CHAPTER SIX

Terraces and Dunes

The Manawatu region has a number of contrasts with the other North Island soil landscape regions described so far. The influence of volcanism, past and present, is relatively minor for the area is composed almost entirely of sedimentary rocks. Another difference is that of climate; although temperatures are not much cooler than those of the Waikato (warm summers, mild winters), the prevalence of strong to gale-force winds and lower annual rainfalls (800 - 1200 mm) can result in pronounced soil moisture deficits during summer and autumn.

Landforms of the Manawatu

Most of the Manawatu-Wanganui region was a basin submerged under the sea during the late Tertiary to mid-Quaternary Period. The sediments that filled this sea basin to a depth of thousands of metres were derived from the rising arc of land extending from Taranaki, across the Tongariro Volcanic Centre to the Ruahine and Tararua Ranges. Sediments eroded from north-west Nelson far to the south were also deposited here. Gradually, as uplift of this northern arc of land occurred, the sea bottom rose to form a large coastal plain (Plate 6.1).

This rising coastal plain was rapidly dissected by rivers, leaving the oldest uplifted sediments - those furthest from the coast - as the present-day belt of Wanganui-Turakina-Rangitikei hill country 20 - 40 km inland. During this time of coastal plain emergence, worldwide glaciations were causing major fluctuations in sea level. Near the coast, the sediments were carved into a remarkable series of marine terraces, each formed during a period of warmer climate and high sea level between the glacial periods. The oldest of these is now 200 - 300 m above sea level but survives only as isolated, deeply dissected remnants. The younger marine terraces are less dissected, more extensive and occur closer to the coast, between 50 and 100 m above sea level.

If this physiographic situation were not complicated enough, the cold/warm climatic cycles of the Quaternary Period were sufficient to cause the major rivers - Wanganui, Rangitikei, and Manawatu - to aggrade and degrade alternately. During times of warm climate the rivers cut down (degraded) into the slowly rising land mass. When the climate cooled, vegetation retreated from the inland mountain ranges, erosion increased markedly and a vast amount of rock debris was transported to the lowlands by the rivers. Burdened by this load, the rivers built up (aggraded) their beds by depositing the rock debris to form wide, bare, floodplains which were braided by the continually changing channels of the river. These floodplains would have been similar to the present floodplains of the Waimakariri and Rakaia within the Canterbury Plains (Chapter 12).

As with the marine benches, the oldest cold-climate floodplains have been largely destroyed as the rivers cut down during the warmer periods. The remnants are preserved as flights of river terraces, best developed in the Rangitikei valley (Plate 6.2) where a sequence of 14 sets of terraces can be recognised (spanning a formation period of around 250 000 years). Extensive remnants of the youngest of the cold-climate floodplains are preserved as the stony plains of the region.

Silt on these braided cold-climate floodplains was constantly swept up into dust clouds by the powerful north-westerly winds and was redeposited as loess across the adjoining terraces and plains (Plate 6.1). The last period of cold-climate
floodplain formation – and hence major loess deposition – ceased around 12,000 years ago. The sea rose to its present level about 6,500 years ago. Since then the lowest parts of the river systems have been infilled with finer alluvium, and the prevailing north-west to west-north-west winds have blown coastal sands inland to form a remarkably wide belt of sand country.

**Soil Formation on Drift and Alluvial Parent Materials**
The parent materials of soils in the Manawatu are shown in Fig. 6.1. Except for areas of organic soils on the Holocene floodplains and in the sand country, almost all the soils have developed in drift materials (loess, windblown sands, or erosion debris in the hill country) or alluvial deposits (the stony and sandy materials of the youngest cold-climate floodplain and the silty material of the Holocene floodplains). This preponderance of relatively youthful and unconsolidated soil parent materials in the Manawatu contrasts sharply with the situation in Northland (Chapter 5) where most of the non-volcanic soil parent materials are sedimentary rocks which have been deeply weathered in situ.

