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GEOLOGY 7

PLEISTOCENE GEOLOGY OF MOOERS QUADRANGLE

BEING A PORTION OF CLINTON COUNTY, INCLUDING PARTS OF THE TOWNS OF MOOERS, CHAMPLAIN, ALTONA, CHAZY, DANNEMORA AND BEEKMANTOWN N. Y.

BY
JAY BACKUS WOODWORTH

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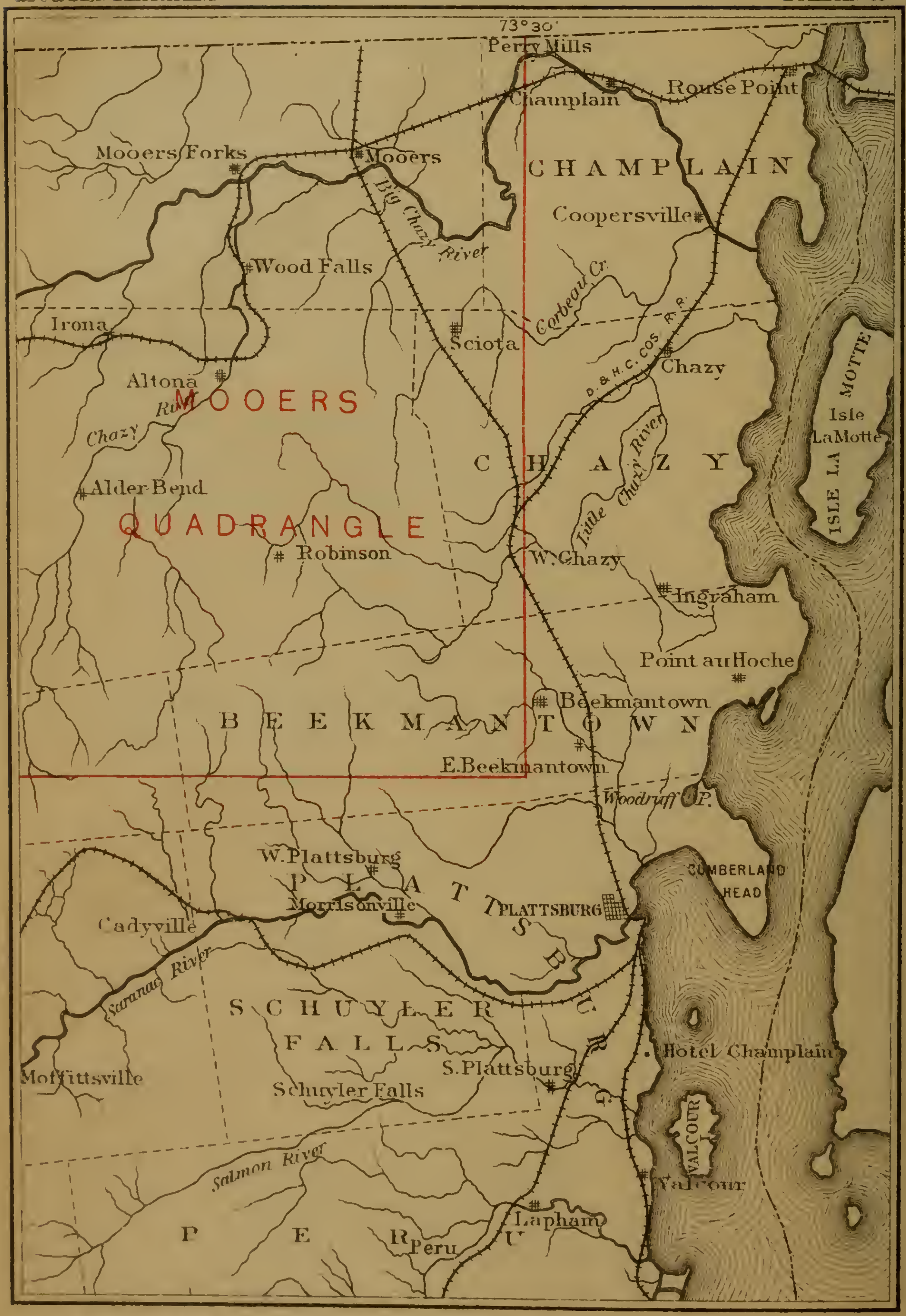
Plate 1



INDEX MAP SHOWING LOCATION OF MOOERS QUADRANGLE

SCALE OF MILES:

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A. HOEN & CO. BALTIMORE

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PREFACE

In 1900 Prof. J. B. Woodworth, of Harvard University, was requested by my predecessor in office, Dr F. J. H. Merrill, to take up a study of the problems of Pleistocene submergence in the Hudson river valley. As a first step, a careful detailed survey was made of the Hempstead and Oyster Bay quadrangles, the results of which were published in Bulletin 48 of the New York State Museum; then an extended reconnaissance of the valleys of the Hudson river and Lake Champlain was undertaken for the purpose of determining the nature and extent of the evidences of marine transgression, this reconnaissance being extended as far north as Montreal with the purpose of correlating the marine beaches there with those which had been recognized in Essex county. This reconnaissance in considerable detail was continued through the seasons of 1901 and 1902, after which it became evident that it was important to make a complete survey of some specific area where there was an abundance of phenomena bearing on the matter under investigation. Accordingly, during the field season of 1903, a complete study was made of the area of the Mooers quadrangle situated in northern Clinton county on the Canadian border. The detailed results of this work, illustrated by a geologic map, are given in the following bulletin.

John M. Clarke
State Geologist

INTRODUCTION

The Mooers quadrangle includes an area of about 225 square miles covering a part of the northeasternmost spur of the Adirondacks and the gravelly and sandy lowlands west of Lake Champlain. The international boundary line between New York and the Dominion of Canada forms the northern limit of the map [pl. 1].

The geologic description of the hard rocks of this area has already been given in a bulletin of the Museum by Professor Cushing. In this and earlier reports published under the auspices of the Natural History Survey of the State, brief references are made to the glacial and postglacial deposits which in this district occur along the margins of Lake Champlain. In the appendix to this paper will be found a list of the principal references, a number of which are quoted in the text.

The Pleistocene geology of this area is of peculiar interest because of the submergence of the Lake Champlain district beneath the sea in the closing stage of the Pleistocene period. The detailed study of the area was undertaken for the purpose of obtaining a more complete and accurate knowledge of the shore lines of this epoch of marine submergence than could be gained by the rapid reconnaissance conducted by the writer in reference to the same problem in the major portion of the valleys of the Hudson and Lake Champlain.

