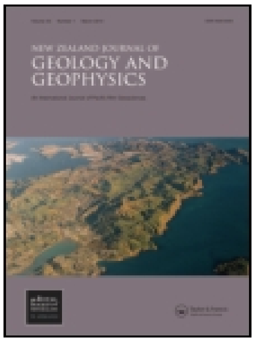

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J. D. Cowie

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DUNE-BUILDING PHASES IN THE MANAWATU DISTRICT, NEW ZEALAND

J. D. COWIE

Victoria University of Wellington*

(With an Appendix on Pollen Analysis by D. J. McINTYRE)

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ABSTRACT

Dune sands with four different stages of soil development cover 330 square miles in the coastal Manawatu district. The oldest—the Koputaroa Phase—is restricted to small areas at the north and south; the other three phases—the Foxton, Motuiti, and Waitarere—form belts parallel to the coast, the oldest belt being the furthest inland. The Koputaroa Phase is considered to be Late Pleistocene or early Holocene and 20,000 to 10,000 years old. The Foxton Phase is older than the eruption of the Taupo Shower and about 4,000 to 2,000 years old. Sands of the Motuiti Phase overlie traces of Maori occupation and a stump that is about 750 years old, and are about 1,000 to 500 years old. The Waitarere Phase started about 100 years ago and is still accumulating.

Sharp differences in soil development indicate that dune formation was discontinuous and much more rapid at some periods than others. The two youngest phases are considered to have been triggered off by the destruction of vegetation on the stabilised dunes near the coast and in the inland river valleys that followed the arrival of the Maori and European. This led to renewed wind erosion of the dunes and to accelerated erosion in the valleys, which caused more sand to be brought to the beaches. The causes of the two earliest phases are unknown.

In an appendix, the pollen floras in a peaty layer associated with the Koputaroa Dune-sand are described and discussed. The pollen results indicate a climate considerably cooler than at present, which is attributed to a late phase of the Last Glaciation.

INTRODUCTION

An extensive complex of dunes, sand plains, and peaty swamps borders the west coast of the southern half of the North Island (Fig. 1). It extends from Paekakariki north for 120 miles to Patea and is up to 12 miles wide, with an area of approximately 210,000 acres. Adkin (1948a) used the name Himatangi Series for this complex. In the extreme south the dunes are parallel to the coast and become progressively older inland. To the north along the Manawatu coast, the part which is discussed in detail in this paper (Fig. 2), the dunes are mainly aligned transverse to the coast and there is no gradual increase in age inland. Instead, the dunes appear to have formed during four distinct dune-building phases. These, in order of increasing age, are named Waitarere, Motuiti, Foxton, and Koputaroa. With the exception of Motuiti, the names are those of the soils formed on the dunes (Cowie, 1957). The name Motuiti is taken from a district two miles

*Now at Soil Bureau, Department of Scientific and Industrial Research, Palmerston North.