**Rangitikei-Pohangina Hill Country**
Hill country extends across the middle reaches of the Whangaehu, Turakina and Rangitikei catchments to the headwaters of the Oroua and Pohangina Rivers, two important tributaries of the Manawatu River which rise on the western slopes of the Ruahine Range. It includes the spectacular landscape traversed by State Highway 1 between Hunterville and Taihape (Plate 6.2). Here the Rangitikei River
and its Moawhango, Hautapu and Kawhatau tributaries have cut steep-sided canyons in the soft sedimentary material. Erosion has produced overall uniformity in these hilly landforms – similar slope angles and summit height (Plate 6.3) and widespread mass movement of the valley sides where the rocks are less consolidated.

Plate 6.2

The spectacular down-cutting of the Rangitikei River and its formation of terraces is evident in this view from Ohingaiti looking eastwards towards Rangiwahia under cloud at the foot of the Ruahine Ranges. The youngest soils are the coarse-textured Rangitikei soils on the present day floodplain adjacent to the river; much larger areas of Mansawatu soils can be seen on the slightly higher river flats just above normal flood level. The intermediate terraces (traversed by the highway and railway, bottom left) have only a thin covering of loess and are mapped as the stony Kawhatau soils (Plate 6.10). In the middle distance a complex of Taihape and Whangaehu steepland soils occur on the sedimentary hill country, with Kiwitea soils in the deep loess on the surface of the older, higher terraces.

Plate 6.3

Hill country in the mid-Rangitikei valley, looking north-east from above Omatane to the Ruahine and Mokai Patea Ranges. The sedimentary rocks have been eroded to similar slope angles and summit heights. Turakina and Pahiatua steepland soils in siltstone/mudstone are the most widespread soils in this landscape; they are among the more stable of the steepland soils under pasture in the east Taranaki-Wanganui-Rangitikei hill country.
The soils of this large area of hill country are a complex mixture; some have formed in the sedimentary rock weathered in situ, others in the erosion debris and the remaining shallow soils on the more recent bare rock erosion scars. They are similar to the steepland and hill soils described in Chapter 4, for this area is just an eastern extension of the east Taranaki-Wanganui hill country. In fact, over 40 different steepland soil and hill soil mapping units have been recognised in this hill-country landscape but because of scale limitations most of the area can be shown only as one simple steepland mapping unit in Fig. 1.6a.

Pastoral farming is the almost universal land use, and travellers on State Highway 1 in the hill country between Mangaweka and Utiku will have observed the slumping tendency of these soils. Consequently plantings of poplars on the hills are widespread as a soil conservation measure, softening and brightening this otherwise angular and fragile landscape.

**Loess-Covered Terraces**

The older terraces of the Manawatu have been mantled with differing thicknesses of loess layers (Fig. 6.1). However, just as only the most recent tephras are soil forming (Fig. 2.4), so too, only the youngest of the loess deposits are the parent materials of the present-day soils. The most important is the Ohakea loess (deposited 25,000 – 12,000 years ago), and a good insight into the rate at which it was deposited is provided through the fortuitous presence of a time marker – the Aokautere Ash* (a portion of the Kawakawa Tephra which erupted 20,000 years ago from the Taupo Volcanic Centre). During the next 8000 or so years, 1 – 3 m of loess were deposited above this marker, the thickest, coarsest deposits being on the immediate leeward side of the river floodplains, as illustrated in Fig. 6.2.

* The Aokautere Ash is so named because it was first noticed in Ohakea loess near Aokautere on the eastern bank of the Manawatu River near Palmerston North.
Plate 6.4
The Manawatu River floodplain, river flats and terraces, looking east from Palmerston North city across Aokautere to the northern end of the Tararua Range. Horticulture is established on the free-draining, fertile Manawatu soils of the river flats although large areas of these versatile soils have been lost to urban expansion on the western bank of the river. Beyond the fans (Ohakea soils), the uplifted marine terraces (Tokomaru soils) step upwards to the rolling summits of the range where the climate is wetter and relatively deep, friable, Ramihia soils have developed in loess mixed with some tephra.

