CONCLUSION

This paper extends the known area of pre-European fires and the dating of a major fire elucidates some aspects of the forest dynamics of the Northern Tararuas. Although only the Tiritea catchment has been studied in detail, this same fire, or another in the same period, apparently swept much of the Otangaue, Kahuterawa and Tokomaru catchments.

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ORIGINS OF THE NEW ZEALAND ALPINE FLORA

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In Table 1 I have attempted to classify the New Zealand alpine and subalpine genera according to their probable country or region of origin. The scheme is tentative, but it is hoped that it comes sufficiently near to the truth to provide an overall picture of the sources of the New Zealand alpine flora.

Guesses as to the place of origin of a genus can be based on a variety of evidence, probably the most reliable being that of the fossil record. Not all genera are represented as fossils, however, and in many parts of the world the fossil record is virtually unknown. The available fossil evidence has been considered in this paper. Present day evidence includes any concentration of species of a genus in an area or any concentration of species regarded as primitive, for instance *Acaena* has most of its species and also most of its primitive species in South America. Where a genus has only one or a few living, or perhaps surviving species consideration of the distribution of related genera or of the family as a whole may be useful: thus *Pseudowintera* is restricted to New Zealand, but the family Winteraceae is predominantly tropical or subtropical in distribution. Morphological features characteristic of certain types of world vegetation may also be taken into account, for instance the living species of *Pseudopanax* are south temperate, but some have a juvenile form of a type exhibited by a number of tropical trees. In addition the family Araliaceae is predominantly tropical or subtropical in distribution.

Perhaps the most interesting group of genera is that regarded as originating in the extensive pre-quaternary tropical to subtropical zone. These appear to be basically forest genera, which in New Zealand have given rise to a few species suited to alpine and subalpine habitats. As a result the woody genera in this group exhibit a remarkable range of plant form. In *Dacrydium**, for instance, there is *D. cupressinum* at one extreme, one of our largest forest trees, and *D. laxifolium* at the other extreme, a prostrate subalpine shrub sometimes described as the smallest conifer in the world. In *Coprosma* there is a complete range from small forest trees, through small

* The conifers in this group have a much longer fossil record in the southern hemisphere than the angiosperms, so perhaps the problem of their origin should be regarded as a separate matter.

TABLE 1. *Suggested countries or regions of origin of New Zealand Alpine/Subalpine genera*

NORTH TEMPERATE	NEW ZEALAND OR ANTARCTIC	AUSTRALIAN	TROPICAL OR SUBTROPICAL
Anemone	*Abrotanella*	*Brachycome*	*Dacrydium*
Caltha	*Aciphylla*	*Craspedia*	*Phyllocladus*
Cardamine	*Anisotome*	*Cyathodes*	*Podocarpus*
Chenopodium	*Carmichaelia*	*Dracophyllum*	*Aristotelia*
Claytonia	*Celmisia*	*Drosera*	*Coprosma*
Epilobium	*Cheesemannia*	*Epacris*	*Coriaria*
Euphrasia	*Colobanthus*	*Exocarpus*	*Hoheria*
Gentiana	*Corallospartium*	*Ewartia*	*Hymenanthera*
Geum	*Donatia*	*Hemiphues*	*Muehlenbeckia*
Gnaphalium	*Drapetes*	*Lagenophora*	*Myrsine*
Helichrysum	*Forstera*	*Liparophyllum*	*Neopanax*
Hypericum	*Gingidium* (*Angelica*)	*Logania*	*Nertera*
Lobelia	*Haastia*	*Mitrasacme*	*Pittosporum*
Montia	*Hebe*	*Olearia*	*Pseudopanax*
Myosotis	*Hectorella*	*Pentachondra*	*Pseudowintera*
Plantago	*Kirkianella*	*Pimelea*	*Senecio* (woody)
Ranunculus	*Leucogenes*	*Poranthera*	*Astelia*
Scleranthus	*Notospartium*	*Pratia*	*Collospermum*
Senecio (herbaceous)	*Notothlaspi*	*Swainsona*	
Stellaria	*Oreostylidium*	*Danthonia*	SOUTH AMERICAN
Taraxacum	*Pachycladon*	*Herpolirion*	*Acaena*
Viola	*Parahebe*	*Lyperanthus*	*Azorella*
Agropyron	*Phyllachne*	*Prasophyllum*	*Discaria*
Agrostis	*Pleurophyllum*	*Pterostylis*	*Gaultheria*
Carex	*Pygmea*	*Schoenus*	*Gunnera*
Deschampsia	*Raoulia*		*Hydrocotyle*
Deyeuxia	*Schizeilema*	SOUTH AFRICAN	*Oreomyrrhis*
Eleocharis	*Stilbocarpa*	*Cassinia*	*Ourisia*
Festuca	*Tetrachondra*	*Cotula*	*Pernettya*
Juncus	*Traversia*	*Geranium*	*Carpha*
Koeleria	*Gaimardia*	*Oxalis*	*Rostkovia*
Luzula	*Oreobolus*	*Wahlenbergia*	*Uncinia*
Poa	*Phormium*	*Bulbinella*	
Scirpus		*Ehrharta*	
Triodia		*Hypolaena*	
Trisetum			