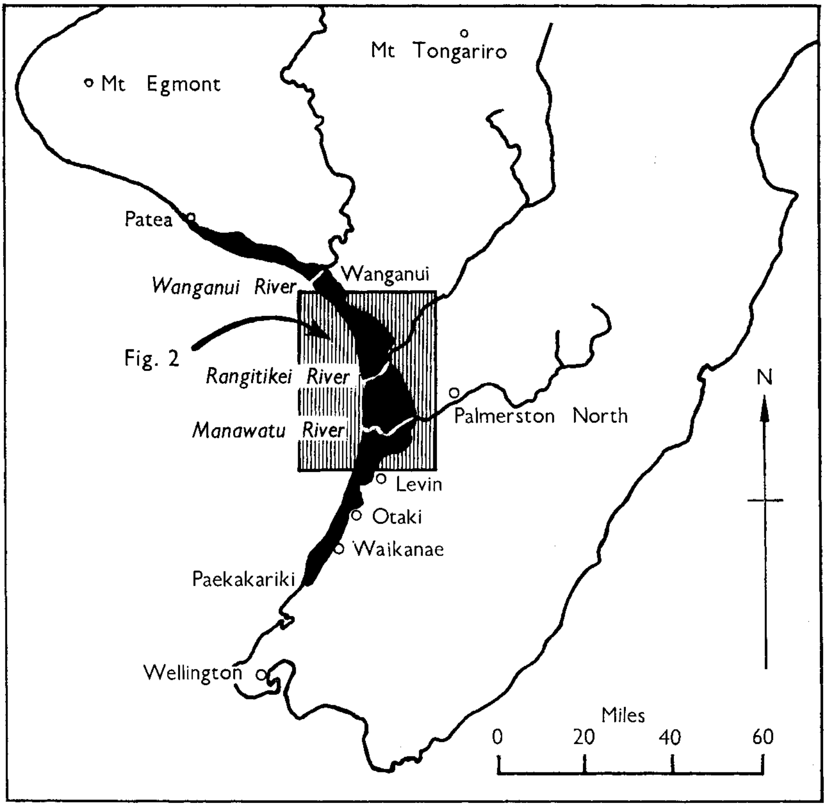


FIG. 1—Locality map showing extent of dunes younger than 5,000 years along the west coast of the southern half of the North Island. The Manawatu dunes shown in Fig. 2 represent the middle of the dune belt.

north of Foxton and is used for the sands on which the soils Foxton dark grey sand, Himatangi sand, and Pukepuke black sand have been formed (Cowie and Smith, 1958).

The dunes of the Waitarere Phase correspond to the third generation dunes of Te Punga (1957); those of the Motuiti and Foxton Phases to his second generation; and the Koputaroa to his first generation.

The term "dune-building phase" is used in a time sense and includes the interval between the formation of the dune complex, either by accumulation of sand along a foreshore or by renewed wind erosion of previously stabilised dunes, and the stabilisation of the complex by vegetation and the initiation of soil development.

WAITARERE PHASE

The dunes of the Waitarere Phase form a coastal belt from one-quarter to two miles wide, and also occur as small patches where previously stabilised

