II. GEOLOGY.

(A.) GENERAL REMARKS.

In contradistinction to the infinite slowness which generally marks the evolution of land-forms that of those of the dune area is sufficiently rapid to be witnessed by an observer in a limited time. A certain definite series of changes can be recognised, leading to a fixed goal, while at the same time a somewhat similar retrogression is in progress. Thus forms resembling one another may be fashioned by growth, or by decay.

Hand-in-hand with the building of dunes under natural conditions goes their occupation by plants, these assisting in various ways to hold the loose substratum in position, and so keep the hills intact. Such vary from extremely unstable to quite firm structures, on which the erosive power of the wind has no effect. But such stability is at the present time the exception rather than the rule, a dune area being for the most part made up of bare stretches of sand, protected by a very scanty plant-covering, and liable to be displaced by the wind. Moreover, man, with his introduced grazing animals, fires, and methods of cultivation, has further assisted to upset the equilibrium of the dunes, rendering them still more desert-like.

A general knowledge of the changes and their causes is evidently an essential fundamental towards any scheme for dune-fixing—that is, for modifying the process of Nature in a definite manner.

B. THE MATERIAL OF DUNES AND ITS ORIGIN.

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(*a.*) Origin of Dune Sand.

The formation of the sand of dunes commences on our mountain-sides, where, by the disintegrating action of frost, variations in temperature, and other causes, solid rock is broken into fragments, forming screes, and these vaster *débris* masses locally called "shingle-slips." From these the fragments pour into our rivers. During their movement seawards breaking up goes on constantly, and fine materials are also added to the load of the river from the country through which it passes. From the waste of the land, materials of all grades of fineness are thus produced, from boulders of huge dimensions down to almost impalpable powder. The term "sand" is usually restricted to these grains, varying in diameter between $\frac{1}{100}$ in. and $\frac{1}{20}$ in. However, there is no real difference as far as origin is concerned between gravel and sand, the one passing into the other by insensible gradations. There is a difference, however, in composition. Gravel is usually a collection of minerals cemented and joined together to form a mass of rock, while sand consists in general of the harder and more refractory units of that mass.

Sand is also formed by the erosive action of the sea (see Photo. No. 8). On every coast, between high and low water mark especially, wear-and-tear is constant, material is torn away from its place and reduced in size by the continual friction, as fragments are dashed against cliffs, or are rolled over one another by waves and by strong tides and currents. Sand is thus formed by the sea itself, but the sea also performs an important function in distributing it, however it has been formed. When poured into the sea by streams some of the sand helps to form aestuarine and delta deposits and shallow water marine deposits near river-mouths; but a great deal is caught by the shore-current, added to that produced by marine erosion, and carried along a narrow belt a little distance from the beach, within which the influence of the waves on the sea-bottom is distinctly felt. While moved along by the shore-current, waves and tides carry a part seawards, where it forms permanent marine deposits; they also carry a part landward, where by the aid of prevailing winds it is swept beyond reach of the sea and formed into dunes. This action is more marked during storms, for then the sea-bottom is affected to greater depth, and the shore-current is usually stronger, so that a greater load can be carried, and additions to the beach, and ultimately to the dunes, are much greater. This is especially the case when dunes are forming at the head of a bay with gently shelving beach. In fact, shoal water gradually deepening off shore seems essential to the formation of extensive dunes on an exposed coast-line. The amount of sand under those conditions capable of being moved by the waves is, then, very great, so that the supply available for dune-building is great also.

When a promontory or obstruction bars the course of the shore-current, and turns it into deeper water, the load is dropped and piled up in front of the obstruction, but usually with an intervening space kept clear by eddying currents. If, however, waves and currents are strong, they carry the finer particles round the obstruction and form a beach and its consequent sandhills in its lee. This is occurring in Caroline Bay, near Timaru. The breakwater stops the coarse gravel, but fine sand travels round the end, and is building up a beach with small dunes on the northern side of the breakwater (see Photo. No. 10).

If, however, the shore-current crosses a shallow bay it forms a spit. This is at first beneath sea-level, but it is gradually built up, and plays its part as a beach, and is finally crowned with dunes. A deep channel is usually maintained close alongside the headland towards which the spit stretches, especially when there is a tidal basin of considerable area, which fills and empties through the opening. Sometimes the opening is completely closed, and drainage is effected by percolation through the bank. Spits frequently tie islands to the mainland. Excellent examples of this can be seen at Ocean Beach, near Dunedin; at Lyell Bay, near Wellington; and far north of Auckland, where the mountain headlands from Cape Maria van Dieman to the North Cape are joined to the solid land near Mongonui by the best-developed sandspit and sand-dunes occurring in the Dominion.