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ART. I.—*On the Quaternary, or Post-tertiary, of the New Haven Region*; by JAMES D. DANA.*

I. THE GLACIAL ERA AN ERA OF GLACIERS, AND NOT OF ICEBERGS.

IT is still a mooted question in American Geology whether the events of the Glacial era were due to *glaciers* or *icebergs*. Agassiz and Guyot, who were long among the most active of Alpine explorers, found on their arrival in New England only the effects of glaciers. But American geologists are still divided in opinion, and some of the most eminent have pronounced in favor of icebergs.

The region of New Haven is exceedingly well situated for settling the question, not only as regards its immediate vicinity, but for the whole interior of New England. For in the first place, the region is a wide and open area at the southern termination of the Connecticut Valley;† and this valley is the great central valley of New England, including the larger part of its surface outside of Maine, the Green Mountains making its western border, and the White Mountains and the height of land southward, its eastern. Then secondly, the valley has a north-

* The principal facts relating to the New Haven Quaternary, which I propose to bring out in the article here begun, are included in a paper by the author on the Geology of the New Haven region, published recently by the Connecticut Academy, in volume II. of their Memoirs.

† The Connecticut Valley has a general course from north to south, varying little from S. 9° W. It is occupied by the Triassic (or Triassic-Jurassic) Red sandstone formation from New Haven to northern Massachusetts, and this indicates the position which it had in the Mesozoic era. The Connecticut river leaves the valley at Middletown, taking there a southeasterly course among the metamorphic rocks of the eastern half of Connecticut.

and-south course; so that, whether glaciers or icebergs were the agents, it would, in either case, have guided their great movements, and the New Haven region would have necessarily become filled with registers of the successive events. Being situated on an arm of the Sound, and at the same time extending inland for seven or eight miles along three streams that here have their discharge, the phenomena presented comprise results from both the sea and the rivers, and also from their combined action. On these several accounts, the New Haven region is eminently well situated for deciding the glacial question for all central New England.

A special study of the region during the last two years has led the writer to the conclusion that the effects are solely those of glaciers, or rather, of a *Connecticut valley*, or *Central New England, glacier*.^{*} To exhibit all the evidence bearing upon the question would require a full discussion of the whole range of facts presented by the New Haven Quaternary. I propose at this time to mention only a few of the more trenchant and decisive points.

The question is—Was the interior of New England in the Glacial era covered by a sea at least 4,000 feet deep for the floating of icebergs; or, was it emerged land as now, (perhaps to a higher level than at present) and submerged only beneath ice, the ice of an immense glacier, 3,000 feet and less in thickness, the ice in Vermont and New Hampshire being 4,000 feet and more above the level of the sea?

1. The sea, if it covered the land in the Glacial era, should have left proof of it along the southern coast of New England.

About New Haven, the height of the stratified Quaternary deposits above the sea (Long Island Sound), or above the river flats, no where exceeds 50 feet. This is the maximum; the particular facts will be stated at another time. Fifty feet is therefore the greatest amount of depression of the land which is indicated, the greatest that can be admitted by those who base their geological conclusions on facts. There are no traces of sea beaches or any thing corresponding thereto at a higher level. On passing the level of 50 feet above the Sound there is an abrupt transition from the stratified to the unstratified drift, except along the courses of streams, and near these, there is the same transition on passing the level of 50 feet (or less) above the existing river flats.

The highest sea-level of the Quaternary era about the New Haven region is thus definitely marked. It is often assumed

^{*} The existence of essentially independent glaciers, (under the continental Glacier) in the Glacial era was recognized by the author in an article in this Journal, vol. xxxv, p. 243, 1863, and in his Manual of Geology, p. 763, published about the same time; and four great glaciers were there particularly mentioned, the Connecticut River, the Penobscot, the Hudson River, and the Mohawk River.

that the *unstratified* drift might have been dropped over the hills by icebergs; but, as Mr. Croll has recently urged, depositions in water cannot be made without stratification. The slightest jar of a vat of water holding sediment suspended will cause that sediment to go down in a laminated state; and so deposits of sands and gravels in the ever moving sea will always manifest their aqueous origin. The stratified and unstratified material about New Haven therefore mark the limit between aqueous and dry-land deposition. Much has been said about "modified drift," or more or less stratified drift deposits, over the hills; but they occur no where, according to my observation, except along water courses or about the sites of old lakes; they sustain the conclusion that the unstratified drift was essentially a dry land deposition.