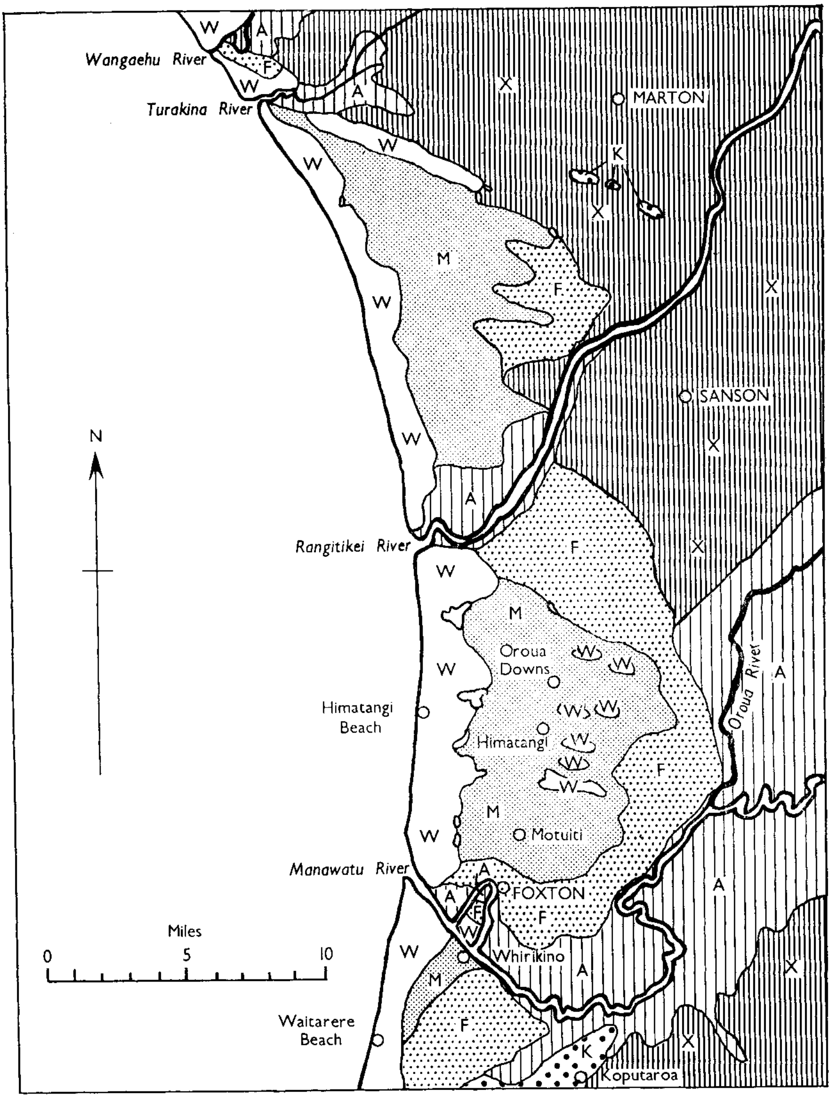


FIG. 2—Sketch map showing extent of dune-building phases in the Manawatu district.

A = Flood plain with Recent Alluvium.
W = Waitarere Phase (100–0 years old)
M = Motuiti Phase (1,000–500 years old)
F = Foxton Phase (4,000–2,000 years old)
K = Koputaroa Phase (15,000–10,000 years old)
X = Loess, Ohakea gravels, Tertiary rocks, and greywacke.

Lakes between dunes, mostly at phase boundaries, are shown.

sand plains and dunes of the Motuiti Phase have been wind-eroded and their sand transported. Apart from a darkening of the surface inch with organic matter there is little soil-profile development and the sands are relatively unweathered.

Most of the dunes are well covered by vegetation, pingao *(Scirpus nodosus)*, spinifex *(Spinifex hirsutus)*, sand coprosma *(Coprosma acerosa)*, marram grass *(Ammophila arenaria)*, and tree lupin *(Lupinus arboreus)* being the commonest plants, but large areas are bare or almost bare of vegetation (Fig. 3).

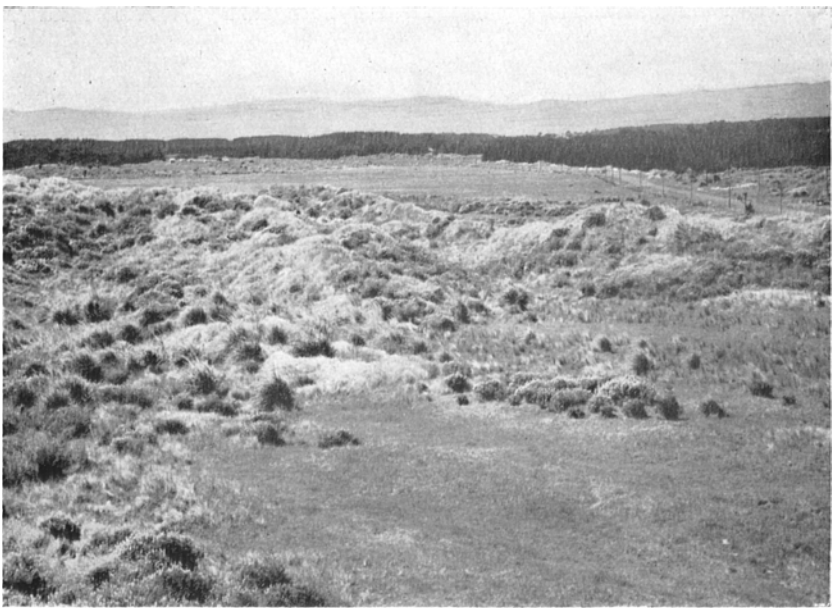
A. P. Underhill, photo

FIG. 3—Actively eroding dunes of the Waitarere Phase at Himatangi Beach, showing miniature barchan dunes formed on bare areas.

The form of the dunes immediately behind the almost continuous foredune is somewhat chaotic, but further inland the dunes have a "windrift" or elongate-blowout form (Melton, 1940), with uneven slopes and a rugged outline (Fig. 4). After prolonged periods of strong winds miniature barchan-type dunes that are usually ephemeral form on bare areas (Fig. 3). Larger barchan dunes that have now been stabilised and planted in trees are conspicuous south of the main highway from Wellington to Wanganui west of the Lake Alice Mental Hospital.

