ART. XIII.—*On the Glaciation of Orford and Sutton Mountains, Quebec*; by ALFRED W. G. WILSON.

IN a report published some years ago Dr. Chalmers,* the Pleistocene geologist of the Canadian Geological Survey, places the upward limit of glaciation in the Eastern Townships of Quebec at 1800 feet above sea level. In a paper read a few months later at the Boston meeting of the American Association for the Advancement of Science, in 1898, Professor Hitchcock† drew attention to the fact that Orford mountain is striated from bottom to top and that the ice movement was in a southeasterly direction. Hitchcock however gives the height of Orford mountain as about 5000 feet. Principal Dresser,‡ a year later and working independently, drew attention to the presence of exotic materials and striæ on the summit of Orford mountain (2800 feet approx.) over 800 feet above the highest limit set by Chalmers. In a recent report to the State geologist of Vermont, Hitchcock§ restates his original observations and adds additional data. In a still later article, published in the *Ottawa Naturalist* for May 1905, Chalmers|| not only reasserts his original position without indicating in any way that he has re-examined the area in the vicinity of Mount Orford, but attempts to question the accuracy and veracity of both the observers whose results do not agree with his own.

During the past few years the writer has been collecting data for a study of the physiography of the St. Lawrence Plain and the adjacent areas. In carrying out these investigations it has been found necessary to review in the field practically all the work that had been done previously. New and it is believed more accurate determinations of the heights of all the prominent elevations on the St. Lawrence Plain have been made and independent studies of the Pleistocene geology of the district are under way.

While the physiographic studies are not sufficiently advanced to permit of immediate publication, the time seems opportune to offer the results of independent investigations which bear directly on the problem of the glaciation of Mount Orford and the adjacent peaks and ridges. Three new elevations are given which are based on barometric determinations that are

* Chalmers, Annual Report of the Geological Survey of Canada, vol. x, Part J, 1897.

† Hitchcock, Proceedings Amer. Asso. Adv. Sci., Boston, vol. 47, p. 292, 1898.

‡ Dresser, Canadian Record of Science, vol. viii, pp. 223-225, 1900-1902.

§ Hitchcock, Report of the Vermont State Geologist, p. 72, 1903-1904.

|| Chalmers, *Ottawa Naturalist*, vol. xix, pp. 52-55, 1905.

thought to be more accurate than the majority of the earlier observations. The method employed was as follows: An observer is stationed with one or two barometers at a point whose elevation is known from a railway profile. This observer takes readings during the working day at half-hour intervals and the data obtained are used to plot a time-pressure curve. In the field, barometers which were compared with the base barometers, both at the beginning and at the end of the day, were employed. The time of observation and the temperature were noted in each case when the field readings were taken. In cases where more accurate results were desired the field barometers were kept at the field stations for several hours and were read at half-hour intervals simultaneously with the readings of the base barometers. The elevations were later determined by reducing the readings obtained, corrections being applied for atmospheric temperatures. In this way a series of sixteen pairs of observations were taken and the six most closely accordant sets of readings were used in finding the height of Mount Orford as given here. In a series of over one thousand readings made by this method during the past two years, the writer has obtained some very satisfactory results where checks were afterwards obtained from railway profiles to determine the probable accuracy of the method employed.

General Character of the Topography of the District.

The eastern margin of the plain of the St. Lawrence is formed by the edge of a belt of crystalline and igneous rocks, the northward extension of the Green mountain range into Canada. The general trend of the structural lines of this belt of rocks is about 20 degrees to the east of north and we find that the trends of the main ridges and valleys in the vicinity of Orford and Sutton mountains are in conformity with the trends of the structural lines. The Sutton ridge, of which Sutton Mountain is the most important peak, consists of a central mass of gneiss flanked by quartzites and schists. It is the western of the two ridges which occur in this locality. Orford Mountain is the culminating peak of the Orford ridge, a topographic feature which extends into Canada from south of the Vermont boundary and lies immediately to the east of the Sutton ridge.

The central core of the Orford ridge is a diabasic rock and it is flanked by schists and serpentines. Between Orford mountain and the International boundary several minor peaks are developed on the ridge, occurring in the order named—Hog's Back, Sugar Loaf, Owl's Head, and Bear Mountain, the

latter lying in part to the south of the boundary. Three miles west of Bear Mountain a similar ridge known as Hawk Mountain is a prominent topographic feature.

West of the Sutton ridge, near the boundary, St. Armand Pinnacle is the culminating peak of a minor ridge of metamor-

1

Sketch plan of the area west of Lake Memphremagog, Quebec.

phic rocks which has a greater development south of the boundary.

The valley between Sutton ridge and Orford ridge is cut on softer schists and serpentines. It is drained by the east branch of the Missisquoi River. This branch crosses Sutton ridge in a deep gorge (two miles south of the boundary line), through which the Canadian Pacific Railway runs, and joins the north branch of the same stream at Richford, Vt. The valley west of the Sutton ridge, between it and St. Armand ridge, is drained by the north branch of the Missisquoi River.

