ART. XX XVIII.—*Remnants of an Old Graded Upland on the Presidential Range of the White Mountains*; by JAMES WALTER GOLDTHWAIT.

THE Presidential Range lies sixty-five miles inland from the sea, in north-central New Hampshire. It extends in a north-east-southwest direction for a distance of eighteen miles, with a width of about three miles. On it are eight principal summits or "peaks," of which Mount Washington is considerably the highest, with an altitude of 6290 feet. From this range streams flow off in all directions, reaching the sea through four of the largest rivers of New England,—the Connecticut, Merrimac, Saco, and Androscoggin. In respect to drainage lines, therefore, this district is extremely remote.

In form, the mountains of the Presidential Range present two contrasted sets of slopes: subdued, well-graded slopes above, and bold, precipitous slopes below. The former appear to be due to long continued sub-aërial wasting of an early cycle; the latter, to deep and extensive stream dissection during a later cycle, accentuated by local glaciation of the ravine heads. Subordinate to these features, but modifying them in detail are index forms of regional glaciation, of a later date than the stream erosion and local glaciation.

On all sides of the range lower ranges and summits exhibit a surface so irregular, from whatever altitude it is viewed, that one fails to see in the landscape any satisfactory trace of an uplifted peneplain such as Davis has described in southern New England. The exposure everywhere of contorted metamorphic rocks and plutonics bears abundant evidence, however, that the interior of New England, like the better known outer portion, has been stripped of thousands of feet of its original rock structure. The lofty mountains of the Paleozoic and Mesozoic landscape have been worn down to an irregular upland of moderate relief. No organized effort has yet been made to correlate the physiographic features of the White Mountains with those of southern New England. The peneplain which extends over Connecticut, Rhode Island, and Massachusetts has never been followed far into New Hampshire. This neglect by the physiographer seems strange, in view of the fact that the White Mountains have become widely known as a vacation resort for the tramp, camper, and mountaineer.

Professor Davis, in his description of the peneplain of southern New England,* says that on "passing northward into

* W. M. Davis: *The Physical Geography of Southern New England*. National Geographic Monographs, No. 5, p. 269-304, 1895.

FIG. 1.

FIG. 1. Outline map of the New England States, showing in black the position of the Presidential Range in New Hampshire and Mount Katahdin in Maine, and the large rivers which rise near them. These rivers are: C Connecticut, M Merrimack, S Saco, A Androscoggin, K Kennebec, P Penobscot, Ar Aroostook, and St J St. John.

Vermont, New Hampshire and Maine monadnocks are common. The White Mountains seem to be only a cluster of unconsumed remnants . . . but in spite of the nearness of these northern states they have not been explored with the upland peneplain and the monadnocks in mind. No definite statement can at present be given to the altitude of the upland in northern New England or as to the degree of perfection that it attained.”* Again in 1899, Professor Davis writes: “The White Mountains have been in my mind tentatively classed as a group of monadnocks; they do not, as far as I have seen them in brief excursions, stand upon any distinct basement comparable to that of the uplands of New England further south. . . . The ruggedness of the district is generally so great that it is quite possible that the peneplain explanation does not apply to the greater part of the area. Little wonder that an observer whose attention is given to this mountainous district under the impression *that its mountain tops represent the remnants of a peneplain* should come to discredit such an explanation.”†

It is my purpose in this paper to point out the possibility that the summit portion of the Presidential Range, contrary to the implication by Professor Davis in the foregoing quotation, may be a remnant of that ancient graded landscape which, according to his theory of baseleveling, consisted in the more southerly portion of New England in a rather fully developed peneplain. In short, it will be suggested that the subdued cones of Washington, Jefferson, Adams, and the other summits of this range are low monadnocks surmounting a peneplain whose only surviving fragments, in this district, are the upland “lawns” and “Alpine pastures” that lie along the crest of the range.

The Upland “Lawns.”

As one ascends Mount Washington from the southeast he is impressed by the extraordinary flat area which he reaches about 1000 feet below the summit. This great “lawn” extends along the top of the range from the upper end of Boott’s Spur for over a mile before reaching the foot of the cone of Washington. Its width is fully half a mile and its rise so slight and so gradual that in contrast to the precipitous headwalls of the ravines below and the rather steep sides of the cone above the lawn appears smooth and level. It is perhaps the most striking feature encountered because the

* Op. cit. p. 283.

