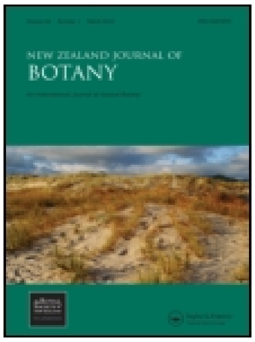

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An interglacial macrofossil flora from Schulz Creek, north Westland, New Zealand

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Abstract On a raised shoreline assumed to be of early Kaihinu Interglacial age (more than 100 kyr ago), in north Westland, well-preserved plant fossils are exposed in sediments in a road-cutting. They were probably deposited in a small freshwater lagoon behind a beach ridge, on a prograded shore. The fossils are robust (wood, coriaceous leaves, tough fruit, or seeds); almost certainly they represent only a proportion of the flora in Schulz Creek catchment at the time. The species composition (including *Dacrydium cupressinum*, *Podocarpus hallii*, *Prumnopitys ferruginea*, small conifers, *Nothofagus* spp., *Metrosideros robusta*, *Elaeocarpus dentatus*) suggests that the climate when the deposit was laid down was probably as mild as it is now. Most of the plant species of the fossil flora occur today in Schulz Creek catchment and the remainder live nearby.

Keywords Kaihinu Interglacial; Rutherglen Formation; raised shoreline; plant macrofossils; forest; mild climate

INTRODUCTION

Distributed discontinuously along the western flanks of the Paparoa Range, north of Greymouth (Fig. 1, 2) are three prominent, stepped terraces, capped by littoral deposits, indicating rapid tectonic uplift during the late Quaternary (Suggate 1973, 1985, 1990). Several smaller terraces are also present. These former shorelines are affected to varying degrees by post-uplift erosion. Where features are well preserved the most prominent landforms associated with the littoral deposits are cliffs in bedrock or cover beds, cut by wave action prior to uplift. Beneath the cliffs are occasional stacks and shore platforms, wave-cut in the bedrock. Extending west below each cliff is a narrow plain, sloping gently seaward. These strand plains consist of pre-uplift, unconsolidated beach and near-shore sediments, some deposited on prograding shores. In places, the littoral deposits are overlain by alluvium and colluvium derived from the higher land to the east.

Between Point Elizabeth and Barrytown, in order from oldest to youngest, the main sets of raised littoral deposits are the Karoro, Rutherglen, and Awatuna Formations. The first was formed during the Karoro Interglacial (about 250–150 kyr B.P.), and the two latter were both formed during the Kaihinu Interglacial (about 130–80 kyr B.P.) (Suggate 1973, 1985; Pillans 1991).

Exposures cut through the raised strand plains by streams, or by road works, reveal irregularly bedded gravels and sands like those being deposited on the present beach and intertidal zone. Older rocks, either hard Tertiary limestone, relatively soft Tertiary mudstone and siltstone, or hard Cretaceous sandstone, siltstone, and conglomerate (Bowen 1964), often underlie the unconsolidated littoral sediments and form the cliffs, stacks, and wave-cut platforms.

On Highway 6 (the coast road), at Schulz Creek, a tributary of Gorge Creek, near Twelve Mile Bluff, c. 45 m above sea level (grid reference NZMS 260, J31/672742) a road cutting, nearly parallel with the modern coastline, exposes an organic deposit. Layers rich in fossil wood, leaves, and other plant fragments are intercalated between beds of silt, sand, and gravel which lack such fossils. The organic bed is presumed to have been deposited close to a shore during the Kaihinu Interglacial, the warm period before the last Pleistocene Glaciation, the Otiran.

Schulz Creek has a very steep catchment with an upper part above the edge of the Karoro terrace (c. 100 m) and a lower, deeply gorged part, with a