East of Orford ridge the lowest portion of a broad valley is occupied by Lake Memphremagog, a long narrow lake which receives a considerable amount of drainage from south of the boundary. The waters of Lake Memphremagog pass out northeastward by the Magog River—a tributary of the St. Francis—and eventually reach the St. Lawrence River. On the Orford ridge Mount Orford has an elevation of 2820 feet; Owl's Head, 2465 feet; Hog's Back, Sugar Loaf, and Bear Mountains are considerably lower. The lowest parts of the transverse depressions on either side of Owl's Head stand at elevations of about 1250 feet above sea level. Sutton Mountain rises to 3120 feet, and the depression to the south through which the Canadian Pacific railway runs has an elevation of about 500 feet near Mansonville station. The Missisquoi River at Richford, Vt. stands at 443 feet. St. Armand Pinnacle has an elevation of over 2500 feet (Dresser). The surface of Lake Memphremagog stands at 682 feet (Feb. 3, 1892) above sea level.

Character of the Surface of the Area.

In the valleys the surface of the bed rock is usually buried under a cover consisting of both modified and unmodified drift. In a number of localities small outcrops showing striated surfaces are known. The directions of the striations indicate that the general direction of the ice movement in the valley was controlled by the structural trends of the valley sides.

On the higher ridges even to the very summits a cover of drift materials, more or less mingled with recent debris from local sources, is found. The rock exposures are usually more numerous than in the valleys, and the striated surfaces indicate that the general direction of ice movement has been in a direction lying about thirty degrees to the east of south.

Special Localities.

Orford Mountain.—The Orford ridge reaches its highest elevation about twenty miles north of the International boundary in the mass usually called Orford Mountain. The highest point of the mountain is located on a rounded dome-like prominence near the southern end of the local ridge that constitutes the mountain. The summit of the dome is marked by a small nearly level area a little less than a quarter of an acre in extent. In detail this summit plain consists of low ridges of trap with rounded contours, the general trend of these local ridges being about S. 35° E. The hollows between these small ridges are filled with loose debris which contains a few fragments of the bed rock, but the greater portion of which consists of material foreign to the mountain. The small bare

rounded rock ridge which constitutes the very summit of the mountain rises about two feet above the surface of the soil cover which lies in the adjacent hollow to the east of it. On the south side of the summit area one of the rounded ridges still shows small rounded hollows on its surface which are the markings Dresser referred to when he wrote of the occurrence of glacial striations on the summit of the mountain. The

2

FIGURE 2. Summit of Orford Mountain, a small rounded dome with glacial scorings.

writer has examined these markings carefully, but could find no evidence to show that these furrows were produced by weathering processes acting on joint planes, as suggested by Chalmers.* Indeed, of all the loose material occurring at the summit, only a very small percentage can be attributed to the local disintegration of the rock in situ. The depth to which the decomposition due to weathering has visibly penetrated the exposed rock surfaces is very slight, except along fracture planes. Microscopically all of the primary minerals are found to be much altered for a considerable depth, but the rock is not disintegrated. The distribution of the effects of weathering is found to be fairly uniform, specimens from the base having practically the same appearance as those from the summit. On the west side of the summit dome, a few feet from the

* *Ottawa Naturalist*, vol. xix, p. 53.

locality where the striations were noted, is a furrow about three feet in depth and of slightly greater breadth, partly filled with loose debris at its southeast end. The form and shape of the hollow suggest that a joint block was removed by the ice and that the cavity was afterwards somewhat rounded out by the corrasive action of the ice sheet.

The soil at the summit consists in part of a sandy material containing many small chips and fragments of loose rock. The writer made a collection of rounded, subangular, and angular fragments derived from 12 different kinds of rock, all of which were foreign to the summit of the mountain. Among the fragments are pieces of schist from near the base, and a number of small pieces of pink granite, gneisses of several types, and vein quartz. Hitchcock also has recorded the finding of a fifteen-pound boulder of gneiss in the same locality. The latter fragments are all unquestionably derived from the rocks to the north of the St. Lawrence river. The greater portion of the soil at the summit consists of a slightly arenaceous fine-textured grey clay which assumes a greyish-white color on drying. A qualitative chemical and a microscopic examination showed the presence of very small amounts of iron salts and of carbonates. Quartz sand is present in considerable amount, approximately 8 per cent, and the balance consists chiefly of kaolin, with a small percentage of mica, probably sericite.

A soil derived from the disintegration of the diabase of which the summit of the mountain is composed would be expected to contain much larger amounts of carbonates, would show a very much larger percentage of iron salts, and would normally be free from quartz. It is recognized that by the process of leaching the excess of the carbonates and of the iron salts might be removed in some cases, and that the quartz might be formed by the decomposition of the silicates. In this locality the soil is fine-textured close to the bed rock and it is not found to gradually grade downward into the underlying undecayed rock. It is also to be noted that this soil occurs less than three feet vertically below and horizontally, within a very few feet of the highest point of the mountain, and therefore it is not in a position favorable for the leaching action of soil waters. On the other hand, not only is the soil similar to that which is normally produced by the disintegration of the Archean rocks to the north, but also when its character is considered in conjunction with the other features already described, the cumulative evidence is such as to lead one to the conclusion that this soil also is of exotic origin. Since it is found to contain only a very small percentage of carbonates, one would infer that the limestones in the plain to the north

between the mountain and the main Archean areas had contributed but a very small percentage of the material of this soil.