Plate 6.5
The deeply dissected uplifted marine terrace surface of the Tokomaru soil landscape is highlighted in this early morning photograph, looking across the Manawatu floodplain from the foothills just south of Shannon; Mount Ruapehu is faintly visible in the left distance. The agricultural management of this landscape poses some problems because of the sharp changes in topography. The flat tops of the interfluves (Tokomaru soils) are easiest for pasture and stock management, while there is a tendency towards reversion to scrub on the shady, steep terrace scarps (Halcombe hill and Raumai hill soils).
The Tokomaru soils have formed on the high terraces on the south-eastern (lee) margins of the Rangitikei and Manawatu Rivers (Plates 6.4 and 6.5) where the loess is thicker and coarser (Fig. 6.2). The photograph shows the dense grey soil morphology of a mottled, veined, and clay-rich Btg horizon (50–80 cm) above large columns of the tragipan (Ctg) developed in the relatively unaltered loess parent material. These subsoil columns are separated by deep cracks ('gammate' veins), the tops of which open up during dry periods. Soil material is washed down into these cracks and subsequently gleyed to produce grey colours which can extend to a depth of over 250 cm down the profile. The mottled nature of the Btg horizon indicates its 'pseudo-gley' nature, i.e. moisture perches above the compact lower subsoil during wet periods. Alternating reducing/oxidising conditions prevail because of seasonal moisture changes.

The Marton soils have formed in the finer-textured loess away from the margins of the major rivers. They are the most widespread loess soils in the Manawatu region (Plate 6.1). They are more strongly gleyed than the Tokomaru soils (Plate 6.6) and the compact horizon at 70–90 cm depth appears to be undergoing disintegration, with more pronounced grey veins and mottling. Whereas the Tokomaru soils have a high content of the primary clay, mica, this is absent from the Marton soils which contain significant amounts of halloysite. Compared with the Tokomaru soils, there is a thinner layer of Ohakea loess above the Aokautere Ash (visible as the orange-mottled band at 60 cm).

The distinctive Tokomaru soils (Plate 6.6) have developed in this deep, coarser loess closer to the river source, particularly on the high terraces on the eastern side of the Manawatu River (Plates 6.4 and 6.5); here the Aokautere Ash is deep in the profile (around 2 m). The morphology is quite striking, consisting of a relatively clay-rich mottled horizon above an impermeable fragipan of relatively unaltered silty loessial material which has cracked to form vertical columns (Plate 6.6). The associated Milson soils are formed where the loess cover is thinner
or barley, 4 to 10 tonnes ha of dry peas). The Rangitikei potato industry is based on Tokomaru soils. Their allophane content is not as high as the Dannevirke soils, which are more similar to the Levin soils than they are to the loessial soils in the short time of less than 20 000 years. Consequently, there has been speculation that the high content of the amorphous allophane clay in the Dannevirke and related Kiwitea soils indicates that their parent materials contained a higher proportion of tephras. Another possible explanation is climatic. The dense grey soils probably developed in a summer-dry environment where soil moisture deficits may have caused progressive shrinkage and an increase in the bulk density of their subsoils. In contrast, the Dannevirke soils did not experience any pronounced summer drought and the iron which weathered out under these oxidising conditions became dispersed uniformly throughout the profile and conferred their good physical structure.

A similar soil transition occurs on the loess-covered terraces of the Horowhenua district in the south of the region. Here the Tokomaru soils on the dissected terraces to the south-east of the Manawatu River gradually merge with the Levin soils as the rainfall increases and summer soil-moisture deficits become less pronounced. The Levin soils are more similar to the Dannevirke soils than they are to the Tokomaru soils. Their allophane content is not as high as the Dannevirke soils, neither is their phosphate retention, but they do have friable topsoils and lack a fragipan.

In recent years higher transport costs from South Island croplands have stimulated a lot of interest in intensifying cropping on the loess soils of the Manawatu. The dense grey soils are very susceptible to structural breakdown with prolonged cropping, and sustainable use involves strict crop rotation, e.g. two years in cereals, one year in peas, followed by four to five years in pasture to allow recovery of structural properties. Yields are moderate (5.5 tonnes/ha of wheat or barley, 4 tonnes/ha of dry peas). The Rangitikei potato industry is based on the friable Dannevirke soils and yields are of the order of 20 tonnes/ha. Most processing is carried out in local factories (potatoes and other vegetables at Feilding and melting barley at Marton).