2. The magnitude, wide distribution, and regularity of direction in the scratches are evidences against Icebergs.

This is no new argument; yet it has lost nothing of its force by long use. Broad furrows, eight to ten inches in depth, made in trap or granite over long distances, uniform in direction, must have required prolonged abrasion for scores of years, and by an abrading agent not liable to change of course through tides or currents, or to changes of form and thereby of center of gravity from waste in the waters over the rocks. Glacial abrasion has been found so generally wherever the soil has been freshly removed that it may be safely inferred, as has been done for other parts of New England, that the abrasion was universal. Passing from the New Haven region westward, over the high plateau of Litchfield, Warren, etc., 1000 to 1500 feet in height above the sea, the scratches have the same uniformity and wide distribution. Grounded icebergs would be sufficient for such results only in case they spread completely over the wide surface and rested firmly upon its every part,—in which case they would be nothing less than partly submerged glaciers.

3. The scratches are, in some cases, in such positions that only a glacier could have produced them.

For example: on Mount Carmel—an east-and-west ridge in the Connecticut valley depression, about 750 feet in height, nine miles north of New Haven—along one of the steep southern valleys, the surface of trap (dolerite) is extensively abraded, and marked with many large and broad north-and-south furrows. An iceberg, moving southward, which could float over the top of Mount Carmel ridge would not touch bottom in this southern valley, for the part eroded is at least 150 feet below the level of the ridge to the north of it. While this erosion is, therefore, beyond the capacity of icebergs, it would be the natural result of a Connecticut valley glacier.

4. Since icebergs are fragments of glaciers broken off by the sea into which they descend, and since their freight of stones is part of the moraines of the old glacier, the boulders of the New Haven region, and of New England generally, should, on the Iceberg hypothesis, be the rocks of the White Mountains (whose highest peak, Mt. Washington (the loftiest in New England) is 6288 feet high), or of some Green Mountain Peak (over a thousand feet lower), if not from some more distant northern source.

But, in fact, the boulders about New Haven have come mainly from the central part of Connecticut and Massachusetts, and largely from the hills or ledges in the Connecticut valley itself; and not from any mountain summit or ridge either side. They are therefore from *the bottom* of the alleged Iceberg sea, and not from any emerged summits.

These boulders are masses of trap 1000 tons in weight and less; and Mt. Tom and Mt. Holyoke, situated adjoining the Connecticut river in Massachusetts, seventy miles north of New Haven, are the most northerly points from which such masses could have come. The tops of these so-called mountains would have been over 2600 feet below the surface if the Iceberg sea were 4000 feet deep. Other boulders are of the Triassic red sandstone; and these also had their origin *in the Connecticut valley*, south of the northern limits of Massachusetts, for none exists farther north. Others, of large size, some of them ten to fourteen feet in length, are of gneiss and came from a gneiss region, either in northern Connecticut, ten to twenty miles west of the Connecticut river, or just north of this in the adjoining part of Massachusetts. Again, six to eight miles west of New Haven, there are numerous large boulders of porphyritic gneiss, which were derived from ledges less than thirty miles distant to the north or northwest.

The facts show, beyond question, that in the Glacial era, the transported blocks came from the comparatively low regions, in the very bottom of the supposed Iceberg sea, not far to the north of New Haven, instead of from distant and elevated heights to the northeast or northwest; and this was true of all the drift material. The observations of others over New England, as well as those I have made over Connecticut, sustain the conclusion that the sand and gravel of the unstratified drift has not come from remote points, but has been shoved southward by some agent that could gather it up over the breadth of the land and bear it onward to drop it after a few miles, or scores of miles of transportation. All this is evidently impossible work for icebergs.

Since, then, icebergs cannot pick up masses tons in weight from the bottom of a sea, or give a general movement southward to the loose material of the surface; neither can produce the abra-

sion observed over the rocks under its various conditions ; and inasmuch as all direct evidence of the submergence of the land required for an iceberg sea over New England fails, the conclusion appears inevitable that icebergs had nothing to do with the drift of the New Haven region, in the Connecticut valley ; and, therefore, that the Glacial era in central New England was a *Glacier* era.