The Waitarere dunes cover European artifacts and the remains of introduced plants and are less than 120 years old. R. A. MacDonald in *Te Hekenga* (O'Donnell, 1929) states that in the 1860s "with the exception of one partly covered littoral dune, or ridge, immediately along the shore, the whole of the country from Otaki to the Manawatu was grassed and remained so until the '80s, when the first drifts began". Until the early 1900s, when extensive marram planting began, most of the Waitarere dunes had only a scattered cover of vegetation and were actively eroding. Most of the drifts are now being brought under control.

The advance of the Waitarere dunes is attributed partly to overgrazing and burning of the original vegetation on previously stabilised dunes, and partly to accelerated erosion inland due to clearing and burning causing increased accumulation of sand along the beaches. According to Adkin (1948b) Waitarere Beach has built out at an average rate of about 2 ft per year for the last 600 to 800 years. For the beach north of the Rangitikei River an average advance of about 3 ft per year for the last 80 years is indicated by the present position of the wreck of the *Fusilier*.



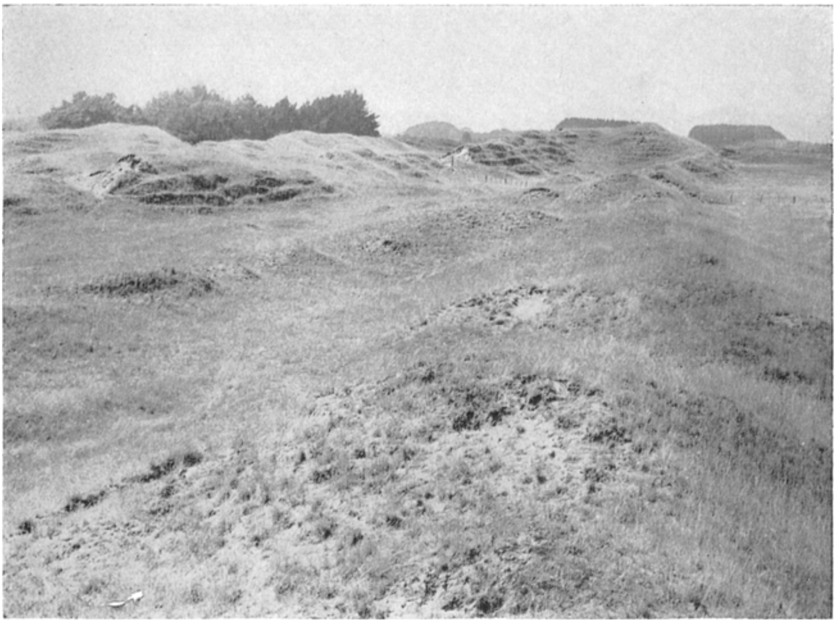
R. Julian, photo

FIG. 4—Dunes of the Waitarere Phase near Himatangi Beach, showing typical cover of marram grass and lupin.

MOTUITI PHASE

Dunes and sand plains of the Motuiti Phase form a belt up to 6 miles wide inland of the Waitarere dunes. North of the Manawatu River a line of small lakes marks the contact between the two. The Motuiti dunes have a rugged outline and usually a windrift form (Fig. 5).

The dune soil, Foxton dark grey sand, has a shallow topsoil up to 6 in. thick and a pale yellowish brown subsoil about 7 in. thick, which overlies grey sand.



A. P. Underhill, photo

FIG. 5—Dunes of the Motuiti Phase near Himatangi, showing their rugged outline and windrift form.

The original vegetation was manuka *(Leptospermum ericoides)*, bracken fern *(Pteridium esculentum)*, and tutu *(Coriaria* spp.*)*. The present vegetation is weed grasses such as sweet vernal *(Anthoxanthum odoratum)*, mosses, flatweeds, bracken fern, and gorse *(Ulex europaea)*.

