CHAPTER ELEVEN

Podzols and Pakihis

The West Coast of the South Island is the most distinctive soil landscape region in New Zealand. The reason for its unique character is its location along the western side of mountain ranges which extend in an unbroken chain for 750 km from the Wakamarama Range behind Golden Bay in north-west Nelson to the remote wilderness of south-west Fiordland (Chapter 9). No other region has this combination of:

- a narrow coastal fringe backed by high mountains, which were extensively glaciated during the late Quaternary Period and today experience very high rainfall yet mild lowland temperatures, which account for the wet, leached soils and luxuriant indigenous forest (Plate 11.1).

Climatic Features – High Rainfall/Moderate Temperatures

The West Coast lowlands span nearly four degrees of latitude (40.5°–44.5°S) from Cape Farewell to Awarua Bay and most of this wet coastal strip receives 2000–4000 mm of rainfall annually. Localities such as Whanganui Inlet and Karamea in the north are milder, with less rainfall and wind than the rest of the West Coast. Because the Inangahua and Mawheraiti valleys lie inland (in the rainshadow of the Paparoa Range), they have a slightly lower rainfall and are more sheltered and susceptible to winter frosts and fogs. At sea level, the rainfall increases from north to south throughout the region (Table 11.1) with an annual figure of 10 000 mm being recorded on average once every 50 years at Milford Sound.

Although the West Coast and parts of Fiordland are the wettest lowlands in New Zealand, their temperatures are moderate. Table 11.1 lists a number of key climatic features for four widely spaced lowland localities throughout the region and Fiordland, and compares them with Christchurch on the east coast. Although the West Coast rainfall is four to six times as high, rain days are only twice as frequent as in Christchurch; sunshine hours (at least for the coastal lowlands) are about the same and the temperature extremes much less. In contrast to the rest of New Zealand, the West Coast has more rainfall in spring than in winter. Prolonged dry periods are very rare.

Glacial Landforms Widespread

When Abel Tasman sighted New Zealand off Okarito in 1642 the nearby Franz Josef and Fox Glaciers extended to the lowland podocarp forests. Although they have subsequently retreated and their terminal faces now lie within mountain walls, they still provide a graphic illustration of the powerful natural forces that shaped so many of the present-day landforms of the West Coast — glacial outwash deposits subsequently left as terraces when the rivers entrenched, the ridges and undulating moraines of piedmont landscapes, ribs of ice-smoothed rock, moraine-impounded lakes, and a fascinating host of more subtle topographic features associated with the melting of the glaciers (Plate 11.2).

Soil Formation in a High-leaching Environment

In the mild climate of the West Coast, rock fragments weather at a moderate rate, but nutrients released through this weathering are rapidly leached out by the high rainfall, unless they are quickly incorporated into the organic cycle. Studies
View across the mouth of the Karangarua River to the highest peaks of the Southern Alps — Mt Tasman (left) and Cook (right) above the névés of the Franz Josef and Fox Glaciers. The Karangarua River is separated from the Ohinetamatea River to the north by the prominent forest-covered ridge of lateral moraine which marks the edge of one of the glacial advances of the Quaternary Ice Ages. These ice sheets were so extensive that all forest was probably stripped off the lowlands; since the retreat of the glaciers, podocarp forest has recolonised the land leaving a 180 km ‘beech gap’ between Hokitika and Paringa. Unlike podocarps, beech seed is not dispersed over large areas by birds; instead seedlings establish locally, and young beeches are slowly invading the edges of the podocarp forests, often along the banks of streams.

of the extent of soil development over 20 000 years on materials deposited by the retreating Franz Josef Glacier give an insight into the rate at which these soils develop — and deteriorate (Fig. 1.2). Soil fertility builds up rapidly during the first 50–100 years, then slows as soil organic matter, clay, and available forms of phosphorus increase to a maximum over the next 5000–10 000 years and a dense rimu/kamahi/totara forest gradually develops.

But the luxuriance of this forest is something of an illusion, for in this environment soil aged from 12 000–15 000 years has passed its prime and is well on the way to senescence. Admittedly such mature soil has a much greater capacity to retain nutrients and incorporate them into the cycle of forest growth — but most of the nutrients from the weathered rock have already been leached away. Gradually this forest seems to degrade to the more open, stunted rimu/silver pine associations which characterise so many of the landscapes with gley podzol soils older than 20 000 years.