It is necessary to state here that the author found, on selecting this area for examination, that he had been preceded in the same quest by Dr G. K. Gilbert, of the United States Geological Survey. Through Dr Merrill, state geologist, Dr Gilbert very generously offered his field notes for such use as could be made of them, not only for the Mooers district but also for the northern flank of the Adirondacks as far west as Lake Ontario. These notes have been used first as guides for localities to be visited and secondly as important checks on the observations and conclusions of the writer, who wishes here to express his great indebtedness to Dr Gilbert.

SURFACE DEPOSITS OF THE AREA

The surficial or loose deposits of the Mooers quadrangle so far as known, pertain altogether to the Pleistocene period or to more recent accumulations which are still in progress. For the most part, these deposits are glacial drift, either very much as left by the retreating ice sheet, in the uplands above 600 feet, or, below that level, more or less rearranged by wave and current action on the bottom of temporary ice-barred lakes or at yet lower levels by the sea. The strictly glacial deposits are also the most recent of the glacial period and are presumably to be classed as of the Wisconsin ice epoch and as pertaining to the later portion of that time.

WISCONSIN EPOCH

The drift of this epoch forms the surficial deposits in the southwestern part of the quadrangle and is almost everywhere present in an unmodified form above the 600 foot level, though, in consequence of processes which will be described later, much modification of the drift has taken place at levels from near 900 feet downward.

The glacial origin of this material is shown by numerous glacial striae on the rock surfaces and by the direction in which it has been transported, as well as by the occurrence of characteristic recessional moraines.

Glacial striation

The direction and grouping of the glacial striae on this area, indicating the direction in which the ice moved across it, are shown on the accompanying map by arrows for particular localities at which the striae may be seen and by the pattern employed on the map for the ice-laid drift over the areas occupied by this material.[2] It will be noted that along the western border of the area the ice moved in a southwesterly direction, and that along the southern border it moved in a southerly direction.

The accompanying table of observed striae includes those noted in the field seasons of 1902-3.

Table of glacial striae

s. 61° w.	Covey hill, Can.; in road gutter on top of hill
s. 46° w.	Mooers; in public road, 3.1 miles n. of Irona railroad crossing
s. 36° w.[1]	Mooers; s. bank of Big Chazy near camp meeting grounds above Mooers
s. 56° w.	Altona; on sandstone ledges in woods s. of railroad, 2¼ miles w. of Irona, possibly off map
s. 56° w.	Altona; on old military road, ¾ mile e. of western edge of map
s. 46° w.	Mooers; on road, ¼ mile w. of Big Chazy at Wood Falls

[1] Locality farther east than others in this part of the table, where the ice moved more southerly.

[2] This latter plan has not been carried out.

s. 38°	w.	Mooers; faint striae, on sandstone, ½ mile s. e. from Wood Falls on wood road
s. 31°	w.	Altona; on Potsdam about 1 mile w. of "Rattlesnake den"
s. 21°	w.	Altona; s. of bend in public road; 1¾ miles e. of Alder Bend
s. 9°	w.	Altona; s. of e.-w. road, 1¾ miles n. by e. from Purdy Mill on sandstone
s. 10°	e.	Altona; on red sandstone in road gutter s. of Purdy Mill
s. 31°	w.	Altona; n. slope of Pine ridge 1.1 m. n. n. e. of Dead Sea
s. 26°	w.	Altona; on Potsdam sandstone by schoolhouse 3⅗ miles due e. from Altona
s. 30°	w.	Altona; in road gutter on grit, near brook just s. w. of Robinson
s. 1°	w.	Beekmantown; on summit of Rand hill by n.-s. road
s. 56°	w.	Altona; on old military road, 1¾ miles s. e. of Robinson on red sandstone; also s. 61° w.
s. 1°	w.	Altona; on military road 1⅛ miles n. w. from West Beekmantown Corners
s. 2°	e.	Altona; in road gutter of flat rock area e. of Corbeau creek, 2½ miles s. by w. from Sciota
s. 4°	e.	Chazy; 1¾ miles n. of West Chazy, on road to Sciota

Interpretation of the striae

The localities named in the above table are grouped as nearly as possible as they would be traversed in going from northwest to southeast so as to give readings along a line normal to the direction of ice flow, beginning on the northwest at a locality in Canada about 4 miles beyond the limits of the map, where the striation of the upper St Lawrence valley is well marked.

For the proper understanding of the divergence of the glacial striae toward the south and west in this part of Clinton county, it is necessary to consider the relation of the Adirondack mountain mass and the valleys which surround it to the ice sheet moving southwestward against it from the center of movement in Ungava. The fact that the ice sheet moved in the direction stated approximately along the lines of striation indicated on the accompanying map is attested by several phenomena: first, by the occurrence within this field of erratics derived from the basic eruptive rocks of the chain of paleozoic volcanic stocks which extend from the northern termination of the Green mountains north and westward to and beyond Mt Royal; second, by the character of the ice-worn surfaces southward in the Champlain valley; and third, by the position of moraines and deposits of gravel and sand laid down in temporary lakes held in on the northern slopes of the Adirondacks by a now vanished wall, which can be explained only by the former presence of an ice front along the flanks of the uplands.

All the facts indicate that the ice moved into northeastern New York in a southwesterly direction. Passing over the St Lawrence plain the ice moved southeastward into northwestern Vermont, and southward into the valley of Lake Champlain, pressing more strongly against the Adirondacks than against the eastern side of the valley. Another part moved southwestward up the St Lawrence valley into the basin of Lake Ontario. As the ice-sheet culminated in thickness and southward extension, it advanced over the outlying spurs of the Adirondacks, such as for instance Dannemora mountain, shown on the Mooers quadrangle. It moved up over the low platform of Potsdam sandstones flanking the Adirondacks on the north, with a southwesterly direction. The eastern margin of this platform forms the belt of higher ground entering the Mooers quadrangle from the northwest and extending through the Flat Rock area of Altona. Over most of this belt the ice moved under the influence of the relief of pressure which was found to the southwestward along the western base of the Adirondacks. On the south and east of this area the ice was drawn into the Champlain flowage. Thus we have in this district the topographic versant on which the ice divided, one tongue going southward to form the Champlain-Hudson glacier and the other southwestward to form the greater St Lawrence glacier. So far as present knowledge goes, it would appear that at the maximum of glaciation the ice passed quite over the Adirondacks, though it must have been in the highest part of that region much slackened in flow as compared with the freer run of the ice through the large valleys on either side.

In the till-covered area of the map, accompanying this report, in which district nearly all the striae were observed, the color representing the till might be made to express by a linear design the approximate direction of striation, and thus the lines along which the till of any particular place presumably has been transported. In such a pattern, of course, where observed striae are relatively infrequent, the lines of flowage must be largely interpreted; and in the southern part of the area, particularly in Dannemora, it may be that the striae when found would deviate somewhat from the lines as shown on a map. The method of interpretation would consist in distributing the lines of flow between the nearest observed striae as converging or diverging lines projected into parallelism with the nearest observed striae farther downstream. The attempt might be made to bend the lines so as to show how the local irregularities of the topography would ordinarily deflect the ice. In fact, only one station in this area was found in which it was clear that the striation had been thus influenced by local slopes.