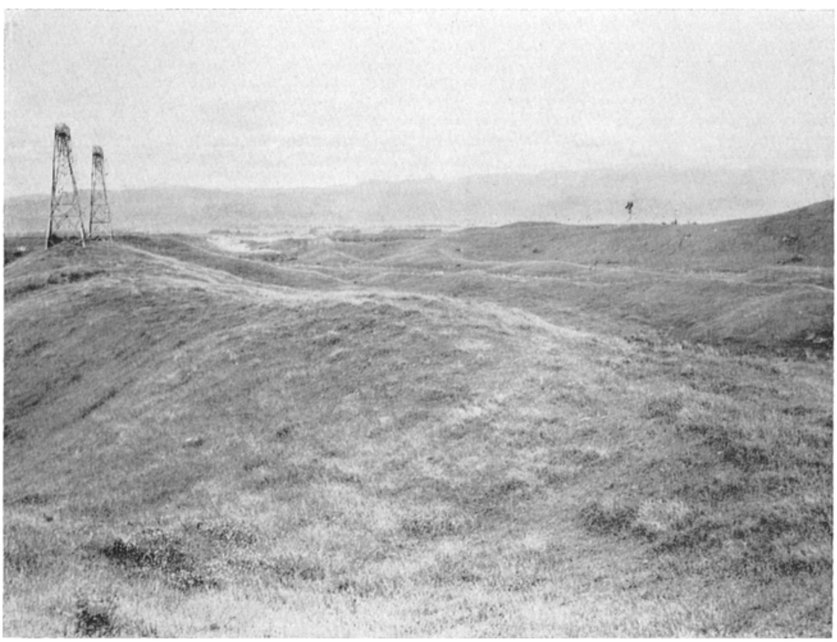
According to radiocarbon dating of a totara stump, the advance of the Motuiti dunes took place about 750 years ago. The stump, one of several, was found during the excavation of a pond at Oroua Downs (N148/882333). It is covered by 12 ft of sand of the Motuiti Phase and is rooted in soil that had formed on sand of the preceding phase—the Foxton. The stump was 3 ft through at 9 ft high. The dated sample was taken 1 ft in from the outside of the stump, and according to the annual rings should have given a date that is about 90 years older than the death of the tree. The sample (N.Z. ^{14}C No. 293) gave an age of 855 $\pm$ 50 years, and the tree was probably killed by the advancing sand about 750 years ago (Grant-Taylor and Rafter, 1962).

At Whirikino, on the south bank of the Manawatu River at the cut across the Foxton meander (N152/775174), a well exposed section shows sand of the Motuiti Phase overlying Maori occupation material (Table 1).

TABLE 1—Section at Whirikino Cut, Manawatu River

	Feet
Very dark brown organic-stained sand	0·6
Pale brownish grey sand with abundant pumice pellets; abrupt boundary	1·0
Black sand with *charcoal fragments, oven stones,* and *shells;* undulating boundary	1·0
Pale grey sand, many reddish mottles; thin iron pan at base	1·0
Yellowish brown sand with few reddish brown mottles	0·8
Olive grey sand with few large reddish concretionary mottles	2·0
Olive grey sand, cross-bedded	1·0
Olive grey sand with iron pans, a few logs and rare lumps of pumice	13·0
Bluish grey sandy clay, much organic staining	3·0
As above with *Chione stuchburyi* (below river level)	?

The Motuiti Phase is represented by the 1·6 ft of sand above the occupation layer, and the Foxton Phase by the 1·8 ft of sand below. The occupation layer is probably no more than 1,000 years old, the radiocarbon date of the oldest occupation material so far found in New Zealand (Lockerbie, 1959), and the Motuiti Phase is thus younger than 1,000 years. From the degree of soil-profile development it is thought that the Motuiti dunes became stabilised about 500 years ago.



R. Julian, photo

FIG. 6—Dunes of the Foxton Phase near Whirikino. Outline is smoother than that of the Motuiti dunes.

The advance of the Motuiti dunes is attributed to destruction by the Maori of the vegetation on previously stabilised dunes.

Much pumice was washed out to sea and on to the beaches after the Taupo eruption of about A.D. 200, and at many places the accumulation of pumice sand caused the formation of dunes with a high proportion of pumice. Such dunes are conveniently called Taupo Pumice dunes. A Taupo Pumice dune is well developed 30 miles to the south at Waikanae (Fleming, 1961) but it cannot be traced north to Manawatu River. The Motuiti dunes contain a large proportion of pumice at many places, but as they are considerably younger than the Taupo eruption they are unlikely to have been directly caused by it. It is thought that the Taupo Pumice dune once existed in the Manawatu district, and that it was destroyed during the advance of the Motuiti dunes, the pumice it contained being incorporated in the Motuiti dunes.