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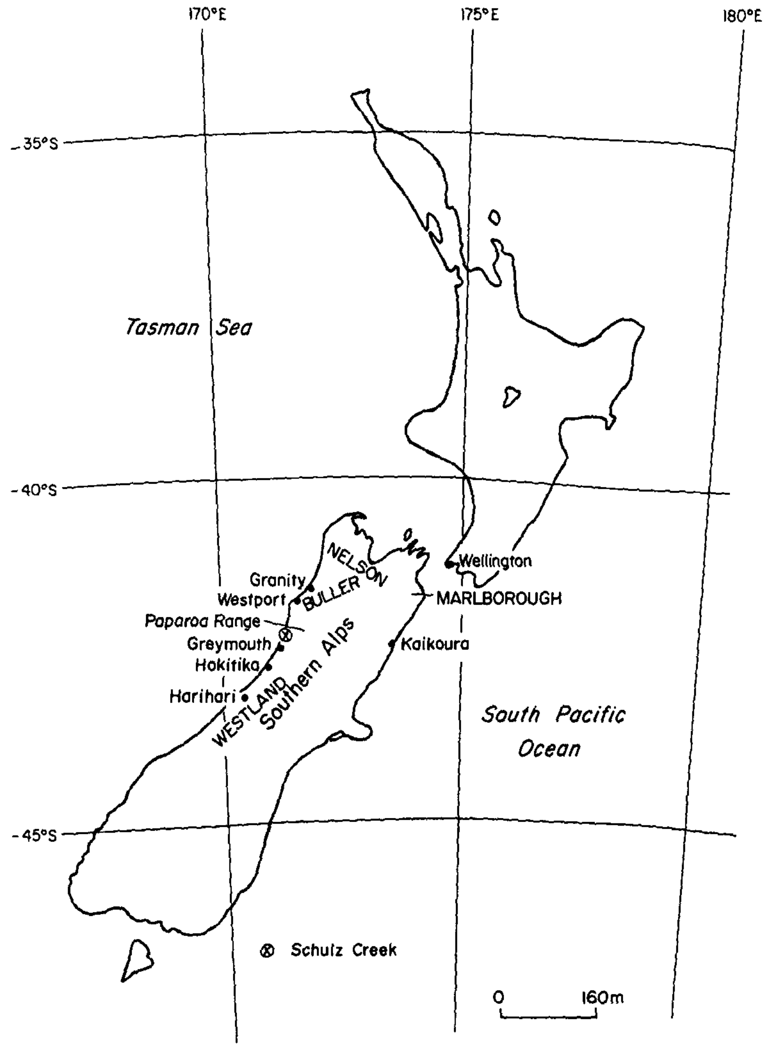

Fig. 1 Location of places mentioned in the text.

coal seam exposed near stream level. Schulz Creek and its single tributary rise on a small, rugged summit at about 260 m above sea level. The steeply falling creek crosses the Karoro terrace surface (c. 100–140 m) in a narrow ravine.

The lower part of Schulz Creek flows into Gorge Creek about 150 m south of the roadside fossil locality. Gorge Creek then falls over a vertical cliff, about 30 m high, cut in the Cretaceous conglomerate and sandstone which is the local bedrock. The sea reaches the base of this cliff at high tide. Stacks are present seaward of the cliff and small wave-cut platforms near its base.

This paper describes the fossil site and stratigraphy, lists the macrofossil plant flora, and interprets the environmental conditions prevailing when these plants were alive. Although some of the fossil plant disseminules have endocarp surrounding the seeds, they are all listed as seeds in Table 1. Nomenclature for plants follows Allan (1961), Moore & Edgar (1970), Connor & Edgar (1987), and (for *Manoao colensoi*) Molloy (1995).

METHODS

Several visits were made to the site (December 1981, August 1982, August 1990, February, April, May, and September 1996), during which the stratigraphy was recorded and samples of the organic horizon taken. Colours of the sedimentary layers were recorded with a Munsell colour chart immediately after cutting back of the exposed surface. At the time of

