

ART. XL.—*On the position and height of the elevated Plateau in which the Glacier of New England, in the Glacial era, had its origin*; by JAMES D. DANA.

THE existence of a region of high elevation in northern America as the source of a continental glacier in the Glacial era has often been assumed, but rather because the glacier theory was lame without it than as a result of special research with respect to the extent and location of such a region. I do not propose, at the present time, to treat the subject continentally, but simply to discuss the question as to the origin of the New England glacier. If I mistake not, however, the discussion, so far as it goes, meets the requirements of the continental question, while it proves that the idea of one central glacier source for the continent is without foundation.

1. *Position of the elevated plateau.*—In my paper of last month, on the "Valley Movements of Glaciers," (p. 233) I mentioned the fact, from the observations of the Vermont Geological Survey, that the glacial scratches on Camel's Hump, Mt. Mansfield and Jay's Peak, three of the high summits of the Green Mountains in the northern two-thirds of Vermont, have a course of about S. 50° E.* In the White Mountains, 70 miles to the south of east (S. 75° E.), the direction of the scratches near the Lake of the Clouds, on the north side of Mt. Monroe, is, as I am informed by Prof. C. H. Hitchcock, at points from 5000 to at least 5200 feet above the sea, in different places, S. 34° E. and S. 54° E. (S. 20° E. and S. 40° by compass); on the north side of Mt. Clinton, 4430 feet high, (one of the White Mountain series of summits about 17 miles west of Mt. Washington), near top, S. 50° E.—S. 54° E.; and on the south peak of Mount Clinton, at a level of 4320 feet, S. 54° E. He observes further that boulders occur at a height of 5800 feet on the north side of Mt. Washington.†

These scratches, and others crossing the Green Mountains, could not have been made with the land of North America at its present level. Elevated land must have existed to the north, if they were the work of glaciers. Moreover, these scratches

* According to the Vermont Geological Report the direction of the scratches on Camel's Hump is S. 50° E. (S. 40° E., compass), on Jay's Peak, S. 56° E., and on Mt. Mansfield, situated between the two, S. 30° E., S. 55° E., S. 58° E., at different points.

† Prof. Hitchcock observed also the course S. 24° E. near the Lake of the Clouds, but it was not common; also, in the saddle between Mt. Pleasant and Mt. Franklin, 4400 feet above the sea level, S. 34° E.; and the same in the gap between Mt. Pleasant and Mt. Clinton, 4050 feet high. It would therefore appear that the course of the general glacier over the White Mountain region was about S. 55° E., and that there were variations from this course due to the lay of the land.

on the higher summits of New England, must point approximately toward the region of elevated land, or the great Icy Plateau, as we may call it, on whose slopes the movement of the glacier originated.

This seat of power in the era of ice was not the Adirondacks; for these stand (as will be seen on any map of North America, and even a map of the World) much too far to the south. The scratches point over Lake Champlain and the low hills and plains beyond, and across the St. Lawrence. On the other side of this river lies the large valley of the Ottawa, and it is almost exactly in their direction; and the prevailing trend of the scratches through its lower half is about S. 45° E. According to the table in Logan's Report for 1863 (p. 890), this is the course at Ottawa City, Hull, Rideau River at Stegman's Rapids, and Horton near Renfrew village south of the Ottawa. At Allumettes Lake, the course S. 25° E. was found; but this locality is higher up the stream, and the course may well have been due to some local influence. There can be no doubt that, if the Glacial era was a *glacier* era, the Ottawa valley ice was a part of the same great ice-stream with that which crossed the Green Mountains, but a portion nearer the source.