† W. M. Davis: The Peneplain, *American Geologist*, vol. xxiii, pp. 209-210, 1899. The italics are not in the original.

FIG. 2.

least expected. The earliest printed description of the White Mountains, by Josselyn, referring to the Presidential Range, says that "upon the top of the highest of these mountains is a large level or plain . . . whereon nothing grows but moss. At the further end of this plain is another hill . . . to outward appearance a rude heap of massive stones piled one upon another."* Similar descriptions of the flat upland surface, not only here at Bigelow's Lawn but at other points on the top of the range, are found in the writings of later explorers and visitors, including particularly Starr King, the author of the classic volume on "The White Hills."† In his "Geology of New Hampshire," Professor C. H. Hitchcock‡ repeatedly draws attention to the importance of this smooth highland. "On descending from the top of Mount Washington to the Lake of the Clouds," he says, "the explorer will find a very flat region, running easterly into Boott's Spur and northerly along the east side of Washington. . . . The abyss in front is Tuckerman's Ravine, with tributary scallopings on the northwest sides. The erosion has been vertical, just as in a gorge worn out of a level plain. . . . Oakes Gulf, Huntington's Ravine [and the Great Gulf] are other deep gorges excavated out of this plateau, . . . This table land is less than ten miles in length and somewhat over 5000 feet in elevation."§ Several illustrations, some of them copied from Starr King's "White Hills," and others, as for instance, the heliograph opposite page 618, which are new productions, show the smoothly graded forms of the cones and bordering lawns, in contrast to the great re-entrant headwalls of the cirques or "ravines."

Although these upland lawns or pastures are most conspicuous on the south and east sides of Mount Washington, they can be traced all along the line of the Northern Peaks. From Boott's Spur the broad plateau known as Bigelow's lawn finds continuation between the 5000 and 5500-foot contours around the base of the great cone in a wide shelf that is known locally

* John Josselyn, *New England varieties discovered*, 1672.

† T. S. King: *The White Hills*.

‡ C. H. Hitchcock: *Geology of New Hampshire*. Final report of the State Geological Survey of New Hampshire, 3 vols., Concord, 1874-1878.

§ *Op. cit.*, vol. 1, pp. 609-610.

FIG. 2. Contour map of the Northern Peaks of the Presidential Range of the White Mountains. Copied with additions and slight alterations from the map published by the Appalachian Mountain Club.

R C, Ravine of the Castles; K R, King's Ravine; B B, Bumpus Basin; M R, Madison Ravine; J R, Jefferson Ravine; G G, Great Gulf; C R, Chandler Ridge; N C, Nelson's Crag; A G, Alpine Garden; H R, Huntington's Ravine; T R, Tuckerman's Ravine; B S, Boott Spur; B L, Bigelow's Lawn; L C, Lake of the Clouds.

as the "Alpine Garden." The semicircular headwalls of Tuckerman's and Huntington's Ravines have been cut far back into this portion of the lawn; but its gentle eastward slope is sufficiently well preserved to convey the impression of a nearly level upland which was once of great extent. See map (figure 2), and photograph (figure 3). Around and beyond Nelson's Crag, which rises as a low monadnock above the lawn, the graded slope continues, passing down the crest

FIG. 3.

FIG. 3. View on the "Alpine Garden" looking over the headwall of Huntington's Ravine. By E. H. Lorenz.

of Chandler Ridge for a mile and a half to an abrupt shoulder at 4000 feet, near the Halfway House. Here the end of the spur was trimmed away by glaciation during the excavation of the Great Gulf, the greatest of the White Mountain cirques. The carriage road takes advantage of this ancient graded surface to accomplish the last half of the eight-mile ascent from the Glen to the summit of Mount Washington. On the north side of Mount Washington the head of the Great Gulf cirque was eaten back beyond the limit of the lawn and up into the slope of the cone itself. On the northeast side of Mount Clay, however, another flat-topped spur appears

between two amphitheatres of the Great Gulf glacier, which is preserved down to the 4500-foot contour. Southeast and east of Mount Jefferson is a longer remnant of the old upland surface. At Monticello Lawn the presence of a considerable patch of boulderless ground in the mantle of glacial drift prompted someone several years ago to put out a croquet set, where visitors might play the game at the very top of the range. This lawn runs down the crests of the two

FIG. 4.