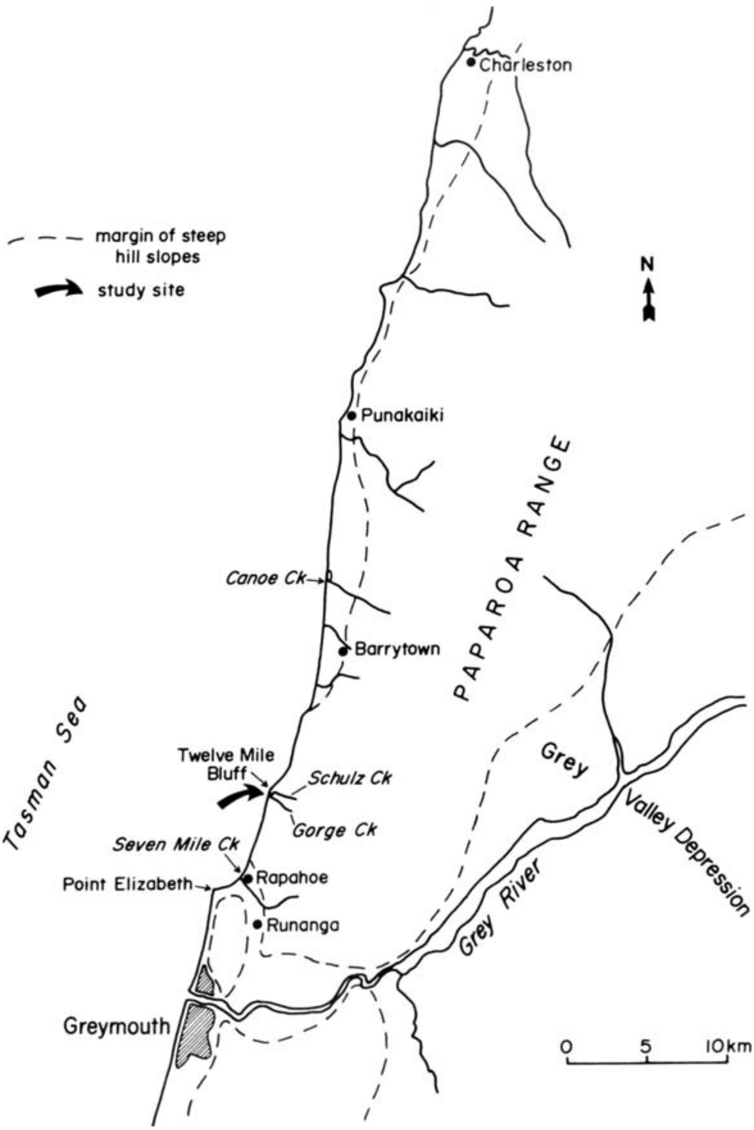

Fig. 2 Location of study site and places in the north Westland region.

the first visit the road margin had been newly cut into the sediments on the north-west side of the course of Schulz Creek. Since then the steep western bank of the road-cutting has become overgrown with ferns, grasses, and shrubs, but slips reveal the stratigraphic details from time to time (Fig. 3, 4).

Samples of the organic sediment (which is relatively rich in sand, silt, and clay) were soaked in tap water for several days then washed through sieves and sorted for identification. Representative specimens of each taxon recovered are preserved in vials, in ethanol or an ethanol-glycerin-formalin mixture. They are stored at the Department of Plant and Microbial Sciences, University of Canterbury.

The catchment of Schulz Creek was investigated to obtain an appreciation of the present flora and vegetation. Beaches, inter-tidal zones, and small lagoons at the mouths of streams were examined at Rapahoe, Gorge Creek, near Barrytown, and near Granity, to seek possible analogues for the geomorphic-sedimentological situation when the Schulz Creek fossil bed was being deposited.

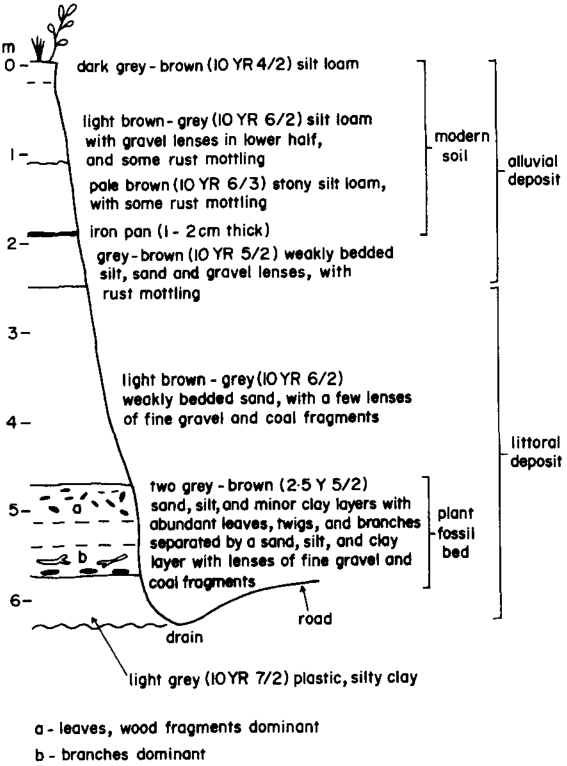

Fig. 3 Schematic diagram of the road cutting section where the Schulz Creek plant fossil bed was sampled, looking north. The fossil bed was exposed along 6 m of the section. The modern soil is developed on old alluvium (of Kaihinu age).

