

ART. XIII.—*Wind Action in Maine*; by GEORGE H. STONE.

DRIFTING sands of the ordinary type are very common in Maine, especially in the western half of the State. These sands are partly of marine, partly of fresh-water deposition. All of the large rivers of Maine, except the Penobscot, covered large areas with sand near where they emptied into the sea during the Champlain epoch, the sea of that period being, as is well known, somewhat more than 200 feet above its present level. For various reasons the drift of the Penobscot valley differed considerably from the valley-drift of any other large

stream of New England. The valley of the Androscoggin is preëminent for its sand dunes. One can travel in a carriage along this river from Brunswick to the New Hampshire line at Gilead and hardly be out of sight of drifted sand for an hour at a time. In Wayne, within the last forty years, the sand has drifted eastward from one half a mile to nearly one mile, and up the western slope of a hill 250 feet high, and now is descending the eastern slope. In places the dunes must have traveled two miles or more away from the river valley where they were originally deposited as valley-drift. Often on hill-sides a pine growth is found where one would naturally expect the hard deciduous trees. Investigation shows that drifting dunes have passed over the hill, and have left more or less sand as a covering of the till. The explorer of the drift of Maine soon comes to regard this blown sand as perhaps his most protean adversary, especially when trying to locate the shore line of the Champlain sea. It is not, however, the purpose of the present writing to treat in detail of the ordinary dunes, but to describe two less common phases of wind action.

I. *Till Burrowing*.—Not rarely spots bare of vegetation can be found on hill-sides exposed to high winds. Here during dry days the wind removes the finer parts of the till and drives the gravel back and forth just as happens in Colorado during the dry winter weather. But the rains fall so frequently in Maine, and the ground during the winter is so generally covered with snow, that under ordinary conditions the wind is never able to blow away much of the till in this manner. A few inches is all that I have ever seen thus removed. But along the borders of the drifting sands the case is different, especially near the tops of hills where the till is not kept moist by springs. Here the protecting vegetation has often been destroyed over large areas by the drifting sand, and the rapid evaporation from the sand seems to keep the till dryer than elsewhere. As a result the till is here blown away much more rapidly than usual. Small bluffs are formed, partly owing to the direct effect of the wind in blowing away the finer parts of the till, and partly from the impact of the blowing sand which is near by. A talus composed of the coarser gravel and boulders of the till is thus left at the base of the cliff and scattered promiscuously over the denuded surface. In this way considerable areas of the till have in some cases been denuded as the drifting sand traveled from place to place. A fine instance of this kind of till-burrowing is found on the top of a hill about one mile northwest of Wayne village. Here, in 1879, the wind had excavated the till to a depth of nearly three feet and the glaciated ledges had been laid bare for a distance of several rods. The glaciated stones of the till retained their scratches in perfect condition,

showing that the process of denudation had been so rapid as not to permit much weathering of the stones or much sand-polishing.

II. *Sand-Carving.*—In Professor C. H. Hitchcock's Report on the Geology of Maine for 1861 (pp. 266–8) reference is made to a peculiar train of bowlders found by Dr. N. T. True at Bethel, Maine, and described by him before the Portland Society of Natural History. A part of Dr. True's description is as follows: "I wish now," says Dr. True, "to call your attention to a collection of bowlders of a peculiar character found in Bethel, in this State. These bowlders are scattered over the surface of the soil for several square miles. On one side may be seen grooves, scratches, strial and polished surfaces. Nothing of this is seen on opposite sides of the same rock. The opposite surface is usually angular, as if it had not been subject to abrasion since its detachment from the parent rock. Frequently, as in the specimens before you, may be seen sharp angles formed by a different presentation to the abrading surface. Sometimes the grooves present an undulating surface as if it had been subjected to a tremulous movement from the impending mass. * * * There is a freshness in their appearance as if they had been grooved yesterday. They present no appearance like rocks on the sea-shore, which have been exposed to the action of water. They are composed of granite, hornblende, and grey-wacke slates." Professor Hitchcock remarks (loc. cit.), "the bowlders in Bethel are very curiously shaped; and it is not easy to say how these shapes were produced." Dr. True sent some of them to President Edward Hitchcock of Amherst, who under date of Jan. 16, 1854, writes: "I am very much puzzled with the specimens. They are different from anything I have seen, and deserve careful study. The grand point of difficulty is to account for the bowlders being held in so many different positions in order to be scratched, or rather grooved, for the striæ are different from those in common rock." Both President Hitchcock and Dr. True thought that the peculiar form of these bowlders was due to iceberg action, a very natural view considering the then prevalent theories as to the origin of the drift.

The writer first studied these bowlders in the field in 1879, when they were pointed out to him by Dr. True himself. At that time, in addition to the characteristic bowlders in the vicinity of Bethel, I found one of precisely the same character in Gilead, also one about a mile east of Gorham, New Hampshire. (Dr. True thought they were only to be found at Bethel.) It will be seen that these localities are all near the Androscoggin river, and but a few miles from the White Mountains. The unusually carved bowlders were all found

on hillsides above the level of the valley-drift and most of them were on the south side of the river on slopes well exposed to the north and northwest winds. In fields and by the road-sides in Bethel, where the bowlders had probably never been disturbed by plowing, I made note of the positions of the polished faces of hundreds of the bowlders. The polished surfaces were turned in every direction, but more faced the west and northwest. Dr. True's observation that one face of these bowlders is usually unpolished was verified, though in one case a boulder was found polished on all faces. In the majority of cases this unsculptured face was *the lower face*. In the year 1880, I deposited specimens of the Bethel bowlders in the cabinet of the Boston Society of Natural History, and submitted them to several glacialists for examination. But during all of this time none of us obtained any inductive clue to the mystery—the cause of the peculiar carvings. In 1881 I removed to Colorado and for the first time saw in the field the sand-sculptured bowlders so common in the arid regions, and their forms were seen to be the same as those of the Bethel bowlders. Here at last was an opportunity to leave speculation for a valid induction. At once several theories were suggested as accounting for the peculiar shapes of the Bethel bowlders, but it has been necessary to wait for several years in order to determine by observations in the field which one is the true hypothesis. Three of these alternatives are here stated and briefly discussed because they bear on the question of the causes of the shapes of the drift materials, and this is sure to be a pressing and significant question for glacialists to solve.