It is important to note that, just as the ice moved southwestward across this district, so in the retreat of the ice sheet, its front would be expected to recede from the district as a wall of ice approximately at right angles to the lines of striation. From this may be deduced the probability that the northeastern slopes of the Adirondacks were freed from the Labradorian ice sheet while it still lay against the northern end of the Green mountains. As another probability in consequence of this mode of retreat, a connection would be established between the Lake Ontario basin, the upper St Lawrence and Lake Champlain along the lowlands at the base of the Adirondacks before the lower St Lawrence was open for connection with the Atlantic ocean. Other effects of this mode of retreat of the ice front would be found in the existence of shores of temporary, ice-dammed lakes on the Adirondack side of Lake Champlain, which had no counterpart on the Green mountain side so far north and at so early a time as when the ice was but partly withdrawn from the upper, open mouth of the Champlain valley. It might well thus be found that beaches exist on the west side of the valley at high levels without their counterpart on the east side of the valley. These possible deductions from the striation of the region in relation to local relief are mentioned because, as will later be shown, certain observations lead to the same conclusions.

Glacial erosion

It is difficult to estimate the amount of erosion by the direct action of the ice sheet in this area. The principal streams are obviously not flowing in their preglacial or interglacial channels, for, except where they are intrenched in modern postglacial gorges, they have shallow beds in the drift coating with here and there bottoms of bed rock, evidently along courses which have been taken since the disappearance of the ice from the uplands and the withdrawal of the bodies of water which submerged the lowlands on the north and east. The earlier channels of these streams, if such exist, have not been discovered.

Glacial deposits

The entire area of this quadrangle appears to have been covered with deposits by the ice sheet; but in more than half of the area the drift has either been removed or worked over by waves and currents to such an extent that at least the upper visible portion of the surface material in the low grounds can hardly be called glacial drift. The unmodified glacial deposits occupy the higher grounds everywhere above the 900 foot level in Altona and the northeastern part of Dannemora and the northwestern part of Beekmantown.

Till of the uplands

In the elevated grounds above the zone of wave action the glacial deposits are mainly unstratified and of the class denominated till or ice-laid drift. The material of this drift is largely the Potsdam sandstone derived from the immediately underlying and adjacent area of these rocks on the north. Angular slabs of the sandstone are almost everywhere met with in the till area. The finer debris between the slabs is also prevailingly of the grayish white gravel or sand from the same rock. But fragments of other rocks, more commonly of igneous origin occur, and evidently have traveled from known outcrops of such rocks in Canada.

The till in the uplands varies much in thickness. A glance at the accompanying map shows by the distribution of outcrops that very slight excavations along certain roads have served to reveal the rock.

In the plateau of sandstone about Alder Bend, the till, so far as can be determined for considerable areas, is probably over 20 feet in thickness, but except in certain restricted belts, where it is heaped up, the till appears to be a relatively thin sheet.

Till of the lowlands

In the low district, below 900 feet in elevation, there are several areas which appear to be distinctly of an ice-laid character; the general distribution of erratics over the surface, and the frequent occurrence of elongated, low hills with wave-washed drift, are evidence that the surface was originally, or at least when the ice sheet disappeared, supplied with an abundant ground moraine of a somewhat diversified relief.

Probable drumlins. In the eastern part of the town of Mooers, there are several low, oval-shaped hills, about half a mile long at the base and extending from east of north to west of south, whose general appearance recalls that of the drumlins of Massachusetts except that the summits and frequently the slopes of these hills are ribbed with beaches or strewn with wave-washed material. These hills lie between the 240 foot level and that of 340 feet, and they rise about 50 feet above the ground at their base. There are three good examples northwest of Mooers Junction, each with beaches on its western slope. The eastern slope of these three hills is decidedly glacial in appearance, strewn with large and small erratics without distinct marks of wave erosion. No cuts have been made in them except for one north of Sperry brook and within a mile of the international boundary where the road cutting on the west slope shows a very thick accumulation of thoroughly rounded waterworn beach pebbles at about 350 feet above present sea level. The eastern slope of these hills appears to be very much as it might have been left by the retreating ice sheet. In a later chapter of this report I shall consider the possibility of the ice front resting against these eastern slopes while waves beat on the western slopes. In the case of the ridge about 1 mile northwest of Thorn the top is wave-heaped, and to the southward both slopes show the wave-assorting of the gravels.

The hills of this class between Mooers and Biddles crossing are wave-marked on the eastern slope and near the crest. The southernmost of the two hills just north of Bullis brook has a decidedly drumlinlike contour.

The major axes of these hills do not coincide with the direction of glacial striation in their vicinity. Their axes lie to the west of south, while the glacial striation, so far as it can be inferred from

Plate 2

Sketch map of Mooers quadrangle showing known frontal moraines (thick lines); approximate ice fronts (thin lines), and probable frontal moraines (broken lines). The arrows indicate direction of glacier motion

Frontal moraine ridges north of the Altona spillway between Altona and Sciota. Looking northeast scanty observations in the low ground, was in that part of Mooers township between s. w. and s. w. by s.

Frontal and recessional moraines

There are a number of patches of thickened till within the area covered by this map, which have been deposited at or near the ice front in the last stages of the retreat from the State. The accompanying sketch map [pl. 2] shows by heavy black lines the supposed position of the ice front when these deposits were made. The clearest examples occur in the depression between Rand hill and Jericho. The road from Jericho to Sandburn brook skirts the eastern base of a morainal terrace. The southern slope of the 1400 foot hill, from 1½ to 2 miles east of Jericho, is characterized by strong morainal ridges apparently deposited on the margins of local tongues of ice sweeping about the eastern and western slopes of this hill. There are other local patches of hummocky till along Smith Wood brook. The detailed mapping of such deposits in the thick woods in the southwestern corner of the sheet appeared impracticable, and there are probably lines of ice front yet to be traced in the area. A very distinct series of frontal deposits appears to the southeast and southwest from Big hill in Altona. The same deposits probably extend through the vicinity of Alder Bend toward Ellenburg. This line probably is to be associated with the heavy drift deposits about the southeastern base of Rand hill between 700 and 900 feet in elevation, where a few kettle holes and a decidedly marginal moraine topography are well developed.