RESULTS AND INTERPRETATION

Stratigraphy and morphology of the deposit

At the place where the fossil bed crops out, over 6 m of exposure, the stratigraphic section is as shown in Fig. 3. From just north of the fossil bed to 120 m south of it the stratigraphy is as shown in Fig. 4. As the soil at the top of the section is dominated by silt, with some clay, and the pebbles in the gravelly and silty layer immediately beneath it are irregular in shape and not flattened, this part of the deposit is interpreted as alluvium.

The basal pebble-cobble bed (Fig. 4) (in which the fine-grained sandstone and rare quartz clasts are smoothed and flattened) and the irregularly-stratified coarse sand with gravel lenses above it, closely resemble modern beach deposits. On the present beaches the dynamics of wave action and tidal movement cause rapid changes in local concentrations of clast sizes, vertically, horizontally, and temporally. Dominant coarse clast deposits, like those of the pebble-cobble bed, often form the high storm-beach ridges, but they can also be found lower in the intertidal zone. Some sand and fine gravel deposits like those of the higher beds occur up to the base of cliffs, or up to rocks on less-steep shores, but usually such deposits characterise the intertidal zone. No marine fossils have been found in the Schulz Creek section.

The upper surface of the coarse pebble-cobble bed at the base of the section, slopes down to the south at c. 2°. Tilting probably occurred during uplift of the shoreline. The pebble-cobble bed rests on a planed surface of Cretaceous conglomerate bedrock (Fig. 4) which is interpreted as a wave-cut platform.

Fossil flora and its environmental setting

The flora (Table 1) contains mainly woody plants, with gymnosperms and beeches most abundant. During field work, all but three of the identified taxa, *Libocedrus bidwillii*, *Myrsine divaricata*, and *Pseudopanax anomalus*, were seen in the Schulz Creek catchment (Table 1), and these three occur not far away, higher in the Paparoa Range and in nearby valleys near sea-level. Several of the taxa listed grow abundantly in the upper valley of Schulz Creek now, on shallow, infertile, gleyed soils over bedrock (*Halocarpus biformis*, *Leptospermum scoparium*, *Phyllocladus alpinus*, *Nothofagus solandri* var. *cliffortioides*, *N. truncata*, *Dacrydium cupressinum*). Other species occur in the lower valley, on deeper, better-drained and more fertile, young, alluvial-colluvial soils. *Dacrydium*, *Prumnopitys ferruginea*, *Elaeocarpus dentatus*, and *Metrosideros robusta* were found only in two samples from the lower organic layer (Fig. 3). Otherwise, the species composition was similar in both organic layers.

Only one herbaceous taxon, *Astelia* sp., was identified from the fossil bed; some small monocotyledon seeds (at least three species) remain unidentified. Present now in Schulz Creek catchment are *A. cunninghamii*, *A. fragrans*, and *A. nervosa*, and various members of Cyperaceae.

Many woody plants (Table 2), herbs, ferns, and bryophytes not represented in the fossil flora, grow now in both the lower and upper valleys of Schulz Creek (list held by author). The differences between the total fossil and modern floras could be because the vegetation differed at the respective times. Even if the vegetation was very similar at these times, differential general taphonomy and preservation of tough leaves, seeds, wood, and other plant fragments could account for some of the discrepancies. However, the abundance of fossil *Libocedrus* leaves, and *Nothofagus menziesii* leaves and wood, suggests that

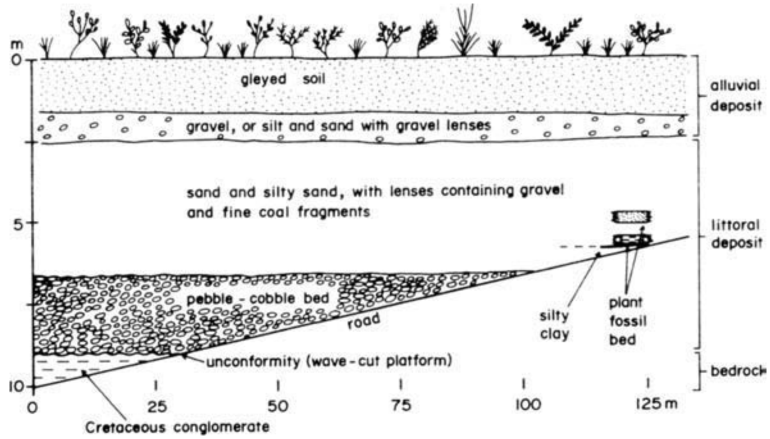

Fig. 4 Schematic diagram of the road cutting section south of the fossil bed site, looking west.