These rates of soil development and deterioration differ throughout the region. Leaching is not so intense in other areas, parent rocks may be even more silica-rich (e.g. granite and gneiss) or they may be less acidic (e.g. limestone) and the vegetation succession may differ from that in the Franz Josef area. Nevertheless, the process is fundamentally the same rather grim struggle of developing soils attempting to retain the limited nutrients in an available form in the face of constant leaching by an over-abundance of water.
### TABLE 11.1

Climate of several locations on West Coast, South Island (compared with Christchurch)

<table>
<thead>
<tr>
<th>Location</th>
<th>Altitude (m)</th>
<th>Rainfall (mm)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>mean annual</td>
<td>maximum in 1 month</td>
</tr>
<tr>
<td>Westport</td>
<td>2</td>
<td>2160</td>
<td>453</td>
</tr>
<tr>
<td>Hokitika</td>
<td>4</td>
<td>2870</td>
<td>739</td>
</tr>
<tr>
<td>Haast</td>
<td>4</td>
<td>3460</td>
<td>1328</td>
</tr>
<tr>
<td>Milford Sound</td>
<td>3</td>
<td>6240</td>
<td>1754</td>
</tr>
<tr>
<td>Christchurch</td>
<td>7</td>
<td>626</td>
<td>—</td>
</tr>
</tbody>
</table>

= not known

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**Buller and Grey Districts**

The relationship of the soils in the northern part of the West Coast to topography, climate and soil parent material can be illustrated in a landscape and rainfall cross-section from Charleston to the crest of the Southern Alps near Arthur's Pass (Fig. 11.1).

South of the mouth of the Buller River at Westport, the Cape Foulwind to Punakaiki coastline is a mosaic of old marine and river terraces interspersed with ribs of limestone. Terraces such as Caroline and Virgin Terraces near Charleston are typical pakihi lands (Plate 11.3). Charleston soils occur where the soil parent materials are marine and dune sands from the local granite and gneiss of the Paparoa Range, and Addison soils where the higher terraces consist of stony alluvium.

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![Annual rainfall](image)

![Topography, soil and precipitation cross-section](image)

Fig. 11.1

Topography, soil and precipitation cross-section of the West Coast from Charleston to the Southern Alps.
Plate 11.3
Virgin Terrace, near Cape Foulwind, looking eastwards to the Paparoa Range which is typically covered in rain clouds. The high terraces have developed shallow, stony Addison soils (Plate 11.4) which currently support a pakihi vegetation of rushes and pakihi fern. These derelict lands have suffered from successive burning and their soils are among the most difficult on the West Coast to establish in either pasture or exotic forest.

Plate 11.5
Near Punakaiki looking south-east up the canyon of the Pororari River towards the cloud-covered crest of the Paparoa Range. The Pororari is one of several westward-draining rivers that have dissected the limestone into a series of plateaux whose forested surfaces are pitted with drainage depressions. This is a superb example of an unmodified lowland karst landscape covered with luxuriant coastal broadleaf forest because of the mild climate and relatively free-draining properties of the limestone soils. In sharp contrast, montane beech forest developed under cooler conditions on the acidic Kaniere steepland soils on the gneiss rocks of the distant Paparoa Range.

The huge talus slopes at the foot of the limestone cliffs (left) are covered with hinau, mahoe, kamahi, tree ferns and nikau palms, with tall northern rata and rimu emerging above this canopy. Within the gorge, however, the lack of the taller trees on the talus slopes may indicate the climatic influence of cold air draining down from the Paparoa Range.

(Plate 11.4). Both soils are shallow with striking colours in their iron- and humus-cemented subsoils; they are moderately to strongly gleyed podzols (see Chapter 5). Some Charleston and Addison soils lie derelict where the pakihi vegetation has been repeatedly burnt, but substantial areas of both soils have also now been established in pastoral farming or exotic forestry.

