Pond and Smith (1886), Smith (1886), Thomas (1888), Hill (1910) and Turner (1928). Most of the Tarawera vegetation was utterly destroyed by the eruption, although there was a gradient of decreasing damage away from the craters. On the lower slopes some trees were not killed but merely stripped of their leaves and small branches. They were thus able to resprout and produce seed again the following year (Aston, 1916).

Post-eruption vegetation

Plant recolonisation on- Mt Tarawera has been documented by various authors, the most comprehensive accounts being those of Aston (1915, 1916), Turner (1928) and Burke (1964). Twenty-seven years after the eruption, Aston visited the north-west slopes and found revegetation was proceeding. pole-sized pohutukawa *(Metrosideros excelsa),* rewarewa and kamahi, and young trees and shrubs covered the cliffs along the shores of Lake Tarawera and, in a few places, extended further up the lower flanks. High up the mountain, a sparse shrub growth predominantly of tutu *(Coriaria arborea),* manuka and koromiko *(Hebe stricta* var. *stricta)* had established along with stunted individuals of kamahi, *Gaultheria* spp., monoao *(Dracophyllum subulatum)* and others.

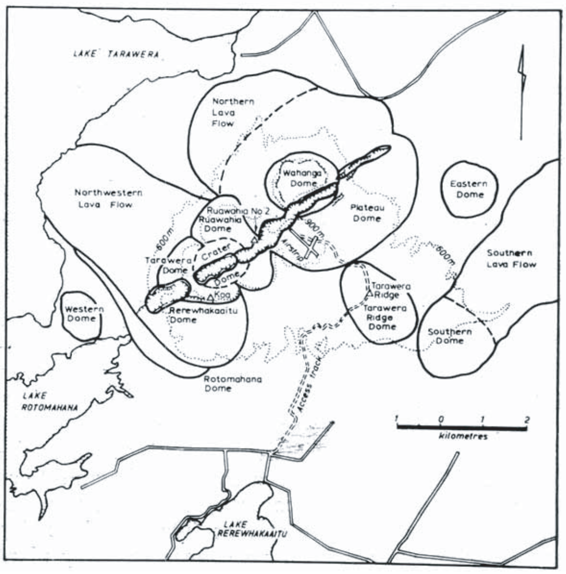

FIGURE 3. *Mt Tarawera study area showing domes and lava flows. (Source: NZMS1 N77; Cole,* 1965).

Vegetation cover, height and species diversity decreased with increasing altitude. On Ruawahia summit the only plant recorded was *Raoulia* sp.

Forty-one years after the eruption, Turner (1928) recorded that the mixed hardwood forest along the shores of Lake Tarawera had in places extended to 180 m up the mountain side. At around 800 m a.s.l. on the south-west slopes simple vegetation communi included emergent kohuhu, were relatively common. Also, mat communities were formed by species such as *Raoulia* spp. and *Pimelea prostrata*. These mat plants bound the fine loose scoria together, providing stability and eventually litter to enable other pioneer plants to establish.

Burke (1964) studied the south-eastern flanks of Mt Tarawera which included Tarawera Ridge dome, Southern lava flow, Plateau dome and its adjacent crater. He recorded forest grading from tawa-dominant at lower altitudes to kamahi-dominant at high altitudes. Bushline, defined by Burke (1964) as the upper limit of complete cover of forest vegetation, was formed by shrubby many-branched kamahi, broadleaf *(Griselinia littoralis)* and other species. It varied in altitude around 853 m a.s.l. Above this, patches of shrubs, especially monoao, manuka and *Gaultheria* spp. grew while on the dome top there was a sparse covering of grasses, herbs, mosses and lichens overtopped in places by stunted monoao and *Gaultheria oppositifolia*. There was little vegetation in the crater. Burke (1964) listed 63 vascular species in the crater and a total of 110 vascular species above bushline.

Present vegetation

Although the summit at 1111 m is well within the altitudinal range for forest for the district, there is as yet only sparse shrubland and herbfield on much of the mountain top. Gradations in successional stage and stature of the vegetation are readily seen when climbing the mountain and in Burke's (1964) vegetation descriptions. The establishment and recovery of vegetation on the volcano is documented in two parts. This paper provides a description of current vegetation types and successional trends on Mt Tarawera from the 300 m level to the summit, while the second paper (Clarkson and Clarkson, 1983) gives a detailed analysis of successional trends and rates of change on one part of the mountain-the high domes. Botanical nomenclature for this paper is given in Appendix 2 of Clarkson and Clarkson (1983).