Table 1 Plant macrofossils from raised littoral deposits at Schulz Creek, North Westland. l = leaves; s = seeds; w = wood; a = common; b = moderate numbers; c = rare (only 1 or 2 specimens); 1 = present in upper valley; 2 = present in lower valley

Taxon	Items identified	Relative abundance	Location in the catchment now
Gymnosperms			
Dacrydium cupressinum	l,s	b	1,2
Halocarpus biformis	l	a	1
Libocedrus bidwillii	l	a	not seen
Phyllocladus alpinus	cladodes	a	1
Podocarpaceae (unidentified)	l, root nodules	b	uncertain
Podocarpus hallii	l	b	1,2
Prumnopitys ferruginea	l,s	c	1,2
Angiosperms			
Astelia sp.	s	c	1,2
Coprosma spp. (at least 4)	s	a	uncertain
Coriaria arborea	s	c	2
Elaeocarpus dentatus	s	c	2
Leptospermum scoparium	l, capsules	b	1,2
Leucopogon fasciculatus	l	c	1,2
Metrosideros robusta	l	c	2
Myrsine divaricata	l	c	not seen
Nothofagus menziesii	l, w	a	1
N. solandri var. *cliffortioides*	l, cupule, s	a	1,2
N. truncata	l	c	1,2
Pseudopanax anomalus	l	c	not seen
Pseudopanax sp.	s	c	uncertain
Rubus sp.	s	c	uncertain
Fern			
unidentified sp.	stem with stipe bases	c	uncertain
Mosses			
cf. *Ptychomnion aciculare*	l	a	1
Sphagnum sp.	l	c	1

the vegetation was distinct compared with the present. *N. menziesii* is rare now in Schulz Creek; *N. solandri* var. *cliffortioides* and *N. truncata* are much more âbundant.

Overall, the fossil assemblage indicates a mild climate, much like the present. *Elaeocarpus dentatus*

Table 2 Additional woody species now in the Schulz Creek catchment, but not represented in the fossil flora (some of the *Coprosma* species may occur as fossils). [1] present in upper valley; [2] present in lower valley.

Gymnosperms	*Griselinia littoralis* [1,2]
Dacrycarpus dacrydioides [2]	*G. lucida* [2]
Lepidothamnus intermedius [1]	*Hebe elliptica* [2]
Manoao colensoi [1]	*H. salicifolia* [2]
	Hedycarya arborea [2]
Angiosperms	*Macropiper excelsum* [2]
Archeria traversii [1]	*Melicytus ramiflorus* [2]
Ascarina lucida [1,2]	*Metrosideros diffusa* [2]
Aristotelia serrata [1,2]	*M. fulgens* [1,2]
Brachyglottis repanda [2]	*M. perforata* [1,2]
Carpodetus serratus [2]	*M. umbellata* [1,2]
Clematis paniculata [1,2]	*Myrsine australis* [2]
Coprosma colensoi [1]	*M. salicina* [1,2]
C. foetidissima [1,2]	*Myrtus pedunculata* [1,2]
C. sp. cf. *parviflora* [1,2]	*Olearia avicenniifolia* [1,2]
C. propinqua [1]	*Pimelea longifolia* [1,2]
C. grandifolia [2]	*Pittosporum colensoi* [2]
C. lucida [1,2]	*Pseudopanax colensoi* [1,2]
Cordyline banksii [2]	*P. crassifolius* [1,2]
Cyathodes juniperina [1]	*P. simplex* [1]
Dracophyllum longifolium [1]	*Quintinia acutifolia* [1,2]
D. townsonii [1]	*Rhopalostylis sapida* [2]
D. traversii [1]	*Ripogonum scandens* [1,2]
Elaeocarpus hookerianus [1]	*Rubus australis* [2]
Epacris alpina [1]	*R. cissoides* [2]
Freycinetia baueriana [1,2]	*Schefflera digitata* [2]
Fuchsia excorticata [2]	*Weinmannia racemosa* [1,2]

and *Metrosideros robusta*, in particular, signify that conditions were warm and moist. *M. robusta* has its present southern limit at Mahinapua, not far south of Greymouth. *Libocedrus bidwillii* and *Nothofagus menziesii* grow now near timberline in the Paparoa Range. However, they also occur at much lower altitudes on the western side of the range, near Charleston and Runanga (Fig. 2) on very infertile, gleyed soils, and around the margins of bogs, where they are associated with *Leptospermum*, *Halocarpus biformis*, *Lepidothamnus intermedius*, and *Manoao colensoi*. They do not necessarily indicate cool climate conditions.