FIG. 4. View of the graded cone and "knees" of Mount Jefferson, seen across the Great Gulf from Mount Washington. By E. H. Lorenz.

"Knees" of Jefferson as far as the 4500-foot contour, beyond which, as in the case of Chandler Ridge, the ends of the spurs have been trimmed off by the Great Gulf glacier, leaving two large triangular facets (see figure 4). Around Mount Adams and its subsidiary summits the sides of the cones flatten perceptibly into graded lawns like those already described. Southeast of the peak of Adams, in particular, the graded surface reaches down to a broad shelf that overlooks the Great Gulf directly opposite to Chandler Ridge. The two remnants of the old graded slope agree perfectly in altitude, standing at 4000 feet.

Throughout the area just described the lawns are covered with loose rocks and glacial boulder clay. Although at first glance one would probably say that this is post-glacial talus, cracked off from the exposed ledges by winter frosts and pushed slowly down the slopes, the disposition of the fragments, and particularly the lines of white quartz blocks which may be seen trailing in the direction of motion of the continental ice-sheet, not straight down hill but obliquely down or even up hill, from striated parent ledges, indicate rather that this sheet of loose rock is not now on its way down hill, but rests exactly where the ice sheet dropped it. In the steep-walled ravines there has of course been considerable sliding of this debris in post-glacial time; but on the gentler slopes of lawns and cones generally it seems to record little if any recent movement. It is boulder clay in the first stages of production, which for want of a specific name we may call "block till."

While the lawns are thus virtually continuous along the line of the northern peaks from Boott's Spur to Mount Adams, the greater part of the crest of the range in this distance is occupied by the cones themselves. A brief description of these may now be given.

The Cones.—Washington, the highest of the cones by nearly 500 feet, is also the roundest. While it is somewhat steeper on the southeast side, the asymmetry is so slight that the mountain appears in profile as a rounded dome from every side. As already mentioned, however, the Great Gulf has been cut back into the north side of the cone fully half way to its summit. This extraordinary foreground, as well as the similar cirque re-entrants of Huntington's and Tuckerman's Ravines on the east side, lend variety to the appearance of the mountain as seen at close range from different viewpoints. The surface of the cone is covered even to its top with block till like that of the lower slopes and lawns, with which are associated peculiar streaks and patches of ordinary glacial boulder clay. The verdure of these patches, especially where they are well watered by springs so as to support a luxuriant growth of Alpine flowers, greatly relieves the cold gray landscape of the rocks. Here and there exposures of bed rock appear, especially on the southeast side of the mountain, where low cliffs may be seen; but these have in most places been so much cracked and loosened that the distinction between them and the scattered blocks is not easy to see. To some extent the ledges, particularly at the summit, show the flattish, smoothed crowns characteristic of glaciation, but there are no distinct striæ or grooves there. The presence of both boulder clay and erratic boulders on and around the summit proves, as Professor Hitchcock discovered in 1875, that the cone was completely covered for a

time at least by the great ice sheet. The boulder clay is much looser and much more largely composed of fragments of the local rock than that at lower altitudes, suggesting that the summit of this highest mountain of New England was not very long nor very deeply covered by the ice sheet.

Mounts Jefferson and Adams, whose altitudes are approximately 5800 feet, represent a rather different type of cone. Their summits are not rounded like the dome of Washington, but distinctly angular; and their eastern sides are much more precipitous than their western ones. On Mount Jefferson this asymmetry is very pronounced, as those have noticed who have approached the mountain from the northeast by way of the Gulfside or Randolph Trails. It seems at first sight as if the lack of symmetry were due primarily to the regional glaciation, which was here in a southeastward direction. The detachment of loosened blocks and talus on the lee side of these high cones would have left cliffs where ledges do occur, while the removal of talus and newly quarried blocks from ascending slopes on the northwest sides would naturally be slow and imperfect. It is not clear, however, how the ice sheet, passing over these cones from northwest to southeast, could steepen their southeast sides so much and at the same time fail to wear down to rounded outlines their summits. The form of the mountains differs from that of typical roches moutonnées chiefly in this angularity of their summits. The argument against regional glaciation as the controlling factor in the form of the cones finds further support in the symmetry of the sharpest and steepest of the peaks, Mount Madison, which, let it be noticed, is also the lowest, and hence the one which must have been most deeply covered by ice. Inasmuch as this peak is 900 feet lower than the top of Mount Washington, it can hardly have been buried by less than 1000 feet of ice, yet its symmetry is nearly perfect and its sharpness highly conspicuous. We must conclude, therefore, that the ice sheet has had little influence on the shape of these cones. They may be regarded rather as products of subaërial wasting.

