

smallest advancing fastest inland. This sorting of grains is well shown in the case of the iron-sands, the black heavy grains forming the ridges and the lighter-coloured ones the hollows. Ridges of black grains an inch or more above the level of the hollow are quite common (see Photo. No. 11), and much higher ridges are formed under certain conditions, which differ little from dunes, but the former are evanescent, while the latter, owing to the greater amount of sand, can never be wholly moved during the period of any special wind. Also, dunes are generally acted on by more than one wind, and are usually more or less governed by a plant-covering.

As ripples are formed at right angles to the wind producing them, and as all further motion is arrested by even a gentle shower, they are evidently self-registering wind-gauges of the particular wind which accompanied the rain, as Jentzsch has shown (15, p. 54).

(d.) PLANTS AS DUNE-BUILDERS.

It is very rare indeed that a dune in course of formation is quite destitute of plant-life; indeed, the majority owe their progress and existence to the presence of some "sand-binding" plant, which, in the first instance having stopped the sand-drift, assists further deposits to collect, while at the same time its own growth is accelerated, it and the sand rising up together. Juvenile dunes occupied by plants are extremely common, both on the upper strand itself, on "sand-plains" within the dune area, and even on decaying hills, the pingao (*Scirpus frondosus*) and the silvery sand grass (*Spinifex hirsutus*) acting as dune-builders. Further details on this subject are given in the botanical section.

A typical dune is a hill with a long windward slope at a variable angle (frequently about 40°) and a steep leeward side which corresponds to the natural angle of rest of the particular sand out of which the dune is built, a matter depending on the form, size, specific weight, &c., of the sand-grains—e.g., the "sand-fall" of a wandering dune may be at an angle of 30° or even more. Near the summit and on the upper part of the windward slope grow sand-binding grasses and sedges, while the leeward side may also have a plant-covering or may be bare sand occasionally trickling downwards through its weight. Shrubs also may play an important part in dune building and maintaining (see Photos. Nos. 28 and 30).

It is astonishing how quite a scanty plant-covering checks the wind and adds to the stability of the dune. Even where the tufts of grass or sedge are only a foot tall, and where more than two-thirds of the surface is unprotected, it is remarkably stable.

(e.) EFFECT OF OBSTACLES.

An obstacle opposed to the sand-drift functions in different ways according to its physical state. Three main classes need mention, but they are connected by intermediates. A knowledge of the effect of obstacles is of great importance in artificial dune reclamation, for on their proper use depends the erection of suitable protection-fences, &c.

(a.) Solid Obstacles.

These are very frequent, and may consist of a piece of drift-wood, a cliff, the steep face of a dune itself, a wall of any kind, &c. The wind striking on such an obstacle is reflected, an eddy is formed, the advancing sand cannot pile up against the obstacle, but forms a heap at some distance in front (see Photos. Nos. 16 and 22). If the wall is low—e.g., a paling fence—the sand rises level with its summit, and then, beyond the reach of the circumference of the eddy, is blown over the fence, collecting on its leeward side, while contemporaneously the eddy ceases, the hollow becomes filled with sand, the fence being finally buried and forming the nucleus of a bare dune. An isolated house may have the sand heaped up not only in front but opposite its sides, owing to the lateral eddies.

The effect of such obstacles as the above are very marked in any dune area, and lead to the partial or complete burying of fixed dunes and other solid bodies and the cutting or forming of wind-troughs, &c.

(β.) Flexible Open Obstacles.

A typical and frequently observed obstacle of this class is a bunch of the pingao (*Scirpus frondosus*) or of marram grass (*Ammophila arenaria*). Here the sand is blown into the calm interior of the bunch, which it fills, but as further sand strikes from the windward it creeps over the interior sand and on the leeward side of the obstacle forms a tongue-like mass. On the stony plains between the mouths of the Wangāehu and Waitotara Rivers the long tongues of sand collected on the leeward side of the small wind-swept shrubs of *Coprosma acerosa* are very noticeable (see Photo. No. 12).

(γ.) Inflexible Open Obstacles.

In this third case the wind-current is checked to some extent in passing through the obstacle; there is no eddy, consequently the sand is piled up on both sides. Obstacles such as these are formed naturally by certain stiff shrubs, which consequently fill with sand. They are also used artificially for sand-catching or drift-arresting.

It can easily be seen that obstacles of various kinds assist materially in dune-building, and that when plants grow upon dunes their height may be considerably increased, while their stability is maintained so long as the obstacles remain unburied. In the case of dead obstacles this must eventually happen, also in living ones which cannot grow upwards at a rate to correspond with their burial, as in the case of all true sand-binding plants. Even these, when the supply of sand becomes too great, are frequently overwhelmed and killed, the dune then becoming the sport of the wind (see Photo. No. 29).