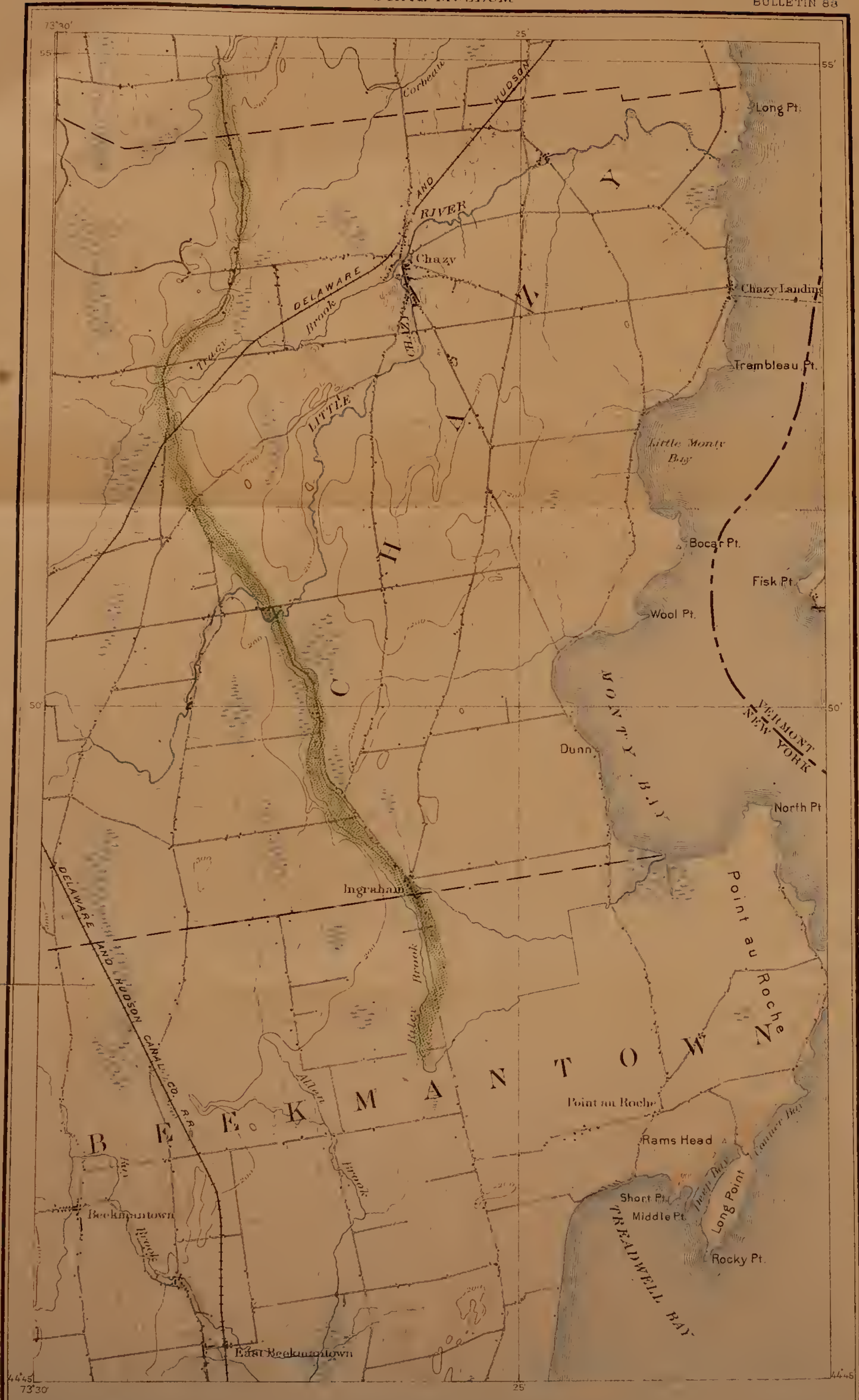
Frontal moraine ridges [*see* pl. 3] occur at an elevation of about 600 feet, north of Altona and along the road between that village and Sciota, on the eastern and northeastern border of the Flat rock area. Strong morainal ridges, apparently lateral moraines, appear at the southern end of Pine ridge between the 600 foot and 700 foot contour lines and in an *en échelon* arrangement continue along the eastern base of the high ground from Altona into Beekmantown, sometimes much modified by wave action on their eastern slopes. The most conspicuous example of a wave-washed moraine or boulder belt occurs in the ridge just north of the Little Chazy river, where, according to the map, it traverses the 600 foot contour line. This moraine, northward to where it is lost on the bare, flat rock, is a pile of blocks mainly of Potsdam sandstone, forming one of the most striking and singular glacial deposits of the northern Adirondack region [pl. 13, showing a photographic view of the eastern, wave-washed slope of the moraine taken near the road over the hill].

Between Deer pond and Cannon Corners, from the north and south road going up the hill on the west to 800 feet in elevation, the slope is encumbered by a peculiar deposit which in many respects suggests strong water action as having shaped the gravels and cobblestones, but the unstratified masses higher up show that the ice sheet was concerned in the final distribution of the material.

The deposit lies immediately east of one of the large, barren rock tracts locally known as Blackman's rock, the interpretation of which is discussed below under the head of Spillways. The deposit probably marks the ice margin. Certainly, a little to the northwest in the valley of the English river and beyond the limits of the map, there is a well defined, low, bouldery moraine made by the ice sheet moving southwestwardly against the ground which here rises to the west. Stafford's rock, another spillway, extends northward from this deposit towards "the Gulf," a ravine near the boundary line, on the southern side of which heavy boulder deposits again appear.

In fact, the whole northern slope of the Adirondacks within the limits of this map and along the western bordering area is marked by deposits showing the retreat of the ice sheet. Almost everywhere from an elevation of 900 feet down to 700 feet there are marked signs of the interaction of powerful streams of water flowing along the ice margin, sweeping bare large tracts of rock and depositing bars and ridges of coarse cobbly drift, now in the open path of the torrent, now against the ice itself. The result is that the discrimination of rudely assorted, stream-transported blocks of the Potsdam sandstone from accumulations of similar material dumped at the ice margin or pressed by the ice into low ridges is often difficult and perhaps impossible.

Other small and apparently disconnected patches of frontal moraine habit appear at Wood Falls and in the low country north of Mooers Junction, between the elevations of 300 feet and



Topography by E. C. Barnard, U. S. G. S.
Surveyed 1893 in cooperation with the State of New York.

THE INGRAHAM ESKER

J. B Woodworth 1903.

Scale 1/62500

Contour interval 20 feet
Datum is mean Sea level

Contour Interval 20 feet
Datum is mean Sea level

320 feet. The latter deposit probably owes its distinctness to its being defended from strong wave action, which elsewhere to the southeast has locally greatly modified any such glacial deposits. About 2 miles east of Sciota on the northeast bank of Corbeau creek, there is a belt of morainal topography with deposits composed of stony till. It is probable that these deposits mark the position of the retreating ice front along a northwest and southeast line. I have drawn such a line on the accompanying sketch map [pl. 2].