The limestone escarpments of the Punakaiki coastline are the most dramatic landscape feature of the locality (Plate 11.5). While the peculiar weathering pattern (karren) of the ‘pancake rocks’ of Dolomite Point is the most popular tourist feature, there is a fascinating maze of less frequently visited karst landforms hidden under heavy forest between the coastal escarpment and the foot of the Paparoa Range. The Punakaiki steepland soils on the limestone have distinctive yellowish-brown subsoils and are relatively deep (80–90 cm) for steepland soils. (The properties of these calcareous soils are described in Chapter 12).
The Addison soils are shallow and stony gley podzols which have developed on alluvium (granite and gneiss) covering many of the high terraces of the Cape Foulwind-Charleston area. The profile consists of a relatively deep (25–30 cm), gleyed, sandy loam to sand-textured A horizon over extremely firm, massive iron- and humus-cemented stones and boulders. The bright ochreous colours in the bouldery subsoil are a most distinctive feature. The presence in this subsoil of high levels of gibbsite, allophane-type clays and aluminium associated with organic matter indicates the more weathered nature of this soil compared with other West Coast gley and gley podzol soils. Addison soils are very wet because of their impeded subsoil drainage and have severe physical and nutrient limitations for pastoral and forestry use.

Plate 11.4

The Addison soils are shallow and stony gley podzols which have developed on alluvium (granite and gneiss) covering many of the high terraces of the Cape Foulwind-Charleston area. The profile consists of a relatively deep (25–30 cm), gleyed, sandy loam to sand-textured A horizon over extremely firm, massive iron- and humus-cemented stones and boulders. The bright ochreous colours in the bouldery subsoil are a most distinctive feature. The presence in this subsoil of high levels of gibbsite, allophane-type clays and aluminium associated with organic matter indicates the more weathered nature of this soil compared with other West Coast gley and gley podzol soils. Addison soils are very wet because of their impeded subsoil drainage and have severe physical and nutrient limitations for pastoral and forestry use.
Plate 11.6
Craigieburn Pakihi, a high glacial outwash terrace on the western side of the Grey valley. These wet Okarito soils (Plate 11.7) are extremely acidic and infertile; they usually support only the fire-induced vegetation of manuka, fern and rushes. To restore forest to such soils, pretreatment is necessary to reduce surface wetness. In this photograph the fine-textured part of the soil has been bulldozed into parallel ridges which will shed water. Exotic trees are then planted on the ridge crests. The technique improves drainage sufficiently for tree survival, but nitrogen and phosphorus fertilisers are also necessary around each tree at the time of planting and three to four years later. In contrast to farming development of pakihi land, forest establishment calls for rapid alteration of soil structure and drainage while the level of fertiliser used in each rotation is only 15–20 percent of that required for pasture development and maintenance.

Plate 11.9
Looking south-east across the Grey River to the Ahaura River, showing the main landforms and land uses of the Grey valley (see cross-section in Fig. 11.1). Ahaura township is just out of the photograph to the right. The river flats in the foreground are subject to flooding and their Hokianga and Harihari soils are only partly in pasture. The pastures on the low glacial outwash terrace in the centre of the photograph have been developed on well-drained Ahaura soils (Plate 11.8). Beyond this terrace, the land rises to the dissected lowland hills on conglomerates and sandstones. Here a complex array of hill and steepland soils have been partly cleared of indigenous forest and converted to exotic plantations.

East of the Paparoa Range, the wide trough of the Grey valley lies within the rainshadow of the mountain ranges to east and west (Fig. 11.1). Like the Inangahua valley to the north, the Grey valley contains a wide range of terrace, fan, moraine and hill country landforms. Most of these, and their soils, are illustrated in the central part of Fig. 11.1.

Extensive flights of terraces, underlain by deep gravels and sands, occupy about one-third of the Inangahua and Grey valleys. The most widespread are the highest terraces (older than 22 000 years; remnants of former glacial outwash surfaces) and the low glacial outwash terraces (14 000–22 000 years old; remnants of later glacial outwash surfaces). A typical high terrace is the Craigieburn Pakihi, part of a band of gently sloping pakihi land extending down the western side of the Grey, from the Mawhera River to near Blackball (Plate 11.6). These high terraces carry a varying thickness (30–200 cm) of fine sandy or silty loess over the underlying gravels. In the Okarito soils under low pakihi vegetation this very firm, massive silt-loam horizon is light grey (Plate 11.7), whereas in the related Mawhera soils under forest the colour of this horizon tends to be more olive (Plate 1.9). Both soils are gleys podzols (see Chapter 5), with zones of iron enrichment (Mawhera soils) or both iron and humus enrichment (Okarito soils) at the boundary of the loess and gravels. They are among the most acidic, infertile, and wet soils of the West Coast but they can be brought into production through sustained efforts to improve their drainage, structure, and level of fertility.
The Okarito soil is the most striking of the gley podzols of the high glacial outwash terraces of the West Coast (Plate 11.6). The deep topsoil (0-30 cm) is a dark, reddish-brown peaty loam with a very high organic matter content (carbon levels of 10-15 percent). The very wet, paler brown base of the topsoil (30-45 cm) is gleyed, and undergoes a sharp transition to the light-grey, gleyed E horizon (45-65 cm). Gravels can be seen at the base of this fine-textured, loess material of extremely low permeability. The zone of humus enrichment (Bh horizon) can be seen in the reddish-brown gravels at 90-120 cm depth. Beneath this, just above the water in the bottom of the pit, lies the dusky red, massive, strongly cemented iron pan (Bms).

