may have been formed from the dunes of geological ages long past, and perhaps represent accumulations in an old Triassic desert or on the shore of an old Jurassic sea. It occasionally happens that such sand-grains have developed the regular outline characteristic of crystals while forming a part of the solid rock, and have again been rounded when removed from their fixed position, two ages of rounding being thus observed in the same grain.

It may be definitely stated, in concluding this section, that sharp-edged and subangular grains rarely form part of dunes, and, even when they do, have been but recent additions to the sand of which the dunes are built.

(C.) DUNE-BUILDING ON THE COAST.

(*a.*) General.

On sandy beaches not completely covered with water at high tide there will be a foreshore consisting of quite loose sand, into which the foot sinks at every step. This material forms the supply out of which the dunes are built, its amount being kept up by fresh sand continually brought from the sea by the tide under the influence of the waves.

It is only a small proportion of the sand moved by the waves which, having become dry, is finally added to the supply of the foreshore; the greater part is borne back to the sea, while some is deposited between the watermarks, building up the lower shore, or the "sea-wall," as it is sometimes called. Other portions are deposited in the shallow water, forming sand-banks, which may be quite bare at low water, and over which the sea breaks. After the turn of the tide, if the weather be fine, the sand wetted by the furthest wash of the sea at high water commences to dry, but this process is frequently very slow, owing to the moisture of the sea-wind; and in the absence of sunshine it will be still more retarded, so that there are many days in the year when little or no additional sand reaches the foreshore from the sea. Until the sand is quite dry there is no movement, and it is at best but a narrow strip of beach which is affected. The limit between the wet sand and that which may dry is known to every frequenter of a sandy shore, who finds there a path for walking, or for vehicles, above or below which the sand becomes gradually less firm and the foot sinks.

(*b.*) Movement of Sand by the Wind.

The wind blowing inland from the foreshore carries with it, according to its velocity, more or less sand. The sand-grains move in three ways. The coarsest are rolled along the ground; those somewhat finer are raised just above the surface for very short intervals, but constantly fall and progress hopping, as it were; finally, the finest particles are blown bodily into the air. From the summit of a wandering dune during a high wind the sand may be seen rising in a great cloud just like smoke. Such flying sand may be carried long distances, as over a river several miles in breadth. The air-borne particles, since they do not fall all at once in heaps, but are scattered over wide areas, play no primary part in dune-building, the rolling and hopping sands being alone of moment in that regard.

At a certain point, depending upon the velocity of the wind, the weight of the sand becoming greater than the wind can carry, a certain amount is deposited upon the ground, and by gradual accumulation a heap of sand—*i.e.*, a small dune—is formed. Very frequently, however, some obstacle, such as a mass of seaweed, a piece of driftwood, a living plant, or an incipient dune itself, arrests the drifting sand and forms a nucleus on which the dune is built. Such a hill will have a long and gentle slope to the windward, up which the sand is pushed, the velocity of the air increasing with the height: but the leeward side is much steeper; there is no pressure of wind down its slope; on the contrary, there is an eddy of greater or less power, and the sand falls by gravity alone.

(*c.*) Sand-ripples.

Very frequently the sand forms ripples as it moves—*i.e.*, small waves similar in appearance to those so well known on the wet shore made by water-movements. The formation of sand-ripples has been experimentally investigated by Dr. V. Cornish (5, p. 279), who in his admirable paper shows that where the sand-grains are all of an equal size no ripples can be formed, but that when coarser grains are added rippling at once commences if the wind be suitable. The explanation of this depends on the fact that when the wind strikes upon a solid obstacle an eddy is formed on its lee side, and rippling takes place when this eddy in the lee of the larger grains is of sufficient strength to lift the smaller. Conversely, if the wind be strong enough to lift the larger grains, so that they do not remain stationary, 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