Glacial drainage and spillways

Of the water action which went on, in and about the glacial sheet in this area, the usual results in the form of kames, eskers and sand plains are inconspicuous. One of the largest and finest eskers in the State, however, occurs on the area of the Rouse Point sheet immediately east, but no definite eskers have been seen on this area. This esker, which is traceable for about 10 miles as a more or less distinct ridge, is remarkable as showing how little modification of glacial form may be produced under favoring circumstances by submergence beneath the sea. The bearing of this esker on the late geologic history of the Mooers area is so close that the following notice of the deposit is here inserted.

Ingraham esker

This esker appears first to have been recognized by Dr Gilbert, who mentions it in his unpublished notes on this region. The village of Ingraham is strung along the eastern slope of the ridge and suggests the name here given. The accompanying map [pl. 4], with contours drawn by E. C. Barnard of the United States Geological Survey, gives a good idea of the course and position of the esker.

It is to be noted that its course is southerly in compliance with the direction of ice movement in this part of the Champlain valley. The short interruptions through which the several small streams pass are presumably original, low places in the ridge. Thus in the case of the Little Chazy river, it is not probable that the ridge at the point where it is crossed by that stream was originally much higher than it now is, else the stream would have been diverted to the south along the course of Riley brook and so escaped to the sea or Lake Champlain. Such notches are normal features in many eskers where no streams occur. The marked crease on either side of the esker is quite characteristic and suggests that, as has been noted of some eskers in the upper Mississippi valley, the glacial stream occupied the bed of an older valley. The esker ends rather abruptly south of Ingraham and affords no evidence of having been the path of a stream connecting directly with a frontal outwash plain or esker fan.

I have examined the major portion of the length of the esker in the search for shore lines. Dr Gilbert first noted slight traces of a beach near Ingraham. Both the esker and the adjacent swampy depressions unfilled by marine or lake deposits show that this belt, which lies from 3 to 5 miles distant from the beaches at the base of the adjacent high ground on the west, received very little sediment during the sojourn of the sea over this field and thus is in sharp contrast with the deposits of marine sands and clays which occur along the lake shore. Below Ingraham the base of the esker is contoured by the 140 foot line; near its northern end by the 200 foot line. The ridge itself seldom if ever rises more than 40 feet above the adjacent low ground.

Deltas contemporaneous with ice fronts

Two classes of deltas of gravel and sand may arise along the margin of an ice sheet. First, those produced by the outwash of sediment from the ice by the discharge of its drainage; and, second, those deposits which are laid down by streams flowing toward the ice margin from the open country which it has perhaps just vacated. Deltas of this latter class may form terraces banked up against the ice margin, or, where temporary lakes form along that margin, the delta may take on its typical form and structure and not be distinguishable in itself from a delta built in any ordinary nonglacial body of water. All the principal streams in this area exhibit occasional deltas of gravel and sand, the upper ones of which are probably to be regarded as contemporaneous with the retreating ice sheet.

Alder Bend deposit

Along the banks of the Big Chazy river, from half a mile to a mile above Alder Bend, there is a deposit of gravel and sand mainly developed on the western bank of the stream. This appears to have been made in a temporary lake whose surface approximately coincided with the 1080 foot contour line, but no other evidence demanding such a lake for its explanation has been observed.

Deer brook deposit

On the north branch of the Big Chazy river northwest of Irona, there is a noticeable area of sands often fine, which is evidently the remains of a delta made on that stream. The deposit has suffered some dissection. The tops of the remnants lie between the 660 foot and 700 foot contour lines and indicate a local water level somewhere between these hights. No definite margin was detected in this deposit to indicate whether it was built up against the ice margin or under the free conditions of open water. The fineness of the sand toward the eastern extension of the deposit favors the latter supposition.

Altona deposit

A smaller delta than the preceding constitutes the flat ground on which a good part of the village of Altona is built. This deposit is decidedly gravelly south of the railroad. Just north of the railroad and west of the station, there is a deposit of fine sand, probably the lobate, free margin of the delta. All the circumstances here point to the building of the deposit in a body of water whose level corresponded with the 640 foot contour line, traces of which in the form of beaches occur to the east of Altona village. It is probable that the delta above described on the north branch of the Big Chazy was deposited earlier than this one in a higher water stage. The Altona delta appears to have been built by the Big Chazy before it had excavated its present course to the east of the village.

Deposits of gravel and sand in the form of deltas occur at lower levels, but they are so clearly associated with the marine invasion of the district that reference to them is deferred to a later page.

Spillways and the flat rocks

The most singular feature of the surface in the towns of Altona and Mooers is the occurrence of large tracts of the Potsdam sandstone, exceeding 12 square miles in area, barren of glacial drift. These bare areas are not entirely valueless, for the reason that in the proper seasons a large yield of huckleberries is obtained from these tracts. In the year 1902, $4000 worth of this fruit was sold by one concern alone from gatherings on the Flat Rock southeast of Altona.

The Altona Flat Rock is the largest of these barren tracts. Two very small and probably originally continuous bare areas known as Moose and Jericho rock occur at an elevation of about 1500 feet on the hillside southwest of Jericho. Southwest of Cannon Corners, extending on the unmapped area west of this sheet for the distance of about a mile and a half to the south, is Blackman's rock. Northwest of Cannon Corners and beyond the limits of the map is another tract known as Stafford's rock, north of which along the international boundary line is another area marginal to and extending west from "the Gulf," an abandoned river gorge and waterfall [*see* pl. 5].

Between Sciota and West Chazy, at elevations ranging from 260 feet to 500 feet above the sea, are small but noticeable areas of the Potsdam sandstone, from a quarter of a mile to half a mile across, bare of drift. The latter occur in the zone of wave action following the disappearance of the ice, the drift is not very thick about their margins, and their occurrence does not appear to demand a special explanation. It is different, however, with the larger areas lying above the 600 foot but mainly between the 700 foot and 900 foot contour lines; a system of bared rock surfaces which extends with slight interruption from the Canadian border on the north across the present lines of drainage around the northern slope of the Dannemora massif to the head waters of the Little Chazy river. With this system "the Gulf" on the boundary line near Covey hill is intimately connected.

To Dr Gilbert belongs the entire credit not only of looking for and finding these features, but also of having explained them.

The explanation depends on a simple consequence of the retreat of the ice sheet from high ground sloping toward its front. In the larger valleys blocked by the ice margin, contemporaneous glacial lakes will result. These lakes will have their outflow along the lowest point in their borders; thus the discharge may take place across the divide at the head of a valley, the usual condition; or it may take place along the ice front; or it may cut into a ridge which separates this valley from the next one. Where the land is relatively smooth, the drainage from the ice or that flowing toward the ice may be compelled to flow for miles along the front before discharging into the open country or a static body of water. All of these discharge ways along the ice front are denominated spillways by Dr Gilbert.