The Cols.—In the cols between the peaks the evidences of severe glaciation are clear. Ledges at the "parapet" southwest of Mt. Madison, and others just north of the Gulfside shelter east of Mt. Jefferson, particularly, exhibit beautifully rounded northwest sides and ragged southeast faces. Among them are quartz veins whose polished surfaces bear distinct hair-like striæ of the southeastward ice flow. Since these points are only a little below the 5000-foot contour, it is clear that the more severe scrubbing of the ledges in them than of those on the summits of cones like Madison is due not so much to a greater thickness of ice as it is to the concentration of flow

where the ice crowded through the saddles. In the case of the Adams-Madison col, at least, the passage of the ice appears to have scoured the crest of the range into a characteristic hyperbola.

The Ravines.—It has been stated that the cones and lawns terminate sharply at the brink of steep walled ravines. This feature is to be seen in the photographs (figs. 3 and 4) and the map (fig. 2). Since an understanding of the ravines is necessary to a proper conception of the upland, attention may now be turned to them.

Until recently the White Mountain "ravines" have been generally regarded as the products of torrent sculpture, aided by frost and landslides.* It is plain, however, to one familiar with the origin of mountain forms that these great bowl-shaped depressions or "mountain colosseums," as Starr King graphically called them, are glacial cirques. That they are extraordinary, to say the least, was appreciated by those who early gave them the names of "gulfs," "basins" and "ravines." Their glacial origin, however, seems to have been overlooked.† Around the five northern peaks there are no less than eight of these cirques. They lie on all sides of the range except possibly the southwest, and trend in nearly every direction. In size they range from the Great Gulf, whose crescentic headwall is 1500 feet high and whose length, measured along the axis of the trough, is about three miles to the little bowl-shaped Bumpus Basin, with hardly one-third these dimensions. Some of the cirques like King's Ravine are isolated; others, like Jefferson Ravine and the Great Gulf, unite as tributaries to form a single great trough. In all the headwalls are precipitous and the rims well-defined.

In view of this sharpness of form of the cirques, one is surprised to find that local moraines at the mouths are wholly absent. Even the debris near the headwalls, far back within the ravines, is not so disposed as to demonstrate by any means the recent occupancy of the cirques by valley glaciers. In fact, the presence in King's Ravine of boulder clay carried south-eastward by the ice sheet far up into the cirque, and now lying undisturbed on its floor, where local morainic ridges ought to appear had local glaciers become re-established in the cirques at the close of the ice age, seems to require that the carving of the cirques took place before and not after the last epoch of regional glaciation. If any local glaciers whatever survived the ice sheet in the White Mountain ravines they must have

* C. H. Hitchcock, op. cit., vol. i, p. 623.

† Professor D. W. Johnson tells me that for several years he has cited the White Mountain ravines as examples of cirques to students in his class, basing this opinion upon the contour maps of the U. S. Geological Survey.

been rudimentary in comparison to the cirques which sheltered them, for the only heaps of locally derived rock debris lie close to the foot of the headwalls. It is, indeed, doubtful whether such rock heaps are not in every case avalanche deposits and rock falls similar to those described by Howe in the San Juan Mountains.*

Slight alterations of the cirque form by regional glaciation may be seen in certain details of slope. Near the top of the headwall of the Ravine of the Castles, for instance, the jointed ledges were heavily scraped by the ascending ice, developing distinct "roches moutonnées" which *face up hill*, and are closely followed, on the top of the Jefferson-Adams col, by glaciated knobs which face out over the head of Jefferson Ravine. Although the Ravine of the Castles and King's Ravine, which lie nearly parallel to the southeastward line of movement of the ice sheet, are symmetrical in cross section, the Great Gulf, which lay athwart the southeastward current, exhibits a steep wall on its left or northwest side and an exceptionally gradual slope on its right or southeast side, on which thousands of blocks lie scattered as if caught there in a pocket. Obviously there has been some rounding off of the rims of these cirques, where they were most fully exposed to the southeastward thrust of the ice sheet, and some concealment of their bowl-shaped floors by deposits of ground moraine. The greatest damage to their form as cirques, however, appears to have come from rock falls, avalanches, and more regular slides, during the post-glacial epoch, especially at the beginning, when the melting away of the ice from oversteepened and loosened cirque walls caused huge masses to fall or slip to the ground. The effect of these avalanches and slides has been to tear away the rims and to fill up the floors of the ravines, somewhat obscuring their cirque form. Kame ridges and irregular hummocks, and near the upper ends of the cirques moraine-like heaps of great blocks complete the jumble of waste which has accumulated below the cirque walls since the ice age.