The Levin soils are horticulturally important, for the Horowhenua supplies Wellington with fresh berry fruit (strawberries, black currants and boysenberries), flowers and vegetables. Also, dairying on these soils is now the major source of Wellington's milk supply.
Plate 6.9

View south across the Hautere Plains (a remnant of the youngest cold-climate floodplain) to the southern end of the Tararua Range, from above the Otaki River. Berry fruit and kiwifruit orchards have been established on the pockets of alluvial silts, coastal sands and peat in the foreground. Further inland, the stony nature of the Ashhurst soils (Plate 6.10) is indicated by the groves of totara trees remaining from the original indigenous vegetation.

Plate 6.10

Stony soils are a feature of cold-climate floodplains and river terraces flanking both sides of the Ruahine-Tararua axial ranges. Greywacke boulders and gravels are common at all depths in the profile. Topsoils are friable, brown, silt loams over yellowish-brown, friable to loose, B horizons.

These stony terrace soils can be distinguished by their degree of leaching and depth of loess/fine alluvium over the gravels. In the Manawatu and Horowhenua they are known as Kawhatau and Ashhurst soils; Takapa soils in southern Hawke's Bay and Wairarapa (Plate 7.9); and Heretaunga soils in the Wellington region.

Stony River Terraces

The youngest of the cold-climate floodplains (Fig. 6.1) did not receive any significant loess mantle during the last 12,000 years and today these surfaces are represented by widespread stony plains at Ohakea-Bulls, Feilding-Cheltenham, Palmerston North-Ashhurst, Ohau near Levin and the Hautere Plains between Otaki and Te Horo (Plate 6.9). This surface is also represented by the stony terraces of intermediate height flanking the major rivers such as the Rangitikei, Oroua, and Pohangina.

Although the stony soils on this surface (Plate 6.10) have different names (Kawhatau and Ashhurst) because of minor differences in morphology, both are moderately leached (the shallow, stony nature enhances the passage of the rainfall through the matrix of finer material). They are rapidly drained, tend to dry out in summer and have a medium level of nutrients. Cropping is difficult because of the stoniness but they are very suitable for intensive sheep farming and some local dairying. Some of these soils are being used, with irrigation, for berry fruit and kiwifruit, which do not require cultivation.

In the higher rainfall areas (1300–1800 mm), deeper Kopua soils occur on these stony river terraces (Fig. 6.2), particularly around Apiti in the upper Oroua valley. They are suitable for the grazing of beef cattle as well as for intensive sheep farming. The Kopua soils have the same volcanic loam properties as the Dannevirke soils – very high phosphate retention and high amorphous iron and aluminium. As with the loess soils, this does not necessarily mean that the Kopua soils have a higher content of volcanic ash. Rather, they are another example of non-volcanic soils which seem to form allophane under conditions of high leaching and acidity.

Shallow and stony soils are a very important feature of the landscape in other central and southern parts of New Zealand – Hawke's Bay and Wairarapa, the Canterbury Plains and MacKenzie Basin, and Central Otago. Because they are so extensive on the Canterbury Plains they are described in more detail as a group, stony terrace soils, in Chapter 12.
Holocene Floodplains

Whereas the Rangitikei River has only a narrow strip of river flats with predominantly sandy and stony soils, the lower Manawatu and Oroua Rivers have built up an extensive floodplain (Fig. 6.1) with a wide range of deep, fine-textured, alluvial and organic soils, during the last 12,000 years.

The Rangitikei soils are sandy-textured recent alluvial soils (see Chapter 7) on the lowest flats bordering the main rivers (Plate 6.2, Fig. 6.2). They are rapidly draining, low in organic matter and subject to flooding. At a slightly higher level on the broader levees, the soils have developed in alluvium which is less susceptible to flooding. These Manawatu soils are deep, with such good internal drainage and friability that they can be worked in all seasons. They are the most versatile soils in the district and are suitable for market gardening, horticulture, cropping and dairying. Unfortunately large areas of Manawatu soils have been lost to urban expansion (Plate 6.4).

