COASTAL SAND DEPOSITS — NORTH-WESTERN NORTH ISLAND

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INTRODUCTION

Coastal sands, of Quaternary age, cover extensive areas of land within a few miles of the west coast of the North Island, from Kawhia Harbour for as far north as Cape Maria van Diemen. The width of these areas is variable. Whereas sand may be wholly absent in high, rugged, rocky localities, it is commonly present in a coastal strip that ranges from 1 to 10 miles in width and extends from one side of the North Island to the other in the Ninety Mile Beach district.

These coastal sand deposits have many interesting aspects. Economically, they include the most extensive of New Zealand's iron ore resources, and they provide sand for the building industry; but, on the other hand, they represent a threat to farm lands wherever dunes are actively advancing inland. Scientifically, they present a most interesting record of sea level and climatic fluctuations during the Pleistocene Period, and they give less certain evidence of volcanic eruptions. Many areas are geologically too young to have developed an adequate soil cover and they are therefore of little use to the farmer. Others are older, support reasonable soil, and are extensively farmed.

From a forester's point of view, the sand areas represent a challenge as a place to grow trees. The success of the project of growing trees to halt the advance of drifting ironsand dunes near Waiuku, has come very much to the notice of geologists in recent years in their work in relation to a proposed steel industry. Because that sand area is far from homogeneous, different tree-growth responses should be expected in different parts of that forest owing to changes in age, thickness, elevation, volcanic ash cover, soil thickness, clay content, and physical and chemical properties of the sand grains. The present paper attempts to describe briefly the importance of these variables, after referring to the form and origin of the sands, for the whole region of coastal sand deposits from Kawhia to Ninety Mile Beach. These deposits show far more variation than can be expected at Waiuku alone.

It is perhaps necessary, initially, to state a geologist's definition of a "mineral" and of a "rock", because these may differ from those of a forester. A mineral is a naturally-occurring chemical compound, and, therefore, has a constant chemical formula. Its analysis will be the same regardless of its origin in the world, and its crystal form, its hardness, its specific gravity, and even, sometimes, its colour are unchanging. Magnetite, a naturally occurring iron oxide, for example, is identical from Canada, India or New Zealand. A rock, on the other hand, is a naturally occurring mixture of minerals, and one sample of limestone from Te Kuiti will always be slightly different from another sample, even if the latter were collected only a few inches away. It will certainly be very different from limestone in the South Island of New Zealand, or in Europe. Rocks

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are not necessarily hard, and a geologist will refer to a loose dune sand as a rock.

FORM AND ORIGIN

Mechanism of Deposition

Most coastal sands are deposited by wind action. Sand grains are blown inland off the beaches and accumulate in dunes which commonly have an average height of the order of 30 ft. It seems unusual for individual dunes to be as much as 100 ft in height, although dune sand deposits, consisting of many separate dunes, can rise considerably higher than this — over 900 ft at Manukau South Head, for example. In any such accumulations, there will be evidence of many periods of dune formation, separated by periods when vegetation covered the sand completely and fixed it in position, followed by further periods of dune formation at a higher level.

Sand dunes have a variety of forms, which need not be described here. It will suffice to state that the wind direction can usually be deduced from them, although the type may be transverse, longitudinal or lunate; and that the advancing front is usually steep, where the sand grains fall under gravity. This steepness is reflected in steep bedding planes in dune sand deposits.

A smaller, but very significant, part of the coastal sand has been deposited by water, rather than by wind. It differs from the wind-deposited material in having more or less horizontal bedding, as opposed to the steep dips in beds of dune origin, and including common thin blacksand beds that may be extremely rich, as are the sands of many present beaches where nearly 100% of the grains may be of various black iron oxide minerals. Water-laid sands are most common on beaches, and along low river terraces and tidal flats.

In some environments, such as sand spits, the agencies of wind and water come very closely together, and it may be difficult to assess whether a particular sand grain was deposited by wind or by water. The same problem arises with the interpretation of older deposits.

