the position *U*, whilst the dune as a whole has at the same time advanced intermittently by infinitesimal increments of space until its crest has assumed successively the positions *a b c d e f . . . u*. When the leeward side has advanced to vv_1, the sand-particle is already buried, and when the leeward side has reached *Y*, the revolution is beginning again. During that portion of the revolving period in which the particle is on the top of the dune, it moves incomparably faster than the dune itself; but when it lies underneath the dune, the velocity of the latter is immensely greater than the velocity of the sand-particle, in fact the latter then = o. The sand-particle's period is thus divisible into two stages; the stage in which it belongs to the windward and leeward slopes is very short, while that in which it belongs to the under side of the dune is on the contrary very long. This circulation applies of course only to single dunes; in the case of dune-accumulations the process is naturally more complicated. And even in the case of single dunes the process is more complicated than our figure shows, for similar periods occur even in the ripple-marks. In outline therefore the figure may also serve to illustrate their revolutions, as also the revolutions of the dune-accumulations. The difference between sand and water is therefore in this respect this, that the dune must advance a distance equal to the whole of its own base before the sand-particle is able to complete its vertical path, whereas the water-particle completes its orbital movement, and returns to its point of departure, during the time that the wave-movement advances onwards, away from it, at a much greater velocity. But in both cases alike a full wave-length is required for the completion of each vertical path, i. e. a complete period.*

We have seen that the advance of the dune involves a transportation of matter, but the advance of the waves involves only a transmission of movement without a transportation of matter. But just as motion can be imparted to solid matter, e. g. the crust of the earth during an earthquake, so also the wave-movement of water can carry with it or involve a transportation of mass. It is not therefore proper to compare dune-movement with wave-movement; for were it not that the sand-particles lack cohesion, the same kumatic motion could be imparted to a sand-field that is imparted to the solid crust of the earth. The dune-movement ought properly to be compared only with the condition that the surface of a sea or lake assumes when the crests of waves are broken and pour on over themselves in the form of spray. In order to make this plain I must once more quote Krümmel.

Airy has proved, that at the moment when a wave is rapidly increasing in height, the force of the wind raises it so high that its inherent continuity is ruptured, and the crest becomes broken by the wind. And the waves continue to pour over until their altitude, and with it their orbital velocity, reaches its maximum value, which is conditioned by the strength of the prevailing wind. The crests of the waves continue to pour over until they attain their maximum height; but once

---

* Mr O. Baschin says: »Es finden bei der Entstehung sowohl der Wasserwellen und der Luftwogen, wie auch der wellenförmigen Anordnung lockeren Sandes, Staubes oder Schnees dieselben physikalischen Gesetze Anwendung, und dieselben Kräfte sind es, welche die Wellenformen erzeugen. Unterschiede bestehen nur hinsichtlich der Dimensionen und hinsichtlich der durch die Verschiedenartigkeit des Materials bedingten Formen.» *Zeitsch. d. Ges. f. Erdk. zu Berlin*, vol. XXXIV. p. 423.