FOXTON PHASE

The dunes of the Foxton Phase form a 2–4-mile-wide belt inland of the Motuiti dunes. Near Foxton they have windrift form, many dunes extending west-north-west for several miles. Further south near Levin, they are much shorter and arranged in festoons. Surface slopes are smooth (Fig. 6).

The soil on the dunes, Foxton black sand, has a well-defined topsoil of black sand about 12 in. deep and a subsoil deeper and browner than that of the Motuiti dunes. The dunes carry a fairly good pasture of cocksfoot *(Dactylis glomerata)*, sweet vernal, ratstail *(Sporobolus capensis)*, New Zealand rice grass *(Microlaena stipoides)*, and subterranean clover *(Trifolium subterraneum)*.

The Foxton dunes are older than the Taupo eruption as they are older than the Taupo Pumice Alluvium (Fleming, 1953) in the lower Rangitikei valley*; their sands lack pumice; and soil development is similar to that on the dunes inland of the Taupo Pumice dune in the Horowhenua district. The dunes are probably 2,000 to 4,000 years old.

Although the cause of the accumulation of these dunes is not known, it could be related to eruptions from the Taupo, Tongariro, and Mt Egmont districts.

KOPUTAROA PHASE

The dunes of the Koputaroa Phase, the oldest phase recognised, are only preserved in the northern and southern parts of the Manawatu district and are inland of the Foxton dunes. Dune form is not well defined, but appears to be elongate-blowout. Slopes are gentle. The soil, Koputaroa sandy loam, has a well developed profile. The topsoil is a dark brown sandy loam with a well developed nutty structure and is 10 in. thick. The subsoil is yellowish brown, 14 in. thick, and grades down into a dull yellowish grey sand.

The much greater degree of soil development shows that the sands of the Koputaroa Phase are much older than those of the Foxton Phase. The Koputaroa Dune-sands, although included as part of the Otaki Sandstone

*Taupo Pumice Alluvium was originally recognised by Fleming in the Wanganui Valley. The writer has now identified this formation in the Rangitikei Valley, near the mouth of the Rangitikei River (N148/778440).

by Oliver (1948), are actually separated from it by a strongly weathered clay that represents a zone of intense and prolonged weathering, and are much younger. According to Fleming (1961), the Otaki Sandstone is of Last Interglacial age.

A distinctive ash band, Aokautere Ash (Cowie, in press), is interbedded in the sands of the Koputaroa Phase at Paiaka Road, Koputaroa (N152/848099). The ash is older than the Ohakea Terrace, the lowest main aggradation terrace in the Manawatu district, and is thought to be about 15,000 to 10,000 years old.

Pollens and spores in a sample of peaty material occurring in Koputaroa Dune-sand near Koputaroa (N152/833077) have been examined by Mr D. J. McIntyre, New Zealand Geological Survey. The section at this locality is shown in Table 2.

TABLE 2—Section near Koputaroa

	Inches
Brownish yellow and olive medium sand with iron-stained bands	60
Mottled grey and yellowish brown sticky clay loam.	14
White, very greasy pumiceous silt (Aokautere Ash)	2·5
Pale grey medium pumiceous sand (Aokautere Ash)	2
White, greasy pumiceous silt (Aokautere Ash)	0·5
Brownish grey medium sand	60
Purplish black peaty silt (samples from top, middle, and bottom)	7
Olive grey, greasy clay loam	15
Brownish grey medium sand	25+

Mr McIntyre's results, given in an appendix to this paper, indicate that the peat accumulated when the climate was distinctly cooler than at present, possibly during a late stage of the Last Glaciation. It is thought that the Koputaroa Phase is Late Pleistocene or early Holocene and from 20,000 to 10,000 years old.

Dunes of the Koputaroa Phase are about 100 ft above sea level. If they are of Late Pleistocene age it is unlikely that they are related to the coast, for the sea level then would have been considerably lower. It is more likely that they are related to the braided courses of rivers draining periglacial areas. This would explain their limited extent.