On the slopes of the mountain, between the summit and the 2000 foot contour, erratics are fairly plentiful. The soil in which the trees and bushes on the slopes of the mountain are growing is similar to that at the summit and consists almost wholly of glacial till.

In conclusion it may be said that not only on the slopes adjacent to the summit but at the very summit of the mountain

3

FIGURE 3. Profile view of Owl's Head looking towards the northeast, showing the stoss and lee sides of the ridge.

itself are found practically all those data which are usually accepted by glacialists as evidence of ice transgression—till containing a large percentage of foreign material, erratics, and rounded and striated surfaces preserved on comparatively little decayed rock.

Other minor summits.—The Hog's Back and the Sugar Loaf mountains stand at a much lower level than Orford and were not specifically examined.

On Owl's Head at the summit rounded contours were observed on the northern and northwestern slopes, with a steep cliff face, presumably due to the plucking action of the ice, on the southeast [figure 4]. No striae were observed at the summit although the surface is well rounded, the curvature

being of the type that one would normally refer to the action of glacial ice even in the absence of striations, which would not be preserved on a rock surface where there was no protecting soil cap. In cracks and crevices at the summit there is an abundance of a sandy clay very similar to that found on Orford mountain. This soil contains numerous chips, many of which are of local origin. The summit rock is nearly bare except for the small amount of this soil found in the crevices and no large erratics were noticed. About twenty feet below

4

FIGURE 4. View showing the cliff face on the southeast side of the summit of Owl's Head.

the summit two pieces of vein quartz were picked up. On the slopes above the 2000 foot contour several small erratics were found in the soil cover, which consists largely of till.

Sutton Mountain.—The summit of Sutton Mountain, the highest ridge of the district, is heavily forested, and the surface of the ground is nearly all concealed beneath a moss carpet. Here and there the tops of minor ridges which cross the summit of the main ridge obliquely toward the southeast show rock outcrops. The soil appears to be much the same as on the other ridges of the district. At the summit the writer did not find any erratics, but this cannot be taken as conclusive that they do not occur within a few feet of it since they might easily be concealed by the vegetable growth of the area. A

number of erratics were found between 300 and 500 feet below the top. These included several pieces of a coarse grit which was probably derived from a basal member of the Potsdam formation, fragments of schists from the valley to the northwest, and a fragment of a coarse pegmatitic granite. At 300 feet below the summit a large boulder of Laurdalite from Brome Mountain, 14 miles to the northwest, was found. Several similar pieces were picked up below this contour.

The most interesting feature of Sutton Mountain, however, is the occurrence of a series of remarkably well developed V-shaped notches which cross the summit of the main ridge in

5

FIGURE 5. Summit of Sutton Mountain. A V-notch ten feet in depth with smooth sides, cut in gneiss, looking northwest.

a direction about S. 25 E. The sides of these small notches are planed off very smoothly, the west sides being the smoother of the two, in each case examined. The depth of these notches varies from four to about ten feet. The west side of one had a dip of 50° and the east side of the same notch was only a little less steep. This notch, whose form may be taken as typical of the form of all of them, was about ten feet deep and the ridges between it and the adjacent notches on either side had sharp crests as well defined as the ridge of the roof of a house. On the striated sides of these notches the large quartz masses in the gneiss were found planed off even with the rest of the surface. In all, twelve of these remarkable gullies were

noted and it is possible that others also occur along the crest of the mountain. They seem to owe their origin primarily to a system of joint fractures which loosened the blocks that once occupied the hollows. The smooth, even, striated sides are to be attributed to ice scouring.

Many of these small gullies cross the summit of the ridge and open out on each side over very steep cliffs. They constitute, in fact, very perfectly developed hanging valleys, but of a most unusual type in those instances where the hollow goes completely across the summit ridge.

St. Armand Pinnacle.—At St. Armand Pinnacle, on the lower slopes of the mountain, the writer has observed smoothed and striated surfaces on the bed rock. At the summit Mr. Dresser has noted similar striae trending to the east of south. A profile view of the peak from the west shows a gently ascending slope on the north side and a well developed cliffed face to the south—the latter presumably a plucked face.

Summary and Conclusions.

In conclusion it may be stated that not only in the depressions in this area, but also on all the important summits of the district, distinct and unmistakeable evidence of glacial transgression have been found. The cumulative character of this evidence has already been referred to, and one seems justified in concluding, with Mr. Dresser and Professor Hitchcock, that the height to which the ice sheet reached in this portion of eastern Canada is as yet an undetermined quantity.

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