Jericho spillway

The first signs of a spillway in this district appear in Moose and Jericho rock, above mentioned, on the northern slope of Dannemora mountain at an elevation of about 1500 feet. When the ice sheet had disappeared from the crest of this massif, its front, probably extending northwest and southeast at right angles to the general line of motion, would have allowed the discharge of the waters confined along the northern slope of the mountain through the pass of Stillwater brook. The scouring of the rocks would thus be accomplished.

Great Flat Rock system

That the flat rock areas extending from Altona to "the Gulf" at Covey hill in Canada belong to a single great stage, is shown by their approximate agreement in range of altitude between 620 feet and 920 feet, their alinement along the same general slope, and by their approximate continuity.

Though the accompanying map shows considerable intervals of till-covered rock between the several bare rock tracts within the area, it is probable that a different mapping would somewhat extend the area assigned to the water-swept rocks. Between the Big Chazy south of Altona and the vicinity of Irona the original area of bared rock is undoubtedly much greater than is represented on the map. The district has been overgrown by forests and covered with vegetal debris. Here and there are certainly clumps of till or rudely assorted, coarse debris. I suspect also that west of Irona, toward the western margin of the quadrangle, what I have mapped as ice-laid drift may in reality be in some part torrent-made debris; nevertheless, I was not able to come to such a decision regarding it at the time of going over it.

In the accompanying sketch map [pl. 5] I have attempted to show the fullest extension of the flat rock areas from Altona to those on the northwest.

Altona Flat Rock. This is the largest of these spillways in the district. It is at least 5 miles in length and varies from 1 to 2 miles in width. A number of its features are worthy of note.

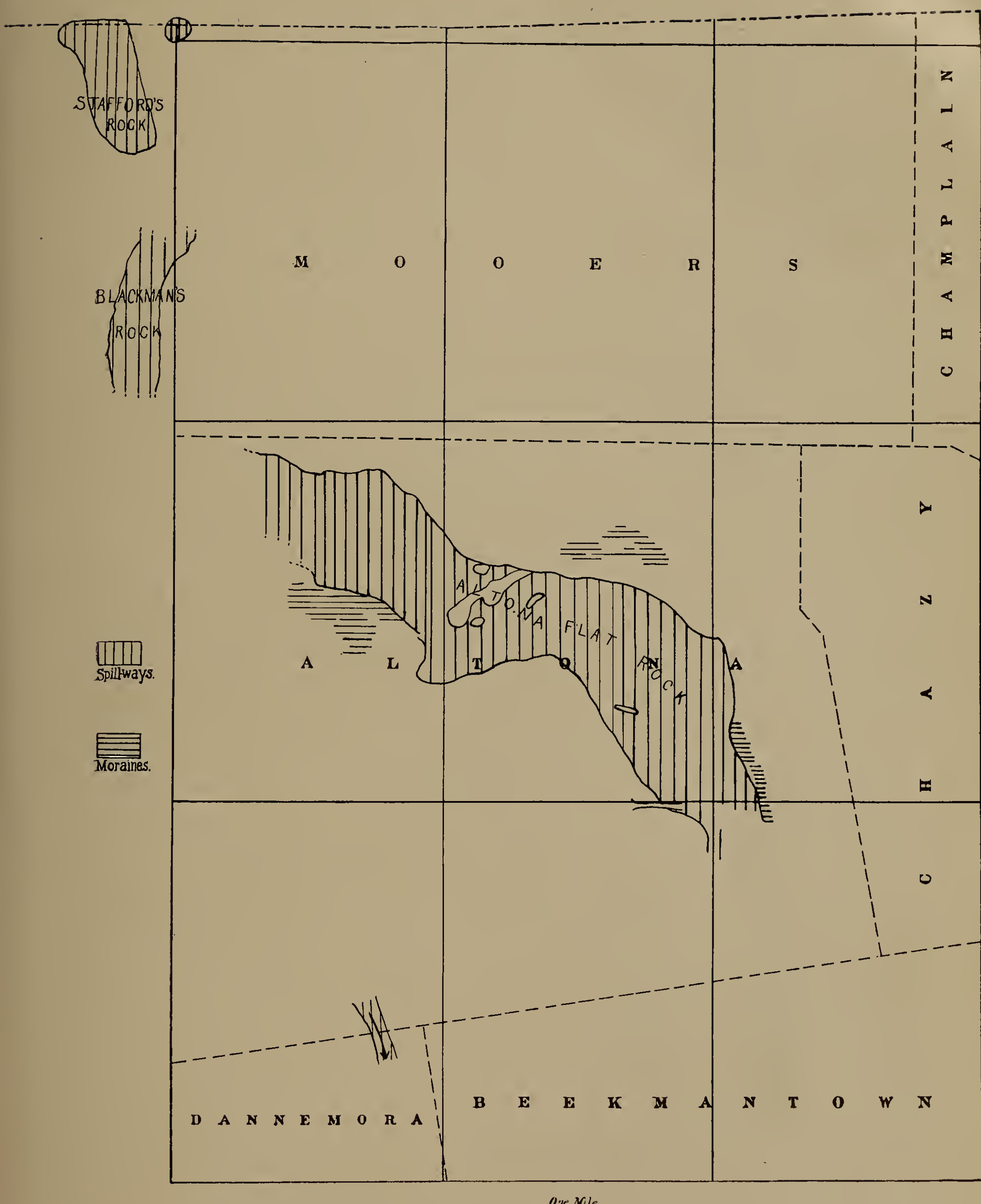
Cold brook, one of the head streams of the Little Chazy river, flows southeastward along the strike of the Potsdam (Saratogan) sandstone in a depression about 100 feet in depth.

The southern and higher margin of the stripped area is roughly determined by the 900 foot contour line. Its lower margin on the north and east is bounded by a beachlike deposit of waterworn cobbles at about 680 feet. For about a mile along this border the bare rock descends to a lower level (630 feet). On the southeastern extremity of this margin the bare ledges of "Pine ridge" are extended southward by a bouldery moraine which I have called Cobblestone hill. The wave-washed slopes of a portion of this moraine are evidently later than the moraine, which must have been constructed when the ice sheet lay against the northern and lower margin of the stripped belt.

The surface of the flat rock bears a few isolated patches of what appears to be till, remnants of the deposit which was laid on by the ice sheet during its occupation of the belt. Two of these patches of conspicuous extent are shown on the map. The boulders in these deposits are largely of the local rock, and many are well rounded, and it is possible that the deposits, as Dr Gilbert has suggested to me, are of torrent origin even where the rocks are decidedly angular. Loose, frost-riven blocks of the sandstone and the pebbles and sands derived from the secular weathering of the Potsdam are the sole surficial rock debris over most of the flat rock area [pl. 6].

