

## PHENOMENA OF BEACH AND DUNE-SANDS

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## BEACH-SANDS.

## VALUE OF THEIR INVESTIGATION.

The following notes concerning certain phenomena of beach and dune-sands have an interest for the reason that they seem to explain some of the conditions under which the arenaceous materials of the seashore journey before they come to rest in stratified deposits. Incidentally they show some facts as to the part which the coastal sands take in protecting the shore from the action of the sea. These observations are the result of work done on the eastern coast of the United States in connection with the tasks which have fallen to me as geologist of the Atlantic Coast Division of the United States Geological Survey.

*RESISTANCE TO ABRASION.*

One of the most noticeable features which is exhibited by beach sands is their extraordinary endurance of the beating of the waves. On examining any pebbly beach exposed to the ocean-surges we readily perceive that the masses of stone wear at a very rapid rate. Thus, at cape Ann, cubes of granite of a kind which forms excellent blocks for city pavements are, when exposed to the surf, worn in the course of a year to spheroidal forms, with an average loss of more than an inch from their peripheries. Experiments with fragments of hard burned brick have shown me that in a year of moderate beach-wearing they may be reduced by the abrasion to half their original size. On the other hand the sand derived from these pebble-beaches endures for an unlimited time, evidently with little wearing. Though subjected for ages to the beating of the waves, with perhaps a hundred times as much energy applied to the surface of which it forms a part as would suffice to reduce a granite-boulder containing a cubic foot of material to a granular or powdery state, the beach sands remain unworn.

An excellent example going to show the endurance of sand-grains on the shore is afforded by the beaches of the Atlantic coast from New York southward to near cape Florida. Collections along this line show that the waste from the northern part of the coast is slowly journeying southward, partly along the beach-strip and partly in the shallow water at a little distance from the shores, yet when these sands arrive on the southern coast of Florida, though their quartz grains are somewhat rounded, they are not much smaller than those on the region of the coast about cape Hatteras.

*CAUSE OF THEIR ENDURANCE.*

On examining the conditions of the sand on a wet beach we find the reason for the slight amount of wearing to which the grains are subjected from the action of the waves. Owing to the small size of the fragments and to the fact that they are generally provided with angular faces a film of water is held by capillarity between the adjacent bits so that they, so long as the beach is full of water, do not touch each other. Thus the blow of the waves is used up in compressing the interstitial water and is converted into heat without wearing the mineral matter in an appreciable degree. A simple experiment will illustrate the extent to which the water is held between the wet grains. By pressing the foot on the surface of a flat sand beach just above the waterline we may observe that the sand usually whitens around the field of pressure, the change in hue

being due to a partial expulsion of the water ; on withdrawing the weight the sand resumes its original color.

Those who will observe the condition of the water along a pebble-beach in times of heavy rains may readily note the fact that it contains a considerable amount of mud derived from the grinding action of the stones as they are drawn over each other by the surf. A similar observation made on a normal sandbeach will show that the fragments yield no waste.

*PROTECTORS FROM CONTINENTAL DESTRUCTION.*

Important geologic consequences arise from this peculiar feature in the action of sand on the seashores. To it, in the main, is due the very effective protection which sandbeaches afford the land areas against the assaults of the waves. Probably more than four-fifths of the shores of the continents which face the open sea are thus protected from the surges by finely divided rock-material. If the agents of wear could deal with the masses of these tiny fragments as easily as they do with rock-cliffs, the history of our continents would have been quite other than that which we trace. The shores, especially those composed of friable materials, would have been easily driven back into the land. As it is, the waves, not being able to grind up the sands, have to deposit them in deep water or in embayments of the shore before they can continue to erode the cliffs which yield the detritus.

Those who have examined the condition of small islands may have remarked the fact that sandbeaches are rarely found along their shores, the reason being that the limited field of erosion is not likely to afford a sufficient supply of the material to make considerable accumulations of that nature. It is partly, at least, in consequence of this lack of sand-barriers that small islands are generally in a process of relatively rapid shore-erosion, the rate of this destruction being in most cases evidently greater than it is on the mainlands.

*SOME SOURCES OF SUPPLY.*

*Seaweeds.*—As the supply of sand on the shores is a matter of much consequence in determining the effectiveness of the wave-action against the land, I venture to note, in passing, two ways in which the deposits of the shore line are augmented. The first of these is effected by a peculiar action of our larger seaweeds. These plants have the habit of attaching themselves to a pebble or shell, it may be, in water so deep that the waves can have no scouring effect on the bottom. As they grow, these plants gradually expose so much surface to the waves and are so upborne by their air vesicles that in the end they often pull the body to which

they are attached from its place on the floor; it is then quickly urged by the surges to the beach. Attaining this position, it is at once stripped of the plants which bore it ashore.