The Ottawa valley, including that of Montreal River (which has the course of the Ottawa and is its western head-tributary), extends to a point nearly 500 miles in an air-line from Mt. Mansfield, and 570 from the White Mountains, with an average trend of S. 65° E. But the source of Montreal River was not the source of the glacier movement; for the course of the scratches in the Ottawa, instead of corresponding with the trend of the valley, is, as stated, S. 45° E. The scratches point, therefore, to the eastward of the western source of the Ottawa, and at least as far east as the region northeast of Lake Temiscamang (the main source of the waters of the Ottawa), on the watershed between the St. Lawrence valley and Hudson's Bay. The scratches of the White Mountains and Green Mountains and those of the lower part of the Ottawa valley point alike toward this area.

It follows that the Icy Plateau, whence the great glacier took its departure, must have existed either about this part of the Canadian watershed, or in the same direction farther to the northwest; and since the line of the scratches, if carried farther to the northwest, would strike Hudson's Bay, or its western border, it is probable that this watershed was the actual position.

This view accords with the great diversity of direction in the scratches about Temiscamang Lake, they varying, according to Logan, from S. 78° E. to S. 7° W., the least easting being found on the *west* side of the Lake; the observations are,

at East Bay, S. 53° E., S. 78° E.; on the east shore S. 38° E., S. 18° E.; at West Bay, S. 15° E.; on the west shore, S. 35° E., S. 18° E., S. 14° E., S. 1° E., S. 7° W.

The courses of the scratches on the heights of northern Maine (S. 59° E. on Mt. Abraham, C. H. Hitchcock) also favors this conclusion. Again, in the part of Canada, north of northeastern Maine, on the Madawaska River, about Temiscouata Lake, Logan found scratches trending S. 54° E., S. 52° E., S. 55° E., S. 66° E., S. 48° E., S. 60° E., (with one of S. 27° E.); and these courses, if the form of the surface has not increased the easting, would point to the same watershed and the part lying between Temiscamang and Mistissinny Lakes, but nearer the latter, and these lines continued would strike into Hudson's Bay, and this is additional proof that the high land was along the watershed.

Again, the courses of the scratches in western New York and on Lake Huron and Lake Nipissing (northeast of Lake Huron and south of Lake Temiscamang), have considerable *westing*. On the north shore of Lake Huron the course is mostly S. 13°–22° W., according to Logan; on the Georgian Bay (northeastern side of Lake Huron), S. 37°–45° W.; at the southeast bay of Lake Nipissing, S. 35° W; in western New York, S. 35° W., according to Hall. This prevalent *westing* points toward the same region northeast of Lake Temiscamang along the Canadian watershed, and seems to shut off from consideration regions farther north or west.

Taking into view all the observations here cited, we may conclude with much confidence that the region of greatest elevation along the watershed, or that of the Icy Plateau, was situated between Lake Temiscamang and Lake Mistissinny; and that its trend was consequently northeast and southwest, this being nearly that of the watershed between the lakes—a trend just right for a southeast movement of the ice.

Over the higher parts of the Green Mountains, *south* of Vermont, the amount of easting in the scratches diminishes southward, their direction being S. 40°–45° E. in northeastern Massachusetts; about S. 30° E. in southeastern Massachusetts; and about S. 25° E. in Connecticut and in eastern New York adjoining. These directions correspond well with the position assigned to the Icy Plateau. But as the Adirondacks lie between the two, it is not possible to say how far the courses may have been dependent upon these New York mountains.

2. *Height of the Icy Plateau above the sea.*—The higher summits of the Green Mountains are, according to Guyot, between 3800 and 4430 feet in elevation, the latter being the height of Mt. Mansfield. Killington Peak, 60 miles south of Mt. Mansfield and east of Rutland, is 4221 feet high (Guyot). The average height of the range, according to the same authority, is

about 3500 feet. The distance from Mt. Mansfield to southeastern Massachusetts is about 200 miles. The scratches of this mountain point southeastward toward the upper Merrimack valley; and those of this valley and of the adjoining region, down this valley in the direction of Boston Bay; and to this bay the distance from the summit of Mt. Mansfield is but 175 miles. Still, taking 200 miles as the length of the old glacier from Mt. Mansfield to the sea, and 3500 feet as the average height of the Green Mountains in Vermont, *the average rate of descent in the land is $17\frac{1}{2}$ feet a mile*, and 20 feet a mile from the summits of the higher peaks. This was consequently the amount of slope that contributed toward the movement of the glacier over a large part of New England.