METHODS

Sixty-five plots covering all the vegetation types recognised on Mt Tarawera from reconnaissance trips, aerial photographs and the forest type map (Nicholls, 1965: N77) were sampled using Druce's (1959) sampling method. Sample sites had to be accessible, homogeneous, 2 m away from tracks or ridge tops, have a constant "lope and aspect, and be of at least 100 by 100 m, the latter constraint imposed by the need to furnish field data for use in Landsat data analysis (Timmins, 1981, 1982). Canopy species composition, cover and height were assessed by eye. The physical conditions of the site were also recorded: altitude, topography and exposure, slope and aspect, soil type and drainage.

Vegetation stands were named following Atkinson's (1962) scheme. The first, floristic, name indicated the major canopy plants and the second, structural name was based on the dominant plant growth forms and/ or non-plant surfaces such as rocks or bare scoria.

Burke's (1964) five forest plots were also resampled and the combined total of 70 plots were analysed by average linkage plot cluster analysis. using the Biomedical Computer Package (BMDP-77) program, BMD: P2M (Dixon and Brown, 1977). Plots were clustered on the basis of their similarity in species composition, measured by euclidean distance (Orloci, 1978). This resemblance measure was chosen from the four measures offered by BMDP-77 as the most appropriate for the Tarawera data which were continuous with no extreme outliers (Williams, 1971). A dendrogram was constructed from the similarity matrix of the cluster analysis.

DESCRIPTION AND ANALYSIS OF VEGETATION

Vegetation groups

The floristic dendrogram prepared by plot cluster analysis is depicted in Figure 4. At the arbitrarily-selected euclidean distance of 40, eight major groups were defined.

Cluster 1: Scoria land. Ninety percent of the cover was scoria. Grass/herb-lichen ring growths contributed the other 10% cover. The dominant plant of these rings was invariably a cushion or mat plant such as *Muehlenbeckia axillaris* or *Raoulia albo-serirea.*

Cluster 2: Scoria-shrubland mixed hardwoods. These plots lacked a single dominant species; similar species were present in many plots, although the proportions varied. A herbfield of mosses, particularly *Racomitrium lanuginosum,* lichens, small herb and herb-like species, sub-shrubs and a high percentage of scoria (20-40% of cover) characterised plots 43 through 26. Stunted scattered shrubs of monoao, tutu. snow berry *(Gaultheria antipoda),* G. *oppositifolia* and *Olearia furfuracea* were also present. Plots 36 to 6 were characterised by a mixture of taller hardwood