The dunes of all four phases are aligned west-north-west, and do not indicate the change in wind direction that was inferred by Fleming (1953) from the orientation of the coastal dunes of the Wanganui district.

ACKNOWLEDGMENT

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APPENDIX

POLLEN ANALYSIS OF A PEAT IN KOPUTAROA DUNE-SAND

D. J. MCINTYRE

New Zealand Geological Survey, Department of Scientific and Industrial Research, Lower Hutt

Three samples (N152/505) from the top (L 2815), middle (L 2817) and bottom (L 2816) of a seven-inch silty peat layer within Koputaroa Dunesand 5 ft below the base of the Aokautere Ash were examined for pollens and spores. The samples were collected by Dr C. A. Fleming and Mr T. L. Grant-Taylor, N.Z. Geological Survey, from a cutting on the south side of the Levin-Koputaroa Road, beside the railway 1⅓ miles from Koputaroa (N152/833077).

Satisfactory and rather similar pollen floras were obtained from each of the three samples. The species in each sample are given in Table 3, and the relative abundances of the important and more common pollens and spores (except *Gleichenea circinata*) are shown in Fig. 7. In each sample counting was continued until one hundred of the dominant tree pollens—either *Nothofagus* of the *fusca* group or *Dacrydium* of the *bidwillii–biforme* group—had been recorded.

Pollen of other trees is comparatively rare, but pollen of Gramineae and of shrub genera including *Coprosma, Myrsine, Dracophyllum,* and Compositae is quite common. The ratio of grass and scrub to tree pollens and the presence of rare pollen of *Gentiana* indicate that the climate was distinctly cooler than that in the area today. The climate may have been similar to the present climate at 2,000–3,000 ft in the Tararua Range. The great abundance of spores of *Gleichenia circinata* (over 600 to 100 of the dominant tree pollen) clearly indicates that *Gleichenia* grew at the site of deposition, which was almost certainly a bog. In all probability the dominant trees on the bog or round its margin were *Dacrydium bidwillii* or *D. biforme* or perhaps both. Beeches of the *fusca* group (probably *Nothofagus truncata* and *N. solandri* judging by spore counts), which produce greater quantities of pollen than the species of *Dacrydium*, presumably grew further away, possibly on better drained ground surrounding the bog. The species of *Dacrydium* were probably present in groups rather than as a canopy layer, and shrubs and herbaceous species occupied the areas between the trees.

The three samples are similar and the 7 inches of peat was probably deposited in a relatively short period of time. A slight cooling is indicated by the upward decrease of pollen of *Dacrydium cupressinum* and the upward increase of pollen of Compositae, Gramineae, and *Nothofagus menziesii.* Upward increase of *N. menziesii* suggests an increase in precipitation. The peat layer was probably deposited in the cooling phase of a stadial (possibly the last) of the Last Glaciation.