To have moved the same glacier from the northwestward *across the Green Mountains*, and to have abraded their highest summits and also scored surfaces on the White Mountains that are full 5200 feet above the sea, the propelling slope, or those of the Icy Plateau, must have certainly been higher than 5200 feet. We cannot assume that the rate of descent from the top of the Icy Plateau to the 5200 foot level on the White Mountains, a distance of about 400 miles, was as great as seventeen feet a mile; but we may reasonably infer it to have been at least *three* feet. This rate for 400 miles would make the height of the Plateau to average 6400 feet. The watershed is now about 1500 feet above the sea; accordingly, the average height of this region should have been at least 4900 feet greater than now.

A grade of *two feet* a mile would diminish this estimate 400 feet, making the required average height of the Icy Plateau 6000 feet.

The facts, therefore, demonstrate that this Canadian watershed was greatly higher—at least 4500 feet on an average—than at present. It is not supposed, or supposable, that the region was the course of a range of crested mountains that have since been washed away. No facts connected with glacial denudation, or that of subsequent time, favors such an extravagant assumption. All that the case demands is simply a bending upward of the surface over a wide area through a general continental movement of the crust having its greatest results to the north; and such we may believe it to have been. Similar oscillations of surface upward, and again downward, have taken place through all geological time, and they are still in progress; and geologists have detected them on some sea-shores where there is a standard water-level for comparison.

Moreover, the work of lifting continents and raising mountain chains went forward on a stupendous scale over Europe, Asia, and both Americas, through the whole era of the Tertiary: and this later upward movement in the higher latitudes of the continent followed on as the close of the long series, all

the preceding elevations, as well as the last, being in preparation for the Glacial era.

Such an *upward* bending is no more improbable than the *downward* bending which the Iceberg theory of the drift assumes to have taken place; and even less so, *since* the latter must have been greater in *vertical change* of level, and also vastly wider in its limits from north to south; and moreover such an event would have been out of joint with the times, tending to ameliorate instead of giving arctic vigor to the climate. And further, as I pointed out many years since, (this Journal, II, vii, 379, 1849,) there is independent proof of a high-latitude elevation of the continent during the Glacial era, in the fact that the drift latitudes are also *fjord* latitudes,—the fiords occupying valleys of erosion by fresh water or ice, which could have been made only when the land was far above the present level.

A bulging of the crust in any region to a height of 4,500 or 5,000 feet above its present level would have carried up the part of the continent adjoining to a greater or less extent. If the above use of fiords is right, they may help us, wherever they occur, in arriving approximately at the amount of elevation in the Glacial era along sea borders. From the depth of those of Maine,—mostly 100 to 150 feet—we thus learn that the land along this coast was at least 150 feet higher than now, and probably 200 feet. Other facts lead us to believe, as stated by the writer in his paper on the Geology of the New Haven region, (Mem. Acad. Conn. ii, p. 45,) that southern New England was 100 to 150 feet above its present level. Hence, the coast line of New England would have been much extended outward by the change of level. Long Island Sound would have been reduced to a narrow channel, and Long Island joined to Connecticut, to which it geographically belongs. St. Lawrence Bay would have been greatly contracted, and the St. Lawrence River lengthened seaward over part of its present site. Lake Champlain would have poured its waters down the valley of the Hudson; and, as others have shown, Lake Michigan down the Mississippi valley.

The elevation of New England would have increased in amount from the southern shore northward, and from the southeastern northwestward, toward the Icy Plateau. Consequently the White Mountains, Mt. Mansfield and other Green Mountain peaks, and the Adirondacks of northern New York, would probably have stood at least 500 feet above their present level. If so, it is necessary, in order to have the slope of one averaging two or three feet in a mile, that as much at least should be added to the average height of the great northern Icy Plateau, which would make it 6,500 to 7,000 feet.