Conditions of deposition

The fossil flora comprises wood, seeds, and coriaceous leaves derived mainly from trees and shrubs. They would be relatively resistant to vigorous taphonomic processes, such as carriage down a stream or some winnowing in the surf. Coal fragments, almost certainly derived locally, occur in the organic horizons.

Deposition of the fossil plant material in its final resting place was accompanied by burial in silt and clay-rich sediment. This may have occurred during one or more episodes of stream flooding. The time period represented was probably relatively short, as the fossil-bearing horizons are thin.

No thick silt- or clay-rich deposits were seen on the seaward side of modern beaches. However, on the beach near Granity, 90 km north of Schulz Creek, at low tide, very abundant, well-preserved plant remains, including twigs and leaves, were seen in the intertidal zone (Table 3). These plant fragments were concentrated in ripple-mark hollows in fine sand with a thin veneer of silt. A richer assemblage, on a sandy substrate, was present on the margin of Seven Mile Creek estuary, Rapahoe. It contained abundant branches and small logs. This estuary is quite open to tidal influence.

A more likely analogue for the conditions of deposition of the Schulz Creek fossil bed was seen at the Barrytown beach. Here, there is a prograded shoreline with a strand-plain nearly 2 km wide, and, where streams meet the coast, small lagoons lie behind the storm-beach ridges. At the mouth of Canoe Creek, the surface of the enclosed, 1–2 m deep lagoon is about 2 m above spring high tide level. On the floor of the lagoon were sand, silt, and clay layers, scarce wood, and abundant patches of leaves and other plant fragments, brought down by the stream.

A difference between the fossil deposit and most of those on the modern shores, estuaries, and lagoons (all tidal or subject to wave surges during storms) is that the fossil pieces of wood have irregular broken ends, while the ends of most wood fragments in modern littoral deposits are well rounded, through abrasion in the surf, before coming to rest. Modern wood-rich deposits in the small coastal lagoons tend to have few associated leaves, seeds, and other small plant fragments.

The fossil bed probably accumulated in a small, freshwater lagoon behind a beach ridge. This ridge was breached by the sea, with deposition of more than 2 m of littoral sand and gravel over the organic sediment, before burial of the whole deposit by a further 2.5 m of terrestrial sediments.

Age of the plant fossil deposit

The strand plain surface, at about 50 m a.s.l., is c. 4.7 m above the fossil bed at Schulz Creek. It is assumed to be the correlative of the Rutherglen

Table 3 Leaves observed in modern littoral deposits in some north Westland locations. *leafy stems; †cladodes

Taxon	Intertidal zone, near Granity	Open lagoon, Seven Mile Creek, Rapahoe	Enclosed lagoon, Canoe Creek, Barrytown beach
Aristotelia serrata			+
Carpodetus serratus		+	
Coprosma foetidissima	+		
C. grandifolia		+	
C. lucida		+	+
Coriaria arborea			+
*Dacrydium cupressinum**		+	
Dicksonia squarrosa			+
Griselinia littoralis		+	+
Hoheria sexstylosa		+	
*Lepidothamnus intermedius**		+	
Melicytus ramiflorus			+
Metrosideros umbellata	+	+	+
Myrsine australis			+
M. divaricata			+
M. salicina			+
Nothofagus menziesii	+	+	+
N. solandri var. *cliffortioides*	+	+	+
N. truncata		+	+
Olearia avicenniifolia		+	+
Phyllocladus alpinus†		+	+
Podocarpus hallii		+	
Pseudopanax crassifolius			+
Quintinia acutifolia		+	
Weinmannia racemosa	+	+	+

(early Kaihinu) rather than the Awatuna (later Kaihinu) shoreline (Suggate 1985). The Awatuna surface is absent at Schulz Creek but present, about 10 m lower than the Rutherglen surface, 1.2 km to the south. The fossil bed probably is more than 100 kyr old (Pillans 1991); uplift of the Rutherglen shoreline probably began soon after the fossil bed formed.