leaved divaricating shrubs of subalpine and other open habitats, to two near herbs of alpine areas.

This occurrence of tropical or subtropical genera in alpine vegetation is probably a result of New Zealand's isolation. One can imagine that the appearance of an alpine zone on a continental mountain mass would be followed by the establishment of an alpine flora largely by immigration from colder areas nearer the poles. At the other extreme there is at least the theoretical possibility of a new alpine habitat on an island so isolated that the development of alpine vegetation by immigration is impossible. In such a case suitable variants from non-alpine vegetation on the island would eventually occupy the "ecological vacuum" and form the basis of an alpine flora.

New Zealand would come somewhere between these extremes. When alpine habitats developed in New Zealand late in the Tertiary the nearest suitable alpine plants would probably have been in Antarctica. There is no doubt that alpine immigrants did come to New Zealand from overseas, but this would be a slower process than the equivalent immigration into new alpine habitats on a continent. In New Zealand there would be sufficient time, while alpine habitats were only sparsely occupied by immigrants, for the derivation and establishment of alpine forms from forest genera. Similarly the Australian element in the alpine flora may have been partly derived from genera of Australian origin present in New Zealand in non-alpine, mostly open habitats before the Pleistocene ice ages.

The largest group of genera has been classified as north temperate in origin. By reference to Index Kewensis and other literature an attempt has been made to determine the percentage representation of some of these genera in the major continental areas. The information is not precise, but in the genera checked (*Gentiana, Cardamine, Viola, Stellaria, Ranunculus, Plantago*) representation in South America is about as strong as in the north temperate areas. In *Plantago* the majority of the New Zealand species belong to a section of the genus otherwise restricted to South America, which suggests that *Plantago* at least has reached New Zealand via South America (and possibly Antarctica) and not directly from the north temperate zone.