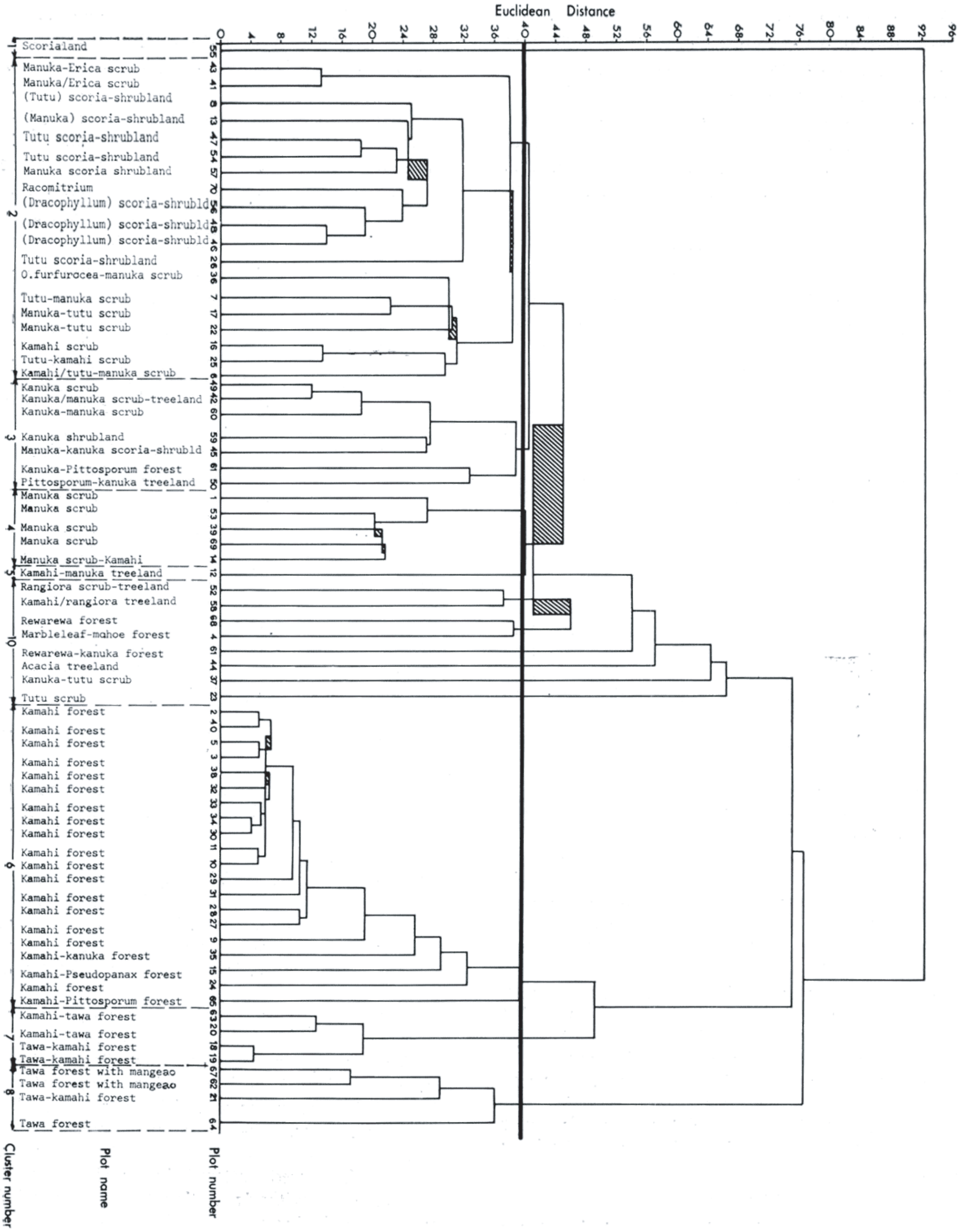

FIGURE 4. *Floristic site cluster dendrogram. Hatching denotes lines which join a cluster at a higher similarity level than the previous linkage. The euclidean distance is a measure of dissimilarity-the lower the euclidean value, the greater the level of similarity.*

shrub species: tutu, manuka, *O. furfuracea*. *Coprosma tenuifolia*. kamahi and broadleaf (the latter two species present as shrubs), together comprising 20-70% of canopy cover.

Cluster 3: *Kanuku scrub*. The dominant kanuka contributed 25-50% cover at a height of 5-8 m. Various shrub species, predominantly of the Ericaceae and Epacridaceae families were associates. This vegetation type was the stably community on the north-western flanks of Mt Tarawera at 400-500 m a.s.l.

Cluster 4: *Manuka scrub*. Manuka, the dominant species, provided 45-65 % of the canopy cover at about 4-6 m in height. Other species included *Olearia furfuracea,* kohuhu, five-finger *(Pseudopanax arboreus)* and kamahi.

Cluster 5: *Manuka-kamahi treeland*. Kamahi was co-dominant with manuka, both contributing 40 % of the canopy cover but the kamahi was 1-2 m taller than the manuka. The lack of manuka seedlings in this stand suggested that in the future broad-leaved species will dominate.

Cluster 6: *Kamahi forest*. These were simple-structured stands of nearly pure pole kamahi. In some plots, species other than kamahi also contributed to the canopy. These species were local and included (in order of importance): broadleaf, kanuka, kohuhu, tawa, five-finger, *Coprosma tenuifolia* and rewarewa. The strong chaining of the cluster 6 plots (Fig. 4) was a function of the percentage kamahi cover; a highly significant inverse relationship was found between percentage kamahi and the dissimilarity value ($r_{(17)} = -0.9$, $p < 0.001$). The gradient in percentage kamahi cover was related to altitude and thus to distance from the 1886 eruption crater.

Cluster 7:. *Kamahi-tawa forest*. Tawa and kamahi were co-dominants and there was plentiful regeneration of both tawa and mangeao. In this forest emergent dead trunks of Hall's totara, killed by the eruption (Burke, 1964) were seen on Tarawera ridge.

Cluster 8: *Tawa forest*. The canopy was dominated by tawa but a few mature mangeao trees were also present. There were many tawa saplings and the rather open forest floor was dominated by tawa and mangeao seedlings. Saplings of broadleaf and mahoe *(Melicytus ramiflorus),* and seedlings of white maire *(Nestegis lanceolata),* hinau and the occasional kahikatea *(Podocarpus dacrydioides)* also occurred.

Miscellany. These plots represented isolated occurrences of particular combinations of species. For example, the vegetation of plot 58, a thicket of rangiora *(Brachyglottis repanda)* through which kamahi was beginning to emerge, had colonised a slip in a kamahi stand. A stand of mahoe and putaputaweta *(Carpodetus serratus)* within kamahi forest (plot 4) reflected disturbance associated with a frequently changing water course.

INTERPRETATION

The above groups form a successional, as well as an altitudinal sequence, both the result of recent volcanic activity. First, bare scoria (cluster 1) is invaded by mat or cushion plants, particularly *Muehlenbeckia axillaris* and *Raoulia* spp. which stabilise the ash and lapilli and improve water relations. This provides a seed bed for low growing species to establish and form grass/herb-lichen ring growths. The number and diversity of species in the rings increases with time (cluster 2).