The most common soils on the Manawatu Plains are gleyed recent alluvial soils and gley soils (see Chapter 3), of which the Kairanga and Te Arakura soils are the most extensive (around 20,000 ha). The Kairanga soils (Plate 6.11) are seldom flooded, have quite a high level of nutrients, but are poorly drained and require artificial drainage. In the lower part of the Manawatu floodplain near Shannon and the Moutoa floodway, the river becomes very sinuous (Plate 6.12) and the gleyed soils grade into organic Opiki and Makerua soils. These are important market-gardening soils for the lower Manawatu and Horowhenua districts. Drainage led to problems initially; the ground level dropped by as much as 2 m in some areas and the peaty topsoils were difficult to rewet after they had dried out. Cropping and regular cultivation have tended to concentrate the mineral portion of the soil and efforts are now made to keep the water table high enough to stop the soils drying out.

The Makerua soils of the lower Manawatu Plains once supported thousands of hectares of flax/raupō swamp. The town of Foxton became one of the most important centres of an early New Zealand export industry – the milling of flax leaves and their conversion into woolpacks, rope, floor-coverings and padding fibre for upholstery (Plate 6.12).
Sand Country

The sand country of the west coast of the lower half of the North Island is the largest area of coastal sands in New Zealand. Extending 200 km from Patea in southern Taranaki to Paekakariki north of Wellington, this complex of sand dunes, sandy plains, peat swamps and lakes covers nearly 100 000 ha and is at its widest extent (15–20 km) in the Manawatu. Apart from its extent, the remarkable feature of the Manawatu sand country is the alignment of the dunes with the prevailing wind — not parallel with the coast as is usually the case in other coastal regions (see Plate 11.16, the Waita dunes in South Westland). These longitudinal or windrift dunes have a raised apex and parallel tails upwind of the apex, giving them a characteristic elongated shape variously described as 'hairpin', 'canoe', or 'parabolic' (Plate 6.13 and Fig. 6.3).

The dunes appear to have formed in four distinct phases (Fig. 6.1):

- Foxton phase (2000–3000 years ago);
- Motuiti phase (500 years ago);
- Waitarere phase (100 years ago); and
- Forerunes and unconsolidated dunes (presently forming).

The changes in profile morphology with the increasing age of the dune soils can be illustrated by comparing the young Waitarere soil profile (Plate 6.14) with the

Plate 6.13

These sand dunes, south-east of Tangimoana near the mouth of the Rangitikei River, belong to the Foxton dune-building phase. The dunes are oriented to the prevailing west-northwest wind and exhibit the characteristic 'canoe' shape, with Foxton soils on the apex and a mixture of the slower-draining Carnarvon, Awahou, and Omanuka soils on the sand plains and peaty hollows between the wings of the dune (Fig. 6.3). Woodlots of exotic trees are a very appropriate use of the dune soils and large plantations — Santoft and Waitarere State Forests — have been established on the less stable dune phases closer to the coast.

Fig. 6.3

Diagram of Manawatu sand-country landscape unit — dune apex and wings, sand plain and peat swamp. Soils shown are for Foxton dune-building phase.
older Foxton soil profile (Plate 6.15). The Waitarere soil shows very little modification of the sand except for the darkening of the top few centimetres with organic matter; the Foxton soil has developed a deep, dark topsoil and a coloured B horizon in the 2000–3000 years since the sand parent material was stabilised. The Foxton soil also has a higher clay content and greater ability to hold plant nutrients.

The dune itself is only one feature of the sand-country landscape, however; the typical landform unit has a sand plain behind the dune, sloping back to a peaty swamp or lake where the water table is at the ground surface (Fig. 6.3). Different soils occur on the different facets of this sand-country landscape, in this respect recalling the complex soil pattern of the lahar landscape of western Taranaki (Chapter 4). Although they occur on landforms of different age and topography, all these sand-country soils are similar in their origins, their youthfulness, and their sandy textures. They are therefore grouped together as coastal sands (see p. 111) in Fig. 1.6a.

The Manawatu sand country offers many land-use challenges. The threat of wind erosion requires constant care in land management. Plantation forestry in Sandtoft and Waiterere State Forests has proven very successful, both as a productive, and a protective, use of the younger, less stable sand-country soils.