Okarito soils have been mapped over 20,000 ha of high terraces between the Buller and Taramakau Rivers in northern Westland; similar soils probably cover large areas of central and southern Westland.

The Ahaura soils cover about 15,000 ha of low glacial outwash terraces in the Inangahua and Grey valleys. They are well drained, with moderately thick (20-25 cm) dark brown silt loam topsoils over yellowish-brown stony silt loam subsoils. Horizontal bedding of gravel and sand lenses (such as that shown at 1 m depth) indicate their alluvial origin. They are acidic, generally of low nutrient status and have a high capacity for the retention of phosphate in their subsoils.

The Ahaura soils have the properties of both the brown earths and the stony terrace soils (described in Chapters 8 and 12). They are a more leached version of the stony Kawhatau, Ashhurst and Heretaunga soils (Plate 6.10) of the southern North Island. Ahaura soils offer some of the region's best prospects for both pastoral, horticultural and exotic plantation development.
In a region so dominated by hills and mountains, the large areas of pakihi land have always been a tantalizing prospect for land development (Plate 11.6). Successful development techniques have been applied by government agencies (Lands and Survey Department in pastoral farming and Forest Service in exotic forest plantations) but the research and establishment costs have been high. At one stage the pakihi lands were being developed at such a rate in Golden Bay and on the West Coast that the Wildlife Service expressed concern at the loss of so much of the remaining habitat for wetland birds, such as the fern bird.

Below the high terraces the low glacial outwash terraces step down towards the main rivers, such as the Grey, Ahaura and the Haupiri (Fig. 11.1). These terraces have much less fine-textured material over the underlying gravels and the soils are a mixture of the well-drained Ahaura soils and the gleyed Maimai soils. Ahaura soils (Plate 11.8) are extensive around Murchison, the Maruia valley and Reefton, and in the central part of the Grey valley from Ikamatua to Ahaura (Plate 11.9).

As rainfall increases down the Grey valley towards Greymouth, the low terraces become dominated by Maimai soils (Plate 11.10), infertile gley soils which tend to have water lying close to the surface for most of the year. For this reason, most Maimai soils still carry some indigenous vegetation – hard and silver beech, kamahi, mountain toatoa and a variety of regenerating podocarps (kahikatea, rimu, yellow/silver pine) in areas which have been selectively logged.

Below the low terraces the river flats consist of recent alluvium from the granite, greywacke and schist rocks of the surrounding ranges (Fig. 11.1); most of the soils are well drained (Hokitika soils), but some of them on the low-lying flats are slower draining (Harihari soils). Both Hokitika and Harihari soils are recent alluvial soils (described in Chapter 7) with shallow (sometimes stony) undeveloped profiles and little accumulation of organic matter. They are relatively unweathered and consequently have high reserves of nutrients such as phosphorus, potassium and magnesium. Most of these soils have now been cleared of forest although some areas are infested with gorse, broom and blackberry. With more flood protection measures (and drainage of some Harihari soils) they probably offer the best prospects for increasing agricultural and horticultural production throughout the West Coast (Plates 11.9 and 11.11).