Later, stunted hardwood shrubs develop around the edge of the rings (cluster 2). The shrubs progressively invade the centre of the rings as the herbaceous plants die (cluster 2). These shrub rings are usually discontinuous but with time they too coalesce, particularly with the advent of tutu, to form a relatively complete cover of hardwood scrub which is eventually replaced by kamahi forest (cluster 6). In some of the kamahi forest plots there were various relics of a scrub community. A few tutu trees were present, many dead tutu branches and spindly *Corokia buddleioides* and *Gaultheria* spp. bemg shaded out by kamahi. These features indicated that previously a mixed hardwood scrub (cluster 2) had occupied the site.

In some areas, kamahi may have developed under a near pure manuka canopy (cluster 4-5). An area south-east of Tarawera ridge which is now manuka-kamahi treeland was described as manuka scrub by Burke (1964). According to Burke (1964) the manuka scrub developed after fire, unrelated to the earlier volcanic activity.

With decrease in altitude the proportion of other species in the kamahi forest increases until tawa forest, which occurs on the lower slopes of the Tarawera ridge and southern domes below an altitude of 670 m and 610 m respectively, is reached. This latter forest type largely survived the eruption except for small pockets where there are now pole stands of tawa.

As the upper limit for tawa in the district is 823 m (Nicholls, 1963), with time it could be expected that tawa forest will extend beyond its present limits. However, kamahi forest will probably dominate at higher altitudes. Kamahi is commonly an early successional forest species at lower altitudes, but at higher altitudes, low fertility-low altitude sites and southern districts, kamahi forest can be the stable vegetaton (Wardle, 1966). Other important components are likely to be broadleaf and Hall's totara. The latter has not yet established on the dome tops (Clarkson and Clarkson, 1983). However, the nearby Makatiti dome top supported a Hall's totara-kamahi. broadleaf forest before the Hall's totara were felled (Nicholls, 1959, 1980).

An exception to the expected pattern of succession on Mt Tarawera, as described above, was seen on the dome tops. Stunted individuals of tutu, monoao, *Gaultheria* spp., broadleaf, *Coprosma* spp. and kamahi were establishing in boulder crevices (see Clarkson and Clarkson, 1983). This occurrence eclipses some earlier stages, and thus accelerates the pace of succession considerably over the progress via ring growth.

COMPARISON OF THE NORTH-WEST AND SOUTH-EAST FACES

The vegetation and rate of succession. differed on either side of the central fissure. Ericalean species and manuka were important shrubs in the scoria-shrubland communities of the north-west occurring in definite clumps; tutu was more important on the south-east. However, on the north-western slopes, stands of tall (2-3 m) tutu interspersed with essentially bare scoria have developed in the last 8-10 yrs.

Kamahi was more important on the south-east than on the north-west. On the latter, kanuka was common as an early successional tree and formed mature stands at the base of the north-western faces of the domes, the pre-eruption vegetation type at this site (Nicholls, 1980). Only very occasionally were seedlings of kamahi found in the scoria-shrubland of the north-western flanks.

Rewarewa was more important in the forests and treelands of the north-west than the south-east and was found in association with kamahi, kanuka and kohuhu.

The origin of these distinctions lies in the pattern of the 1886 eruption. The vegetation on the north-western flanks of the mountain, which suffered heavy . deposits of ash, was completely destroyed by the eruption. Pyroclastic flows, funnelled by topographic 'gaps', would have rushed from the crater down the mountain side to Lake Tarawera, sticky Rotomahana <mud' would have caused even greater devastation by adhering to the vegetation.

By contrast, large tracts of forest less than 4 km to the east of the fissure, were virtually unaffected by the ejecta (Nicholls, 1963; Fig. 3). The forests in the small dips of the ridge and southern domes would also nave been protected, particularly on the lee side, from the base surges, the ground hugging shock waves that would have coursed down the mountain at a speed of greater than 150 km/hr (R. M:. Briggs, pers. comm.). Furthermore, regeneration since the eruption has been much slower on the north-west than on the south-east because the two areas vary in distance from propagule source, The north-western flanks are isolated from direct link with seed source by Lakes Tarawera and Rotomahana, except for the narrow land isthmus between the two (Fig. 2). On the south-east the tracts of forests at the base of the mountain plus numerous individual trees closer to the chasm which survived the eruption (Burke, 1964) have provided ready propagule sources for the rapid recovery and spread of forest there. Sprouting stumps of tawa, mangeao, mahoe and kamahi, remnants of the 1886 eruption, have also been reported on the south-east (Burke, 1964).

Although reasons for the differential revegetation of the north-west and south-east faces can be advanced, further study is required to explain all the observed variation in succession on Mt Tarawera. It is clear that as a result of the 1886 eruption, the vegetation of Mt Tarawera forms both an altitudinal and a successional series. However, the subsequent regeneration is proceeding by more than one pathway controlled, at least in part, by history of the site, seed source availability, microclimate and substrate.

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