1. These bowlders may have been sand-carved by the wind in their present positions, and recently. If true, this hypothesis could easily be verified by finding the process now in operation.

2. They may have been sand-carved by the dashing of the rain chiefly. That this is a cause of sand-carving there can be no doubt; but if such extraordinary forms as those at Bethel are due to this cause, then similar surfaces ought to be common everywhere, unless there is something in the Bethel bowlders fitting them to receive or preserve such polishing better than other bowlders. But on the other hand they are only ordinary drift bowlders, representing various common rocks; they are neither harder nor softer than many others, nor can they resist weathering any better. Many of them are of a very feldspathic granite, while in others quartz predominates.

3. They may have been sand-carved by glacial streams. Whenever swift sediment-laden streams impinge obliquely against a rock surface, that surface is carved into tremulous grooves showing many sub-conchoidal depressions very nearly

like the Bethel boulders under consideration. On the average, the depressions are perhaps shallower in proportion to their breadth when made by water, than when the abrading agent is driven by the wind. This kind of sculpturing I have seen in a great many places both in Colorado and in Maine, almost everywhere, in fact, where the rock does not weather faster than the streams can polish the surface. Fine examples can be seen at the Rumford Falls of the Androscoggin, also at the High Falls of the Saco, near Hiram. Crystalline rocks are more likely to show this kind of eroded surface than sedimentary rocks, unless the latter are very firmly cemented.

So far as my observation goes, sand sculpturing by flowing water only takes place when the water strikes against a surface that is stationary for a considerable time. This is not likely to happen except in case of the solid rock or of boulders of considerable size. The swiftness of current necessary to produce sand-carving will from time to time roll the smaller stones and boulders into new positions. The attrition and concussion of the stones against each other so modifies the forms due to the sand and gravel driven by the water that the stones are rounded into pebbles, and do not receive the peculiar conchoidal depressions and tremulous groovings due to pure sand-carving. Thus, for instance, in the beds of the swift streams of the White Mountain region, the fall is often 100 or more feet per mile, and the bowlderets and smaller stones are well rounded like beach or Kame pebbles and cobbles. Some of the Bethel specimens are only two or three inches in diameter, too small to have been sand-carved by water under ordinary conditions. But Bethel was not far from the end of the local Androscoggin glacier, and it may be said that it is possible that the peculiar carvings were due to sediment-bearing sub-glacial streams acting on stones and boulders which were for a time held fast in the ice. At several points in the Androscoggin valley, between Gorham, N. H., and W. Bethel, Me., I have found surfaces of the solid rock grooved lengthwise of the valley, i. e., nearly parallel with the flow of the local glacier, which it is well known lingered here for a time after the great ice-sheet had melted. These were not the ordinary glacial scratches, but had the gouged appearance and conchoidal depressions made by sand-laden water. Some of these places were above the highest level of the river during the Champlain floods. A fair inference is that the unusual grooves were probably due to the muddy sub-glacial streams of the local glacier. But even if we admit sand-carving of the underlying rock by sub-glacial streams, can we do it in the case of moraine stuff held in the ice? I have failed to find any recorded observation on this point, though the Alpine glaciers ought to afford facilities for such observations. If

at Bethel boulderets and smaller stones were held so long in one position in the ice as to be sand-carved, then, either such sculptured surfaces ought to be common in the kames, or we must re-cast our theories as to the kames being deposited by glacial streams. During an investigation of several years, the writer has failed to find a well marked instance of pure sand-sculpturing in the kames and osars, though now and then there are indistinct traces of it.

During the past summer the writer, in the course of an investigation of the glacial gravels of the region, has explored the Androscoggin valley from Brunswick to the N. H. line. Incidentally the Bethel mystery was solved. In numerous places, both in Bethel and elsewhere near the mountains, I found boulders and even small stones which are now being sand-carved *by the wind* as plainly and incontestably as in Colorado. The drifting dunes of fine sand do not produce this effect to any great extent, probably because the stones are covered and uncovered too rapidly. But there are bare spots not protected by grass where coarse sand and gravel are driven back and forth by the wind, and here the carved boulders can be seen in considerable numbers and in all stages of the process. In some cases it appeared probable that these bare places were where drifting sand had swept over the surface and the till had been partially denuded by the wind in the manner before described. It now became evident why one face of the Bethel boulders is in most cases unpolished. That rough face was the under surface, and was protected from the attrition. If a boulder, after having its exposed faces polished, was rolled over by the up-turning of a tree or by any other cause, the other face or faces became polished also. Where a boulder lay deep in the ground only a small part at the top could be polished. If it lay on the surface evidently every face except the bottom could be carved simultaneously, provided it was not too large. Large boulders are only carved laterally; their tops, being above most of the flying sand and gravel, weather faster than the progress of the attrition. The freshness of surface noted by Dr. True is due to the fact that the process is recent. Indeed every feature of the Bethel boulders under consideration is fully accounted for by the hypothesis of sand-sculpturing under the action of the wind. An accessible locality for observing the process of sand-carving now in operation is found about one mile from West Bethel on the east side of the road leading to Mason. The fields around Bethel village have so generally been plowed that one finds it hard to determine their original condition.

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