Alternative hypotheses to account for the lawns.—The contrast between the smooth lawns with their gentle grades and the bold slopes and cliffs of the flank of the range is strong enough to demand explanation. It has been pointed out that where the graded upland surface passes farthest down along the crests of spurs, it seems to flatten out near the 4000-foot contour. It does not require much imagination to fancy this graded slope blending with wide lowland surfaces at about this altitude, even though no traces of such lowland surfaces now remain. In short, one is inclined to look favorably upon the

* Ernest Howe: Landslides in the San Juan Mountains. Colorado, U. S. Geological Survey, Professional Paper No. 67, 1909.

theory that the old graded slopes are the slopes of residual mountains which grouped themselves around broad intermont lowlands along the frontier of the New England peneplain.

At the same time the evidence is so fragmentary that other possible explanations should be considered. It might be suggested, for instance, that the flatness of the crown of the range is due chiefly to the more rapid reduction of the slopes above the tree line, where frost action and the movement of rock waste are more vigorous than in the forest. This hypothesis, however, has to meet the fact that since the last passage of the ice sheet over the range there has been almost no splitting apart of the roches moutonnées, and surprisingly little movement of the loose rock; and moreover it seems very improbable that the tree line has been at all constant in position through the Pleistocene period. Again, one might look for some structural control of the upland flats,—some dominant system of joints, or some very extensive development of schistosity in planes near the horizontal. The answer to this is simply that while the theory cannot be rejected, the facts thus far observed lend no support to it. Finally, it may be urged that the flattening out of these graded slopes, in their descent, near the 4000-foot contour is not as real as it appears to be; that the original well-graded slopes of the range have been so deeply and so widely scooped away by local glaciers and the resultant spurs have been so much worn, especially at low altitudes, by glaciation during the subsequent regional glaciation that the effect is a false appearance of an uplifted and extensively dissected cluster of low monadnocks.

While suspending judgment in choosing between these interpretations, it is interesting to note that the same gently graded upland topography occurs on the top of Mount Ktaadn in northern Maine. Tarr, in his paper on "the Glaciation of Mount Ktaadn"* thus describes it:

"The main part of the elevated portion of the mountain is occupied by the 'tableland' . . . from which several spurs extend as divides between stream valleys heading on the mountain top. In places this tableland is remarkably level."†

If there is any truth in the theory that the plateau-like aspect of the lawns is due to an over-emphasis of the pre-glacial graded slopes by the cirque cutting and general steepening of the lower portions of the flanks of the Presidential Range, it is to be noticed that this theory applies equally well to Mount Ktaadn, whose profound "basins," as Tarr showed, are glacial cirques like the "ravines" and "gulfs" of Mount Washing-

* R. S. Tarr: The Glaciation of Mount Ktaadn, Maine, *Bull. Geol. Soc. America*, vol. xi, pp. 433-448, 1900.

† *Op. cit.*, p. 440.

ton. It is perhaps of even greater significance, however, that Mount Ktaadn, like Mount Washington, stands at the headwaters of three great river systems, the Penobscot, Aroostook, and the St. John,—to which might fairly be added also the Kennebec, since this river system which now heads in Moosehead Lake, some distance southwest of Ktaadn, probably drained the slopes of the mountain in pre-glacial times. The occurrence of old upland topography in these two typically remote spots among the drainage systems of New England (see fig. 1) raises the question whether we ought not to expect remnants of the New England upland to survive at the extreme headwaters of these great rivers long after all traces of that upland had vanished from the more dissected region occupied by their larger branches and trunks. With this idea in mind it will be interesting to see if similar scraps of graded upland come to light in the Green Mountains and other remote inland places.

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