Origin of Sand

Sand simply comprises those fragments, resulting from the chemical and mechanical breakdown of rocks, that range in size from 0.1 to 1 mm. Material of such a size can be transported readily by sea or wind. If its transport is rapid, and over only a short distance, the fragments will remain angular, and will consist of actual fragments of broken rock. If the distance travelled and time taken are greater, individual particles will be much more rounded, and they will consist predominantly or wholly of those materials that are most resistant to mechanical and chemical attack, such as quartz or titanomagnetite.

In any one sand deposit, the individual grains may have a variety of separate origins. The most obvious is, perhaps, from the nearby headlands along the coast. Wave action erodes the cliffs and causes large blocks to fall into the sea, where they are slowly broken down by being ground, one against the other, to produce small sand fragments. This sand is then washed up on to nearby beaches. Sand is, of course, a natural product in those common areas where the cliffs have been cut in pre-existing sand deposits of, for example, an earlier cycle of dune formation.

The harder and chemically more resistant minerals may survive for a long time on the beaches, and on the coastal sea bed. They may, therefore, be transported for considerable distances by long-shore currents. There is good reason to believe that most of the ironsand north of Kawhia was originally derived from Mt. Egmont and its nearby ancestors, and from similar long-extinct volcanoes as far north as Kawhia Harbour, with only relatively small amounts from the Waitakere Hills. Sand from these volcanic rocks has drifted as far north as Kaipara Harbour, a total distance of 200 miles.

Although many rivers draining into the Tasman Sea are small, and carry only mud as sediment under normal conditions, others transport sand. The Waikato River, in particular, carries vast quantities of sand to the sea from the Central Volcanic Region. The sand is composed largely of grains of the minerals quartz and feldspar, and fragments of a variety of different volcanic rocks, including rhyolite pumice, obsidian and andesite. There are smaller amounts (5 to 10%) of dark minerals — iron ores, and a series of iron- and magnesium-bearing minerals that are collectively termed "ferromagnesians".

In addition to these three main origins (local headlands, coastal drift, and river sediment), material may also be transported to the sea by unusual agencies, such as volcanic ash showers, lahars (mud-flows), and human activity.

VARIATIONS IN SAND DEPOSITS

General

From a forester's point of view, sand is important in that it is the parent material from which the soils of the coastal areas are formed. Differences in soils will therefore reflect those variations in sand deposits that are discussed below.

Any variations that might be due to local variations of present climate, or to the climatic effects of changing latitude, are neglected here.

Physical Properties

In their original condition, most sands were presumably comparatively similar. Those near rocky headlands would have tended to be coarser and more angular than those further away. Permeability would have been so high, and drainage so good in all localities, however, that neither property would have differed by amounts that were significant to a forester. Since the older sands were formed, however, weathering has yielded large quantities of clay which must have reduced both the permeability and drainage. This factor is essentially one of age and is considered further below.

Composition of Sand Grains

Although detailed work is only just beginning on the composition of these sands, a few factors are already clear. Regional differences can be noted because of the differences in the origin of the sands that have been noted above. Rocky headlands supply fine fragments from a wide variety of sedimentary and volcanic rocks. Some rocks may also release minerals that are therefore restricted to those lengths of coastline where the rocks occur. Ilmenite, for example, has been reported only from deposits north of the Waikato River mouth (Nicholson and Fyfe, 1958), presumably because it is either derived from Waikato River sand or from the coastal andesite cliffs of the Waitakeres.

Many minerals have been recorded — quartz and feldspar in major quantities, iron and titanium oxides, various ferromagnesians, and zircon — along with shell and even wood fragments. The mineral titanomagnetite, the major ironsand constituent, has the most known of its distribution. Nicholson and Fyfe (1958) recorded the titanomagnetite percentage in young coastal sands from New Plymouth to Kaipara and this work has been extended in recent investigations by the writer for the N.Z. Steel Investigating Co. Titanomagnetite contents have been shown to be highly variable — from a few per cent. up to over 80% in sands of different ages, and the grains have been shown to be both smaller and more rounded than the other sand particles — implying prolonged transport.