There are several noticeable rock cuts which indicate the action of powerful streams capable of removing blocks of the

Plate 5



Sketch map of the Spillways, from the Canada line to the Little Chazy river, on and west of the Mooers quadrangle

View in the Altona " flat rock " spillway, about ¾-mile northwest of " Dead Sea ;" elevation 750 feet, looking s. 26° w.

Plate 7

The Dead Sea in the flat rock area southeast of Altona, showing a current-washed pool in the Potsdam sandstones; view from the head of the gorge. Looking east

Plate 8

The Dead Sea in October, 1902, looking s. 76° w.

Plate 9

View from western end of Dead Sea looking northeast to north wall, showing Potsdam sandstone and high water mark

Plate 10

View near Dead Sea, from east end of pool 100 feet east; looking north over the washed ledges of Potsdam sandstone, dipping away from observer rock as fast as they were loosened. Such excavations as "Foxhouse gully," "Rattlesnake den," and "Leadmine gully" near Altona, if not existent previous to the time of the stripping, would seem to owe their origin to streams flowing down the natural slope of the rocks rather than to glacial torrents.

At the southeastern end of the area, about a mile northeast of Robinson, there is a deep trench not shown by the contours of the map. This trench extends partly through the till-covered rocks about the southern margin and in places is as much as 50 feet deep. At the time of my visit in 1902, there was a small stagnant lakelet held in by driftwood near the eastern part of the channel. Westward the channel passes into a partly drift-filled vale with kamelike habit, suggesting the presence of the ice sheet during the cutting of the gorge. It is probable that the channel is due to the escape of waters from the head of Robinson brook at a time when the ice front was passing away from the vicinity. That the channel represents glacial drainage rather than natural stream work is shown by the manner in which it cuts across the low spur of the sandstone shown by the northward loop in the 900 foot line on the map.

A more pronounced channel with a remarkable pool is found at Dead sea. This lakelet is apparently one of the group of abandoned waterfall pools, for the reason that no permanent stream capable of making so large an excavation now traverses the area [pl. 7-10]. The waters which produced the Dead sea rock basin evidently flowed eastward; the same is true of those which produced the channel near Robinson. All the ascertained phenomena from this district bearing on direction of water movement show that it ran eastward across the col at "the Gulf" south of Covey hill; southward along Stafford's and Blackman's rocks; thence southeastward past Irona and over the Altona Flat Rock district.

In the case of the Altona Flat Rock tract, it is to be noted that bared ledges begin on the west at a point where the retreating front of the ice sheet might have diverted the Big Chazy river to the eastward along the ice margin; and, whether or no waters came along from the west, including those of the north branch of this river, some scouring of the drift would thus have been accomplished.

The mere breadth of the Flat Rock area might be explained by the gradual stripping of the drift along the receding ice front, without making it necessary to suppose that this belt was at any one time entirely covered by a torrent. The bare surface of Pine ridge, north of the deep vale of Cold brook, however, makes it difficult to see how a stream of small width as compared with the breadth of the stripped belt could have followed the retreating ice front to the north of this depression. A broad and powerful torrent of waters comparable to that which must be evoked for the work done at "the Gulf" could reasonably be supposed to have filled this depression and scoured the rocks on either side. While some of the phenomena are explicable on the hypothesis of a continual shifting of a small stream, there are still other considerations which appear to demand a broad and powerful torrent flowing over the district. Thus, in the case of the Dead Sea basin, its reported depth of from 42 to 90 feet appears to be greater than can be expected for the work of so slight a fall as the rock cliff [*see* pl. 8] at its head would indicate if the stream were a small one; but it is quite conceivable that a heavy torrent might have produced the results.

The location and vertical distribution of beaches about the southeastern end of the Flat Rock area and for a considerable distance along its northern margin show that the torrential waters which produced this field of bare ledges discharged into a standing body of water along the course of the Little Chazy from 3 to 4 miles west of West Chazy at an elevation at least 600 feet above the present sea level. The disposition of the cobbles, gravel, sand and clay which must have resulted from the stripping of such large tracts of drift is not altogether satisfactorily accounted for. It will be noted on the map [pl. 26] that the marine-modified drift south and west of West Chazy must be relatively thicker than is this group of material north of that village, for there are no outcrops of the bed rock observed in this survey in this southern belt between the 300 foot and the 700 foot lines. Heavy bars and ridges of waterworn drift there occur, and the unusually thick deposits are probably to be attributed primarily to the wash from the flat rock districts.

A full and satisfactory account of this series of spillways can hardly be presented till the region on the west of the Mooers quadrangle has been mapped. The outlines of these bare areas shown on the sketch map [pl. 5] are mere approximations obtained from a single traverse of the area between the north branch of the Big Chazy and "the Gulf."

Blackman's rock. Half a mile southwest from Cannon Corners there begins a bared strip of the Potsdam sandstone which stretches southward nearly to the north branch of the Big Chazy river. Only the northeasternmost extension of this spillway appears on the Mooers quadrangle. This spillway stands at an elevation of about 800 feet.

Stafford's rock. This stripped area lies wholly west of the Mooers quadrangle and extends from near the north bank of the English river toward "the Gulf" on the south side of Covey hill. It is reached by taking the first left-hand road north of Cannon Corners, which may be followed out northward to "the Gulf." The area appears to be separated from the flat rock at "the Gulf" on the international boundary by a torrent-washed or at least a bouldery moraine.

Armstrong's bush flat rock. The settlement in the wooded district of the northwestern corner of the Mooers quadrangle is known as Armstrong's bush. In the extreme northwest corner of the quadrangle and extending across the boundary line into Canada is a small stripped area lying between 750 feet and 770 feet elevation and at the top of a low hill. Its relation to the other spillways is not perfectly clear.

From the distribution of the frontal moraines and these spillways, it would appear that for some time before the ice sheet melted away from the north slope of Covey hill, its edge as an unbroken wall extended along the northeastern face of the Adirondacks between the 680 foot and 900 foot contour lines from Covey hill southeastward to the Little Chazy river in the vicinity of West Chazy. At this last named locality, at least in the later stages of the torrential action along its border, the ice front turned eastward across the valley of Lake Champlain but without leaving, so far as is at present known, any definite frontal deposits. In front of the ice over the southern part of the