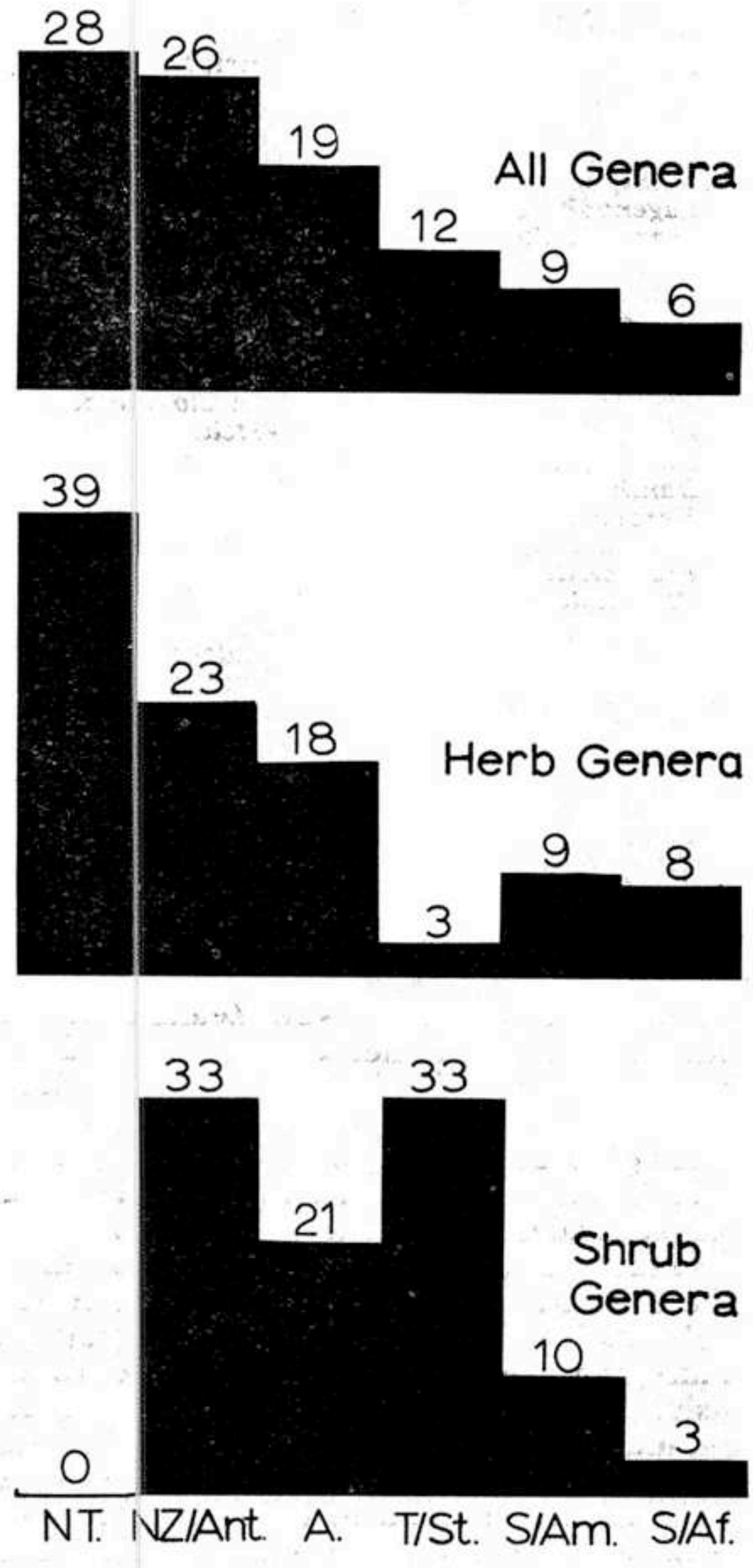

FIGURE 1. *Suggested areas of origin of the New Zealand alpine/subalpine genera. The figures are percentages. NT. = north temperate; NZ/Ant. = New Zealand or Antarctic; A = Australia; T/St. = Tropical/subtropical; S/Am. = South America; S/Af. = South Africa.*

Several north temperate genera give the impression of having undergone active speciation in New Zealand, for example, *Ranunculus, Epilobium, Gentiana*. The present species may have evolved from one or a few immigrant species which reached New Zealand when many ecological niches in the alpine areas were still unoccupied. In the flora of Hawaii, comparable to that of New Zealand in many respects, Fosberg (1948) suggests that the 1700 species and varieties of the present flora may have been derived from 272 original immigrants.

