there will be no ripples, a state of affairs which frequently occurs during high winds, especially on dunes such as those of east Canterbury, where the grains are small and fairly uniform. On the windward side of the large grains a long but gentle slope is formed, up which the grains travel, but at the summit the larger ones are arrested by the eddy and build up the ridge of the ripple, while the vertical motion of the eddy scours out a trough in the loose sand, raising the finer grains, some of which, together with those passing up the long slope, are blown to leeward. The ridges advance by the larger grains falling by the influence of gravity over the crest of the ridge, thus building up a steep lee-slope at the natural angle of rest of the particular sand-grains. Thus the ripples are continually advancing, a ridge taking the place of a hollow, and so on. The rapidity of advance varies with the force of the wind. During a violent east wind I have observed the ripples of an east Canterbury dune moving at the rate of an inch a minute. The ripples frequently merge into one another, on account of the different rate of movement of different parts, a matter depending on the height of a ridge, the higher this being, the slower the movement. From the above it may be seen the wind exercises a distinct winnowing or selecting power, the sand-grains being sorted according to size, the smallest advancing fastest inland. This sorting of grains is well shown in the case of the ironsands, 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. 8), 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.

Specially coarse sands, such as those of Fortrose, form very large ripples, but the most striking are to be found on those inland dune-areas of Central Otago, where all the sand except the coarsest has been blown clean away by the violent westerly gales. In such cases, as Photo No. 11 shows, there are frequently two series of ripples, one much taller than the other and not to be moved except by the very highest wind, but otherwise to be added to and so become dune-chains in miniature.

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 (18, p. 54).

(iv.) 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 4°) and a steep lee 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 "sandfall" 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 Photo No. 22).

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.

(v.) Effect of Obstacles.

(*α.*) *General.*

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.

(*β.*) *Solid Obstacles.*

These are very frequent, and may consist of a piece of driftwood, 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 sand at the base of the obstacle is scooped out, and the advancing sand cannot pile up against the obstacle, but forms a heap at some distance in front (see Photo No. 9). 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 should the sand-supply continue. 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.