Considerable research remains to be done before local variations in the composition of individual sands are well known. It is strongly suspected, however, that, apart from changes in the denser minerals, the composition of an individual sand formation is relatively constant over areas of the size of a potential forest, and local differences will be expected only in sands of different ages. The effects of age are discussed further below. Differences in concentrations of denser minerals are due to one of two effects. The first is the riffle-like concentration that occurs beyond rocky headlands in the direction of longshore drift. Many examples are known, perhaps the best being at Muriwai where Nicholson and Fyfe's (1958: Fig. 11) work, and later results, have shown a steady decrease in titanomagnetite content from about 30% near the headland to ½% five miles up the coast. The second effect is due to the fact that the denser minerals also tend to be the most resistant, and therefore to have lasted the longest and to be the most rounded. Good rounding enables the grains to be picked up more readily by the wind, and thus to become relatively more concentrated inland. Such an effect has been noted at Raglan, where the order of concentration of titanomagnetite increases from 5 to 25% inland.

The effect of sand grain composition on soils may therefore be summarized by stating that variations will occur regionally because of differences of source, but in any one district they may be considered as another function of age. There may, however, be gradual changes in composition of denser minerals that occur either longitudinally or tranversely to the coastline.

Age

Of all factors that cause variations in sand deposits, age has perhaps the greatest effect. It has a direct effect in that different sources of sand would have been available at different times in the past. Many indirect effects are of even greater importance, however, because continuing geological processes have been affecting the sands ever since they were deposited, and the older the sand, the more intense the change. Those that are considered separately below are the degrees of erosion and of weathering, and the thicknesses of soil and of ash cover.

The oldest sands date from the Pliocene Period of geological time, and others extend through the Pleistocene into the Holocene. During the Pleistocene, there were very considerable fluctuations of sea level as more or less sea water became trapped in the polar ice caps during colder times, and was released again to the oceans during warmer times. Differences of sea level of many hundreds of feet seem likely to have occurred. The consequences of this effect are considered further below.

The ages of the sands are not known in very great detail, beyond the certain fact that they are Pliocene-Holocene. Estimates of age have been attempted from the supposed sequence of sea levels, and from a study of the beds of pumice and peat that occur within the sands themselves. The pumice can be related to eruptions, largely early in the Pleistocene, and the peat beds yield identifiable leaves, seeds, wood, spores and pollen grains, which enable both an estimate of age and an interpretation of past climate.

Sea Level Changes

As sea level fell during each of the several glaciations of the Pleistocene, large areas of sandy sea bed would have become exposed. This sand, unwetted by the tides, would have been blown inland readily. Thus the periods of time at the onset of a glaciation must have been those when dune formation was at its most intense. On the other hand, as the climate became warmer, ice melted, sea level rose, and sand deposition must have been mainly by water. At times of relatively constant sea level, either dune formation or water deposition would have been possible, and both could have occurred in adjacent areas.

These variations of sea level are responsible for the fact that some dune sands occur well below sea level, and some water-laid sands are now found high above present sea level. Throughout much of the western coastal area, for example, titanomagnetite-rich beds, that were probably formed on a beach, are found at heights of 500 ft and more above the sea, and the richest sand beds of the Waiuku State Forest were deposited when sea level was 110 to 130 ft higher than at present.

When sea level remained constant for a considerable period of time, relatively flat areas must have been formed near the coast — like those that exist now in and around the large Kawhia, Manukau and Kaipara harbours. When sea level subsequently fell, these flat areas would have been preserved as high level terraces. Such terraces and their eroded remnants have been studied in many places (*e.g.*, Brothers, 1954; Kear and Waterhouse, 1961), and the levels at which they occur have been correlated with similar levels known in Europe. The most widespread of these appear to be at 550, 350, 220, 110–130, 45–75, 25, 10, 6, and 2 ft above present sea level. The highest of these levels are the oldest, and it is a very broad generalization that sands at higher levels are older than those at lower levels, although many exceptions occur where sand dunes climb several hundreds of feet to overtop hills in older deposits.