A band of low, dissected hills is located in the central portion of the Grey valley. These hills consist of weathered conglomerate (Old Man Gravel of early Quaternary Age, similar to the Moutere Gravels of Nelson, Chapter 8) and mixed sandstone and siltstone. Where the soils have developed in the deep, gravel conglomerate (Blackball and Arahura hill soils, Mahones and Blackwater steepland soils) the level of available nutrients is very low but the risk of slip erosion is not so severe as to rule out exotic forestry. Consequently, these well-drained soils are some of the most important forestry soils in northern Westland. However, attempts to establish a network of logging roads on the hard sandstone/siltstone hill country (Callaghans and Granville steepland soils) and the associated felling of indigenous forest has led to extensive slip erosion. It has been found necessary to leave most of this broken country under indigenous forest.

South-east of the Ahaura River an extensive forest-covered moraine and high terrace surface is located between Lake Hochstetter and the trough along the Alpine Fault. The forested moraines are mainly covered with shallow, stony soils with a pronounced gleyed B horizon. These Flagstaff soils (Plate 11.12) generally carry thick forest litter and have a dark brown topsoil with no gley features, in contrast to the Maimai soils which have a distinct gleyed A horizon. In addition to the limitations imposed by poor drainage, shallowness and stoniness, the Flagstaff soils have very compact subsoils and very low natural fertility. Windthrow of trees is a management problem and soil use may be best restricted to indigenous forest management, with pastoral development in those areas already cleared of forest.

In the hollows on this moraine surface, pockets of organic soils (Kini soils, Plate 11.13) occur, just as they do in minor depressions on most of the landforms of the West Coast. These organic soils (see Chapter 3) are of very limited use because of their high water table and very low natural fertility. Some of them can be drained and, with care, used for dairying or cropping, but the high rainfall and the localised nature of the peat pockets makes the task difficult. Often these peatlands are of wildlife and scenic importance, supporting flax and kahikatea forest fringing attractive lakes nestling among the moraines and hills (Plate 11.14).
Immediately to the west of the Alpine Fault an ice-worn ridge of hard granite (Bell Hill) protrudes above the glacial outwash and moraine (Fig. 11.1). It is one of a series of symmetrical granite knolls and peaks (e.g. Granite Hill, Hohonu Range, Tuhua) which extend as far south as Mt McLean at the mouth of the Arawata River in Jacksons Bay. East of the Alpine Fault, associations of steepland soils occur on the schist (Otira steepland soils) and greywacke (Wakamarama steepland soils) of the western slopes of the Southern Alps in the wet mountain region (Chapter 9).

Many of these rocks are badly shattered through fault movement, and protection of the soil/vegetation mantle (particularly the control of wild, introduced herbivores) is of critical conservation importance.

Plate 11.11
View westwards across the floodplain built up by the alluvium from the Styx, Kokatahi and Toaroa Rivers (right to left, foreground) and the Hokitika River (left, distance), towards the Tasman Sea. Lake Mahinapua (Plate 11.14) is in the distance near the coast. These Hokitika and Harihari soils are moderately fertile, relatively well-drained, recent alluvial soils which have been developed into the most important dairy farms in the Grey-Hokitika district.

Plate 11.12 (far left)
Flagstaff soils are gley soils which occur on about 12,000 ha of the forested moraine landscapes of the Grey valley. In contrast to the Maimai soils (Plate 11.10) their A horizon is not gleyed but is a very dark-brown humic silt loam or loamy sand. Unlike most West Coast podzol and gley podzol soils, many Flagstaff soils do not show any evidence of horizons of humus (Bh) or iron (Bms) enrichment; instead, this profile shows a pale yellowish-brown gleyed Bw horizon, containing vermiculite and kaolinite clays and secondary quartz. Like most West Coast wetland soils, the lower part of the profile (Cw, 45 - 75 cm) is much less weathered and contains higher proportions of mica and vermiculite and very little quartz.

Plate 11.13 (left)
Kini soils are widespread throughout the length of the West Coast, occurring in minor depressions on the surface of the high glacial outwash terraces and in hollows among moraine ridges or behind sand dunes (Plates 11.1 and 11.16). Consequently, they are associated in the landscape with Okarito, Mawhere and Flagstaff soils. Their original vegetation was a mixture of acid-tolerant trees and shrubs, such as Dacrydium (rimu, yellow-silver pine, bog pine), Dracophyllum, and Phyllocladus species, and the usual small plants of wetlands — sphagnum moss, rushes and sedges. This profile of dark reddish-brown, well-decomposed peat, is deep (over 130 cm) and typically contains some wood fragments.
At the outlet of Lake Mahinapua, just south of Hokitika, flax and kahikatea forest grows luxuriantly on organic soils (Rotokohu soils, similar to Kini soils, Plate 11.13). The lake is held back from the Tasman Sea by ridges of moraine and sand dunes and is protected from the floodplain of the Hokitika River (in the distance) by moraines which are now covered by both indigenous podocarp forest and exotic plantations. Most of the lake environs are in scenic reserve.