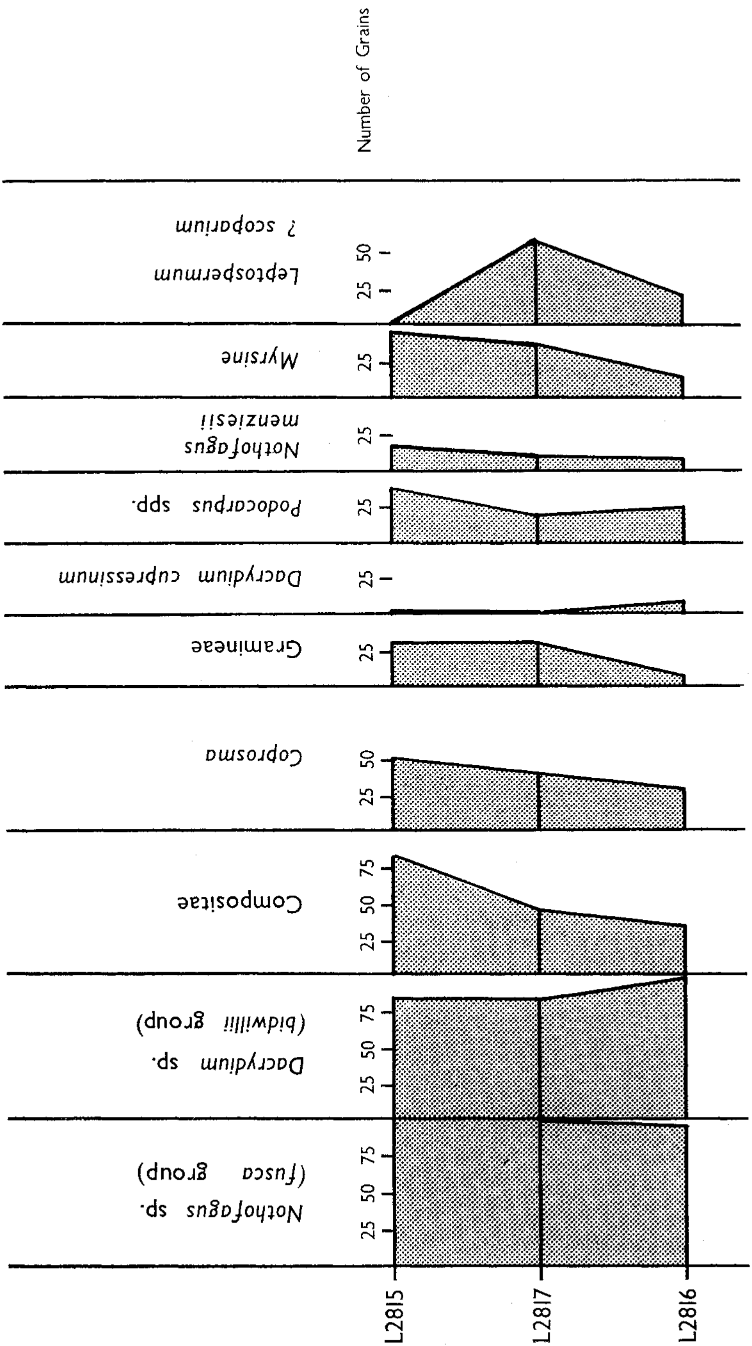

FIG. 7.—Pollen diagram for 7 in. band of peat in Koputaroa Dune-sand 5 ft below base of Aokautere Ash. Numbers indicate the number of grains counted. The diagram shows the most abundant and the important species, but for convenience of representation the most common species, *Gleichenia circinata*, is not shown.

TABLE 3—Spores and Pollen Grains in Koputaroa Samples

	L 2816	L2817	L 2815
Lycopodium volubile Forst f.	x	x	
L. scariosum Forst f.	x	x	x
Gleichenia circinata Swartz	x	x	x
Hymenophyllum sp.		x	
Dicksonia squarrosa (Forst. f.) Swartz			x
Paesia scaberula (A. Rich.) Kuhn	x	x	x
Pteridium aquilinum (L.) Kuhn		x	
Blechnum spp.	x	x	x
Phyllocladus sp.	x	x	x
Dacrydium cupressinum Lamb.	x	x	x
D. sp. (*bidwillii–biforme* group)	x	x	x
D. colensoi Hook.		x	x
Podocarpus cf. *totara* G. Benn. ex D. Don	x	x	x
P. cf. *spicatus* R. Br. ex Mirbel	x	x	x
P. cf. *ferrugineus* G. Benn. ex D. Don	x	x	x
P. dacrydioides A. Rich.			x
Pseudowintera sp.			x
Ranunculaceae			x
Cruciferae		x	x
Haloragis sp.	x	x	x
Gunnera sp.			x
Coriaria sp.		x	
Metrosideros sp.	x		
Leptospermum cf. *scoparium* J.R. et G. Forst.	x	x	x
Aristotelia sp.		x	
Hoheria sp.		x	x
Nothofagus menziesii (Hook. f.) Oerst.	x	x	x
N. sp. (*fusca* group)	x	x	x
Araliaceae	x		
Umbelliferae	x		x
Dracophyllum sp.	x	x	x
Myrsine sp.	x	x	x
Coprosma spp.	x	x	x
Compositae	x	x	x
Gentiana sp.	x		x
Hebe sp.	x		x
Cyperaceae	x	x	x
Hypolaena lateriflora Benth.	x	x	x