Degree of Erosion

Erosion continually affects all rocks, and must be particularly severe during glaciations when the combination of cold climate and low sea level apply. Recognizable dune form seldom remains in sands that are older than the formation of the 75 ft terrace level, and perfectly flat areas of ground are seldom found on the surface of deposits older than the 110 ft level. The oldest deposits are eroded into extremely steep topographic forms, which are stable only because of their considerable clay content.

Degree of Weathering

Rain water picks up carbonic acid from the air and humic acids from the soil. These act upon those sand grains that are not resistant to chemical attack, and, in particular, on rock fragments and on feldspar and ferromagnesian minerals. The most obvious products are iron oxides and clay, the former staining the sands yellow and brown, and the latter binding the grains together. The older the sands, the greater the depth of weathering and clay formation. Typical depths are over 100 ft for sands older than the formation of the 110 to 130 ft terrace, 30 to 40 ft for sands of that age, 15 ft for sands formed at or slightly after the formation of the 25 ft terrace, and 0 ft for Holocene dunes.

One interesting effect of clay formation is that it allows lakes to form, because of an impermeable surface layer, Lakes commonly occur immediately inland of drifting dunes, where they are actively covering older clayey deposits.

Depth of Soil

Modern sands have no soil upon them and the Waiuku State Forest was planted, of course, with a view to arresting the extension of loose sands on to agricultural lands. With increasing age, however, there has been more and more time for soil formation, and, soil thicknesses, like clay thicknesses increase.

In some areas, soil formation is attended by a consolidation of the sand immediately below. Although the resulting rock cannot be described as hard, and is readily broken by the fingers, it is sufficiently resistant to stand naturally as prominent low bluffs.

The availability of plant nutrients depends to a great extent upon the degree of weathering, and therefore upon the age of the sand. Sands of Holocene age do not generally have sufficient soil cover to allow the establishment of more than coastal scrub under natural conditions. They are seldom grassed, and attempts to grass them have commonly led to a recommencement of dune activity, in the form of blow-outs at the site of grassing, and dune-formation further inland.

The oldest soils have had ample time to become impoverished in important nutrients, so that, after an initial improvement with age, a deterioration of fertility with further age must be expected.

Ash Cover

Volcanic ash is an important parent material of soils in the North Island. Although the areas of coastal sand are largely down-wind of those regions that have been most productive of volcanic ash, ash does cover the less steep surfaces of the older deposits, particularly those older than the formation of the 110 to 130 ft level. In such cases, the soil has the characteristics of the ash, and not of the sand.

Thickness and Other Formations

The thickness of a sand formation is immaterial, except where it is so thin that plant roots can penetrate into an older formation below. There are many instances, however, where remnants of only partly-buried hills project through the sands, and may cause the presence of unexpected soil types in the midst of those formed from sand formations.

CONCLUSIONS

The sand deposits of the western coastal area of the north-west of the North Island comprise a complex of formations that occupy a coastal belt up to 10 miles in width. Variations in soil can be related to variations in the parent sand formations. Formations differ from one district to another because of different sources for the sand grains, the most important of which are the rocky headlands, longshore drift, and river sediment. In any one district, the important differences are largely of age. The older sands were formed during a period of fluctuating sea levels, with dune formation during periods of falling sea level, and deposition from water during periods of rising sea level. The older deposits: (1) are related to the higher terrace levels; (2) are eroded to the greatest degree, such that no dune form or flat surface remains on the oldest of them; (3) are weathered most deeply, such that secondary clay occurs in the sand to depths ranging from 0 ft in the youngest to over 100 ft in the oldest; (4) have the thickest soil cover, with an initial improvement in fertility followed by a subsequent reduction; and (5) have the thickest cover of volcanic ash.

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