South Westland

In South Westland the lowland strip narrows markedly and the mountains are much closer to the Tasman Sea (Plate 11.2). Although the same general environmental features occur here, there are several significant differences from the north:

- South Westland is much wetter;
- moraine landforms are much more common than glacial outwash terraces;
- beech forest is absent for 180 km (the ‘beech gap’) between the Taramakau and Paringa Rivers; instead, the soils carry podocarp/hardwood forest.

As yet, the soils of most of South Westland have not been surveyed in any detail, such is their remoteness and the unlikelihood of significant agricultural or forestry development of this predominantly natural, undisturbed landscape (Plate 11.15). Soil surveys around Lake Ianthe near Harihari have indicated the predominance of Flagstaff-like gley soils on the forested moraines and Okarito-like gley podzols on the glacial outwash surfaces. A large piedmont landscape of forested moraine and glacial outwash between Ross and Bruce Bay is dissected by floodplains built up with recent alluvium from the Wanganui, Whatarea, Waiho, Cook and Karangarua Rivers (Plate 11.2). These flats are smaller than those of northern Westland but they are regionally important since their Hokitika and Harihari soils support most of the district’s cattle farming.

Wetlands are major features of the lowlands, particularly south of the Poerua River. Compared with the pakihi land of north Westland, most of these wetlands are relatively unmodified and constitute a very important wildlife and nature...
conservation resource which should be carefully protected (Plate 11.15). Particularly interesting are the sand dune/lake complexes, like the Tawharekiri Lakes between the Waita and Haast Rivers (Plate 11.16). In contrast to the sand dune ecosystems of the Manawatu (Chapter 6), the soils of these dunelands have been only slightly disturbed through human impact. This whole sequence of sand dune and wetland soils offers excellent opportunities for scientific studies of the nature and rate of soil development, with time and progressive changes in vegetation. Some of the soils on these coastal sand dunes are podzols (Plate 11.17).

South Westland has many outstanding scenic natural landscapes but the scientific importance of some of these is only beginning to be investigated. The region is unique for the opportunity that still remains to protect whole landscape sequences, such as those protected by the addition of the Okarito-Waikukupa lowland forests to Westland National Park in 1982. The soils protected under natural vegetation in such a sequence would range from the highest peaks in the Southern Alps, down across the glaciers and mountain walls, to the forested piedmont landscape and the swamps behind the shores of the Tasman Sea.

South of Bruce Bay in the Ohinemaka State Forest lies one of the most attractive and least modified natural ecosystems on the West Coast. This isolated arc of beach is backed by scrub- and forest-covered dunes, with forested strands of moraine and eskers set among swamps and partly infilled lakes. This wetland complex is all wedged between two large lateral moraines (one is the ridge in the foreground leading to Heretaniwha Point) which mark the outer limits of the glacier that carved out this depression in the late Quaternary Ice Ages. The scientific importance of this landscape is recognised by its designation as a state forest ecological area.
Looking north-east across the Tawharekiri Lakes coastal dune/wetland system, from near the mouth of the Haast River in South Westland. The parallel bands of dune and wetland are one of the best remaining little-modified examples in New Zealand of a dune system that has gradually moved seaward over the last 8000-or-so years. Kini soils (Plate 11.13) occupy the former lake-bed at the extreme right of the photograph; the Maori River (draining the main Tauwharekiri Lakes) can be seen meandering north to the Waita River. The peaty interdune hollows also contain Kini soils, and podzols occur on the older dunes (Plate 11.17).
An example of a podzol on the strongly leached coastal sand dunes of the Waita-Haast River sand dune/lake complex. This dune is probably around 3000–5000 years old and the characteristic bleached E horizon is well developed, although it varies in thickness with subtle changes in the microtopography (and possibly the forest vegetation). By way of contrast the similarly aged Foxton soils of the Manawatu show no sign of podzol features in their coastal sand soil profiles, because they occur under a much lower rainfall (Plate 6.15).