On the beaches of eastern Massachusetts a mile of ocean front, in a time of heavy storms, often receives in the course of a day from ten to twenty tons of pebbly material, borne in by seaweeds. In some cases the rate of the importation much exceeds this amount. The pebbles thus delivered to the shores are not infrequently from three to six inches in diameter. Where pebbles do not abound on the bottom, as is the case along most sandy shores, the shells of the larger mollusks are in the same way uplifted and brought upon the beach.

*Floating Pumice.*—A certain contribution of débris to the seabeaches, the amount of which is not yet determined, arises from the stranding of floating pumice. Observations which I have made on the shores from Eastport to Key West show that every part of this coastline receives a certain share of this volcanic matter. On the Florida shore the quantity of the material appears to be much greater than elsewhere, this probably because of the strong and far journeying current which passes by that promontory. On this part of the coast it appeared to be easy at certain points on the strand to gather an identifiable bit of pumice in each square yard. As we go to the northward, passing away from the margin of the Gulf stream, these pumiceous fragments become much more rare until on the New England coast it may require a careful search to reveal a bit of the material.

Owing to the frail nature of pumice, as well as to the chemical instability of its composition, it appears rapidly to break up; it is thus not easy to determine what part of the beach-matter is from this source. Inasmuch as these volcanic materials enter into a mass which, as we have seen, is in a way protected from erosion, a small annual contribution may not be unimportant. At present my inquiries concerning the distributions of pumice along the eastern coast of the United States are in a way checked by the need of carefully discriminating between the pumiceous material thrown out from volcanic vents and the similar materials contributed from the boiler furnaces of steamships; the discrimination is possible, but it cannot in all cases be readily effected.

## DUNE-SANDS.

### OBJECT OF THEIR INVESTIGATION.

The origin of dune-sands has been well determined, as has also the general principles of their movement; there are, however, many details

of their natural history which, so far as I know, have not been made the subject of inquiry. Some of these I now propose to consider.

*RESISTANCE TO PERCOLATION OF WATER.*

Those who may have watched the movement of dunes may have had an opportunity of noting that they are often found with their surfaces in the state of dry sand in the course of a few hours after a heavy rain. Observing this fact and knowing how readily water is drawn by capillarity through the materials of which they are composed, I watched the effect of heavy showers on these wind-built hills. To my surprise I found that after a summer shower giving a rainfall of an inch the dune-materials would often not be wet for more than three-fourths of an inch beneath the surface; below that line the sand remains quite dry, wet sand not being found until the section is carried some feet down into the mass.

The explanation of this phenomenon appears to be as follows: When rain falls on dry sand the water finds difficulty in overcoming the repulsion which the dry material offers, and so works but slowly downward; at the same time the interstices of the outer layer permits it to flow down the slopes, keeping near the surface until it reaches the bottom of some depression such as abound on the surfaces of dunes. Here the hydrostatic pressure becomes sufficient to drive the fluid downward. Only in the winter, when the water in the upper part of the dune-sands has been from time to time frozen, do we ordinarily find the mass wet to the depth of a foot or more.

*MIGRATION.*

*Little affected by Rain.*—In consequence of this peculiarity of dune-sands which retards their deep wetting in ordinary seasons they are retained in marching order. In a few hours after a rain the thin, water-soaked layer, not having water supplied to it from below, may become perfectly dry, so that a strong wind may excavate and bear away large quantities of the material. I am inclined to believe that the ready movements of these sands are in the main to be attributed to these conditions.

*Retarded by Decay of the Material.*—An examination of the dunes of the Atlantic coast has shown that the detritus of which they are composed is generally in process of division and decay. This is indicated by the fact that the materials, if taken from a site where they have evidently remained for years in repose, show the existence of much fine dust, while the recent accumulations and the beach-sands from which they are derived

may exhibit little or none of it. Watching the movement of dune-sands we note that if the marching of the mass be considerable the amount of fine dust blown to a distance by the wind is very noticeable. In fact the indefinite advance of dunes from the shores is to a great extent hindered by this process, by which a large part of their masses is converted into dust which blows far away.

*Prevented by Vegetation.*—The process of decomposition, which is indicated in a large manner by the amount of the dust developed in dune-materials serves in another way to bring these masses into stable conditions. As the decay advances, the mass becomes more and more fitted to sustain plant life, particularly the grasses that have become specially adapted to the environment which these sands afford; of these the common beach-grass is a familiar type. This plant has the habit of sending certain of its main roots to a great depth, where they are tolerably sure of a water-supply; its horizontal shoots are forced laterally at a considerable depth beneath the surface, and are thus in a measure secured against risk of exposure by the movement of the sand, while the leaves by their hard nature and their order of growth are well fitted to resist the cutting action of the blown sand and to bring it to rest in their interspaces. In fact this plant of all the dune-bearing species is the most effective in defending the accumulations from the further action of the wind.

*Limited as to Distance.*—The decomposition of dune-materials is evidently favored by the considerable amount of organic matter which is derived with the sand from the beaches; it is also rapidly promoted by the vegetation which begins to feed in the lean soil, so that the distance inland to which a dune can in ordinary climatal conditions be able to journey is never very great.