If the Icy Plateau, instead of being along the watershed, was situated to the north and northwest of it, somewhere in

central or northern North America, the height must have been greater in proportion to the remoteness.

3. *The movement of the Glacier.*—The great glacier moved southeastward (the Icy Plateau trending northeastward) down the valley of the Ottawa and the slopes east of it, and marked its course deeply in the subjacent rocks. But on nearing the St. Lawrence, the lower part of its mass yielded to the impulse of gravity according with the slopes of this transverse valley, so that along this valley only *southwest* scratches were made, as facts show. Yet, the upper part of its mass continued on its first course, and, in northern New York and Vermont, and over southern Canada adjoining the latter State, the southeastward moving ice again touched bottom and resumed its work of abrasion. This is precisely parallel to what happened to the glacier, as I have shown, in its passage across the Connecticut River valley. In each case the valley determined the movement along its course of an under portion of the glacier, while the upper portion, spanning the valley, continued the grander movement initiated in the Icy Plateau, and favored by the general slope of New England. The great glacier, 6,000 to 8,000 feet in thickness, had no difficulty in keeping on its course according to the general slope of the land, and, at the same time, in following underneath the larger valleys or even many of the local slopes. It could not do otherwise. Icebergs in a continental sea, on the contrary, would have been puzzled to find all the criss-cross currents needed to help them along the valleys, up hill and down, and through all points of the compass.

4. *One cause of the cold of the Glacial era in North America.*—Increase in the extent and height of high-latitude lands may well stand as one cause of the cold of the American Glacial era. This rising of the land of northern Canada into a great plateau, at least as high as the summit of Mt. Washington, with the less elevation of wide regions north and south as a part of the great swell of the surface, and with the simultaneous elevation of other, perhaps higher, plateaus over the more northern and northwestern portions of the continent, and all a sequel to the majestic uplifts of the Tertiary, would have made a *Glacial* period for North America, whatever the position of the ecliptic, or whatever the eccentricity of the earth's orbit, though more readily of course if other circumstances favored. Having the most elevated land of eastern North America along the region pointed out, the courses of the winds and the distribution of moisture would have been different from the present. Canada being then on the *seaward* slope of the high land instead of, as now, on the landward slope, could not have had its comparatively dry climate with only an annual fall of 30 inches of moisture.

5. *Epochs of the Quaternary in North America.*—In view of the facts with regard to the elevated northern lands of the Glacial era here set forth—facts if Glaciers had anything to do with the Glacial phenomena—the epochs of the Quaternary, before deduced by the writer, come out in great boldness.

The movement of the GLACIAL era carried the northern lands upward, at least 5,000 feet above their present level in northern Canada, and probably as much or more over the higher latitudes to the west and north.

Then followed a slowly progressing subsidence—the great characteristic of the CHAMPLAIN era—which ultimately sank the same lands even to a greater extent than they had been raised, placing the valley of the St. Lawrence, about Montreal, over 500 feet below its present level, and probably 1,000 feet at least below its level in the Glacial era. With the commencement of this movement, or as it progressed, began the melting of the glacier; but the era continued, as proved by elevated beaches full of shells and other deposits, long after the melting ceased. During it, owing to the larger amount of subsidence to the north, north and south rivers had their slope greatly diminished, and in some places leveled out entirely for long distances; and owing to the vast depositions of drift, rivers, like Niagara, sometimes had their channels obstructed and were forced to begin new cuts, while other water-courses of the Glacial era were wholly cut off, as that from the Champlain Lake down the Hudson valley.

Afterward the return movement, that of the TERRACE era followed, placing the land finally at its present level, leading thus to a deepening of river channels, and thereby to the making of the river and lake terraces that cover the continent.

The fact of these grander movements which mark the three eras does not preclude the possibility of minor local oscillations of level during their progress.