There is scope for more integrated uses of the sand country because of the wide differences in plant productivity of the different soils. For example, the three soils formed on different landscape facets of the Motuiti dune-building phase have very different annual dry-matter pasture production levels, namely Motuiti soils (sand dune) up to 2000 kg/ha; Himatangi soils (dry sand plain) up to 5000 kg/ha; and Pupepuke soils (wet sand plain) 7000–12 000 kg/ha. Woodlots would be a more productive use of the Motuiti soils and there is scope for some horticultural use of the better mineral and organic soils on the sand plains. The coastal climate in the more temperate regions of New Zealand is distinctly warmer and sunnier than the hinterland (see Fig. 14.3), although wind and salt spray are disadvantages. Irrigation would be necessary along with shelter but this cost would be balanced by lower land prices, the ability to drill seeds during winter, and the earlier warming of these sandy soils during spring. To date, commercial crops of vegetables such as asparagus, melons and carrots have been successfully grown in the Manawatu-Horowhenua sand country.

Plate 6.14 (far left)
The Waitarere soils occur on the dunes of the Waitarere dune-building phase (Fig. 6.1). They are very young (100 years) and show virtually no modification of the grey, quartzofeldspathic sand parent material, except for the darkening of the top 2–3 cm with organic matter. Waitarere soils are unconsolidated, drought-prone and liable to severe wind erosion if their vegetation is disturbed. Pasture establishment is difficult and they are recommended for forestry use (both protection and production), recreation and other conservation uses.

Plate 6.15 (left)
The Foxton soils are much more developed than the Waitarere soils, with a deep, black A horizon over a yellow-brown to olive-brown Bw horizon. They are very suitable for dairying and other pastoral purposes when used in association with the Awahou and Carnarvon soils of the sand plains (Fig. 6.3), although care is needed to avoid wind erosion if the topsoil is exposed by stock trampling.
Distinguishing features of dense grey soils

PARENT MATERIALS AND LOCATION – dense grey soils are formed from silt-sized, siliceous parent materials, typically quartzose-feldspathic loess, alluvium, and colluvium derived from sedimentary rocks. They are found in eight regions: Manawatu, Hawke’s Bay and Wairarapa in the North Island, and Marlborough, Canterbury, North Otago, Central Otago and South Otago/Southland. They are known as ‘yellow-grey earths’ in the New Zealand Soil Classification (see Appendix).

CLIMATE – the climatic environment of dense grey soils is a pronounced summer dry season and a relatively low annual rainfall (600–1150 mm).

PROFILE CHARACTERISTICS
- pale yellowish-grey coloured, compact, and weakly structured subsoil;
- fragipan or related massive horizon occurs in the top of the parent material (Cx horizon). This horizon is traversed by grey veins, called ‘gammations’ because of their resemblance to the Greek letter gamma (γ). These veins descend deep into the loess parent material, which cracks during dry periods and develops a columnar structure;
- pseudo-gley features – a mottled Btg horizon above the impermeable fragipan indicating periodic waterlogging through perching of surface water.

TEXTURES – dominantly silty loam; clay content low, usually 12–35%.

STRUCTURES – weakly to moderately developed crumb or nut in topsoils; subsoils coarse blocky (Bt) to prismatic (Cs).

CONSISTENCE – friable in topsoils but firm to compact in subsoils.

BULK DENSITIES – medium in the topsoils and Bt horizons (1.0–1.3 T/m³) but high (1.5–1.9 T/m³) in the fragipan.

PLANT-AVAILABLE WATER CAPACITY – medium to high in topsoils (18–30% of soil volume); low in subsoils (8–14% of soil volume).

POORLY DRAINED – subsoils have low macroporosity (5–6%) with the values for the fragipan being as low as 2–3%; many topsoils are freer draining (macroporosity, 10–15%).

CLAY MINERALS – vary with the parent material and weathering environment:
- vermiculite is common (as are the primary clay minerals, mica and chlorite) in the weakly weathered dense grey soils of Otago;
- halloysite and kaolinite are present in some moderately leached North Island dense grey soils (e.g. Matapiro, in Hawke’s Bay) where volcanic ash may be a significant component of the profile;
- The content of free iron oxides and amorphous clays is low. Consequently retention of phosphate is low (10–30%).