The New Zealand/Antarctic category is problematical. It comprises genera restricted to New Zealand or virtually so. The two most likely possibilities with these genera are that they originated in New Zealand or in Antarctica. Probably as a result of severe glaciation few plant fossils are known from Antarctica and there are none that suggest alpine vegetation. Nevertheless, I am inclined to believe that the majority of genera in the New Zealand/Antarctic category, which incidentally includes practically all the alpine cushion plants, originated in Antarctica and extended to New Zealand when alpine habitats became available here. In this group, as in the last, several genera appear to have undergone active speciation in New Zealand — *Hebe, Aciphylla, Celmisia*.

In view of the frequently stressed affinities between South America and New Zealand the South American element may seem surprisingly small. However, the genera listed are only those thought to have originated in South America, the other genera shared by the two countries are thought to have originated elsewhere. A preliminary assessment according to the present scheme of the origins of genera found in both New Zealand

and South America provides the following percentages: North temperate 40%, Tropical or Sub-tropical 12%, New Zealand/ Antarctic 12%, South American 14%, Australian 9%, South African 5%, Cosmopolitan 8%.

The South African element has always been regarded as much less significant than the South American, but in this analysis both are about equally small.

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AGE OF THE ALPINE BIOTA

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The suggestion that the New Zealand alpine biota is geologically young is not new, but has recently been revived in the light of developing ideas on Tertiary and Pleistocene climatic and topographic history (Fleming 1962 b). Cockayne was aware of the problems raised by evidence of very warm Tertiary climates and minimal land relief, and he suggested that a nucleus of plastic species, descended from a Cretaceous mountain flora, survived until the growth of mountains and cooling climate in the Pliocene allowed them to exploit the alpine environment once more. A history back to the time of the Cretaceous mountains is, however, unlikely because the mountains formed in the Early Cretaceous Rangitata Orogeny were already dwindling by the time angiosperms were distributed in the Later Cretaceous, and because there is no evidence that climatic conditions in New Zealand were suitable for the alpine biota at that time.

The present pattern of altitudinal vegetation zones in New Zealand was shown by Zotov (1938) plotted on a base line showing mean midsummer-month temperature at sea level. In Figure 1 the snow-line and timberline which limit the Alpine Zone are plotted on a latitudinal base line and projected north to intersect the same boundaries at 15,400 ft. and between 11,000 and 12,000 ft. in New Guinea (from Reiner 1960, and Robbins 1961). Irregularities in these boundaries due to rainfall differences are not of sufficiently large order to affect the general picture. Also shown on Figure 1 are the altitudinal limits in New Guinea (Robbins 1961) and New Caledonia (Bader 1960) for *Nothofagus* of the *brassi* group (which formerly lived in Australia and New Zealand) with the optimum zone for beech forest distinctively shaded. From this it can be judged that these beeches could probably still live in New Zealand if they had been able to return after their Pleistocene extinction here.

In Figure 2, the climatic-vegetational zones have been lowered on the average 1200 meters to correspond with the geological evidence of snow-line position during the Last Glaciation (about 20,000 years ago) from data given by Willett (1950) for New Zealand and Reiner (1960) for New Guinea, and the *Nothofagus brassi* Zone correspondingly lowered. For simplicity the zone boundaries are shown as straight parallel lines, whereas the present boundaries seem to be slightly curved and not strictly parallel. The glacial-age sea level was probably about 119 meters lower than its present position (Curray 1961). Note that the upper limit for *brassi* beeches falls north of New Zealand confirming the suggestion of glacial age extinction.

Figure 3 attempts to show the same zones fitted to Pliocene (pre-glacial) topography and climate. Sea level temperatures are judged by evidence from Pliocene marine mollusca in New Zealand and Campbell Island; the Pliocene occurrence of *Dysoxylum* in Otago suggests the same order of warmth*. Geologists agree that the relief of

* Recorded from Middlemarch diatomite; the Pliocene age is, however, not certain.