DISCUSSION

Westland-Buller has proved to be a fruitful location for fossil floras that permit interpretation of the environmental conditions prevailing during interglacials prior to the Otira Glaciation. Almost all studies published on these cover the Kaihinu Interglacial (Dickson 1972; Moar & Suggate 1979; Moar 1984; Soons & Lee 1984) and most of the vegetation data are derived from pollen analysis. None of the sites contains a complete sequence through the Kaihinu. The composite series of pollen diagrams described by Moar & Suggate (1979) from several sites near Westport indicates that this interglacial, which lasted about 45 kyr (Pillans 1991), was climatically diverse. *Nothofagus* spp. dominated early Kaihinu vegetation near Westport. This was followed by a cold episode when grasses and shrubs were prominent. Then, in the later Kaihinu, *Dacrydium cupressinum* was dominant for a time before *Nothofagus* spp. again flourished.

At a site just south of Greymouth (Soons & Lee 1984), a pollen flora from organic sediments in a buried depression on the Rutherglen terrace contains *Dacrydium cupressinum* (very abundant), *Prumnopitys ferruginea*, *Elaeocarpus*, *Metrosideros*, *Weinmannia*, *Nestegis*, *Dodonaea*, *Ascarina*, *Quintinia*, *Carpodetus*, *Myrsine*, and *Phyllocladus*. Also present were *Nothofagus menziesii*, *N. solandri*, and *D. cupressinum* leaves; *Pittosporum*, *Hoheria*, and *Libocedrus bidwillii* wood; and *Myrtus*, *Coriaria*, and *Muehlenbeckia* seeds. The assemblage resembles that from Schulz Creek in several respects (Table 1). Two amino acid racemisation dates were obtained for wood in this deposit, 120 000 yr B.P. (BJP-153A) and 140 000 yr B.P. (BJP 153-B) (error factor 30%) (Pillans 1990) and a similar age range is assumed for the Schulz Creek organic deposit.

A more continuous sequence through the Kaihinu Interglacial is represented in drillhole sediments from Petone, near Wellington (Mildenhall 1995). However, sampling for pollen analysis was at distant intervals and there are non-fossiliferous sections of the core. The moderately rich flora contains species now found in warm, moist, climatic conditions, among them large podocarps, *Rhopalostylis*, and *Ascarina*.

The Schulz Creek plant macrofossil bed may represent only a short part of early Kaihinu time. Only a proportion of the total flora will have been preserved in the sediments (cf. Burrows 1974; Drake & Burrows 1980). The preserved taxa include some (especially *Elaeocarpus dentatus* and *Metrosideros robusta*) that indicate climatic conditions at least as mild as those of the present. The occurrence of *Nestegis* pollen in Kaihinu Interglacial sites extending from Westport (Buller) to Harihari (South Westland) (Moar 1984) hints that conditions then were warmer than at present. *Nestegis* species are present only in the Nelson and Marlborough regions of the South Island now (extending as far south as Kaikoura on the east coast but apparently absent from the west coast) (Fig. 1). It might be, however, that such a distribution (which is similar to that for *Beilschmiedia tawa* and a few other species) is a result of slow southward migration of the species during the 14 000 years of time available since the end of the Otira Glaciation. A much longer time was available during the Kaihinu Interglacial. Mildenhall (1995) reported *Ixerba brexioides* pollen present in the Kaihinu Interglacial part of the Petone drillhole core. That, too, is far south of its present southern limit, at about 39°S (Fig. 1) (Clarkson 1985). B. R. Clarkson (pers. comm.) notes that *Ixerba* is confined to old, weathered soils and is not frost sensitive, so its failure to extend further south in the present interglacial may also be through lack of opportunity.

The Schulz Creek site is at the western foot of the Paparoa Range. This mountain block, separated by the wide Grey Valley depression from the main mountain ranges of the Southern Alps, is thought to have been a refuge for forest species, including *Nothofagus menziesii* and *N. solandri* var. *cliffortioides*, during the Otira Glaciation (June 1982). Modern distribution patterns and inferred migration rates of the beeches provided the evidence for this assumption. *N. menziesii* leaves have been found in Otira Glaciation age deposits near Greymouth (C. J. Burrows unpubl. data). These species, therefore, appear to have inhabited the Paparoa Range for more than 100 000 years. Various other woody species would have accompanied them through this time.

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