SOIL CHEMISTRY – medium to high nutrient content, with plentiful levels of magnesium. Organic matter is generally low, as is available sulphur.

SUSCEPTIBILITY TO EROSION – structurally unstable and erosion prone under cultivation. Organic matter appears to be critical in maintaining soil-aggregate stability. Hill soils in loess parent materials are particularly susceptible to tunnel-gully erosion (e.g. Wither Hills soils, Plate 7.15).

USES OF DENSE GREY SOILS

Dense grey soils are well suited for both pastoral and mixed cropping uses. However, because they have weakly structured topsoils, continuous cultivation can lead to severe sheet and wind erosion. Crop/pasture rotation and contour ploughing are recommended techniques for minimising this tendency. Since drainage is impeded by the fragipan, the soil surface can become pugged during the wet season; the growth of rushes in pastures is an associated problem. Tile drainage is generally a reliable remedy for this slow subsoil drainage. The dense fragipan also limits root penetration by deeper-rooting plants.

Dense grey soils benefit from phosphate and lime application. Potassium fertilisers are necessary only where farming is intensive, but local deficiencies of sulphur, molybdenum and selenium are known, especially in the South Island.
Distinguishing features of coastal sands

PARENT MATERIALS AND LOCATION – Coastal sands are formed from a wide variety of sand-sized mineral grains derived from the breakdown of parent rocks and their transportation to the coastal regions. Quartz, which is more resistant to weathering, is the most common sand mineral, particularly in areas dominated by greywacke or granite rocks; the coastal sands of the west coast of the North Island between the Wanganui River and the Manukau Harbour are dominated by the heavy ferromagnesian minerals (especially augite, hornblende, titanomagnetite and ilmenite) of volcanic origin. The concentration of iron- and titanium-rich minerals in these ‘ironsands’ is high enough for them to be mined as ores.

The coastal sand soils cover an area of 250 000 ha throughout New Zealand. They are particularly important in the Manawatu and in Northland and also make up significant areas in the Bay of Plenty and North Canterbury.

PROFILE CHARACTERISTICS
- shallow A horizon over parent material (C horizon) in younger soils (Plate 6.14);
- deep A horizon (25 –30 cm) over yellow-brown or yellow-grey Bw horizon in older soils (Plate 6.15).

TEXTURES – sandy and loamy sand; clay content very low, generally 1 –8%; some of the more weathered, coastal sands of Northland have 10 –20% clay.

STRUCTURES – weakly developed crumb to granular in topsoils; free sand grains beneath.

CONSISTENCE – loose to friable.

BULK DENSITIES – medium in topsoils (1.0 –1.1 T/m³) but high in subsoils (1.3 –1.6 T/m³).

PLANT-AVAILABLE WATER CAPACITY – medium in topsoils (16 – 20% of soil volume) but low in subsoils (3 – 9% of soil volume); thus the coastal sands are droughty soils because of the inability of their subsoils to retain moisture.

RAPIDLY DRAINED – some soils are excessively drained (macroporosity 20 –30%) but most dune soils drain rapidly (macroporosity 12 –20%); drainage in the soils of the lower parts of the sand plains is much slower.

SOIL CHEMISTRY – variable, but most soils low in organic matter, phosphorus and potassium; low capacity for nutrient retention. Phosphate retention low (0 –30%) in the poorly drained sand plain soils (where amorphous iron oxides are probably responsible).

SUSCEPTIBILITY TO EROSION – because of their very weak structure and their exposure to coastal winds these soils are extremely susceptible to wind erosion if their vegetation is disturbed. Most of the indigenous vegetation of the sand country has long since been destroyed and introduced plants such as marram grass, lupin and kikuyu grass are important in preventing erosion.

USES OF COASTAL SANDS
Coastal sands have a number of severe limitations, especially summer drought and potential for wind erosion. Traditional uses are pastoral but large areas of erosion-prone soils have been established in exotic tree plantations. Further from the coastline, there is probably scope for an interesting mix of productive uses – forestry on the dune soils, pastoral farming on the drier sand plains and market gardening or other forms of horticulture on the better mineral and organic soils of the sand plains.