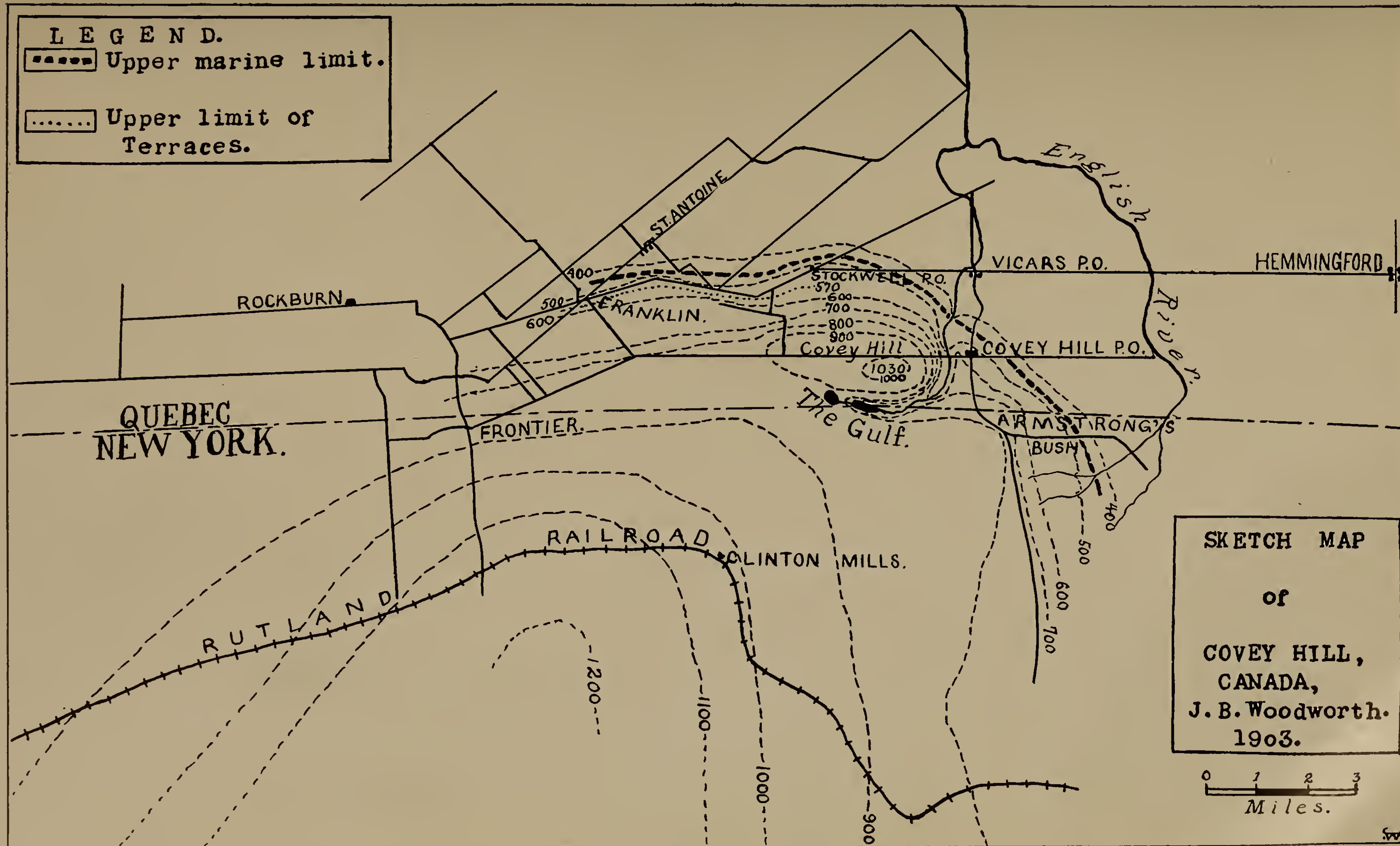
Champlain valley stood a fresh-water lake held in on the north by the ice front.

With the retreat of the ice from the northern slope of Covey hill, the waters heretofore pouring along that front on the west of the hill and forced over the col into "the Gulf," began to escape around the northern slope, thus leaving "the Gulf" and its waterfall without an apparent cause for existence. The pool at the base of the fall remains as a lakelet fed by springs, an "abandoned Niagara."

"The Gulf" at Covey hill. Mention must be made in this account of the most interesting feature connected with these spillways in the remarkable ravine known as "the Gulf," which lies just beyond the northwest corner of the Mooers quadrangle and partly across the international boundary. Its importance depends on the light it throws on some of the problems which arise from the occurrence of shore lines and spillways within the limits of the Mooers quadrangle. The general topographic features of the vicinity of "the Gulf" are shown on the accompanying sketch map [pl. 11].

"The Gulf" is quite as remarkable as the chasm of the Ausable. It appears to have been visited by Ebenezer Emmons, the geologist in charge of the second district, and is briefly described by him in his report on Clinton county in 1842 as being "300 feet deep and about 16 rods wide." He mentions the statement that the small lake at the bottom is 150 feet deep, the accuracy of which may still be doubted. "At the present time," he states, "no causes are in operation sufficiently powerful to remove the broken masses from a gorge of this description. . . At this place there is merely a small rill discharging itself from a small lake of dead water, insufficient in itself to accomplish any perceptible change. To account for the present condition of this rock, we have therefore to go back to a period, when some current swept through this gorge with great force and power; for by no other means could the materials, which once filled the space between the present walls of the gulf, be removed."[1]

[1] Emmons, Ebenezer. Geol. N. Y. 2d Dist. 1842. p.309–10. *See also* by same author, Agric. N. Y. 1846. 1:133–34.


LEGEND.
Upper marine limit.
Upper limit of Terraces.
ROCKBURN
ST. ANTOINE
FRANKLIN.
QUEBEC
NEW YORK.
FRONTIER.
STOCKWELL P.O.
VICARS P.O.
HEMMINGFORD
English River.
COVEY HILL P.O.
Covey Hill
1030
The Gulf.
ARMSTRONG'S BUSH
CLINTON MILLS.
RAILROAD
RUTLAND
400
500
570
600
700
800
900
1000
1100
1200
SKETCH MAP of COVEY HILL, CANADA, J. B. Woodworth. 1903.
0 1 2 3
Miles.

This quotation is given here for the reason that it appears to be the first recognition of an important class of abandoned gorges found in New York State excavated across northward extending promontories of rock and lying so far above the present drainage of the country that no existing stream under the geographic conditions of the day could have performed the work. Dr Gilbert appears to have been the next geologist to examine this gulf and the first to understand it: it was he who first called my attention to its existence. His notes on the place give the depth of the ravine as 160 feet; top of cliff above lower lake, 805 feet above sea level; the lower lake, 645 feet above sea level; upper lake, 830 feet above sea level; bluff above upper lake, 870 feet above sea level; swamp at summit, 875 feet above sea level; margin of channel opposite swamp on north side, 900 feet; water level of torrent at swamp inferred to have been between 900 and 910 feet. These are aneroid readings compared with the U. S. G. S. measurement of the elevation of Covey hill top, which is given as 1030 feet. No accurate measurements have yet been made of the depth of the upper and lower lakelets. The international boundary line crosses the lower lakelet as shown in plate 11. The upper lakelet lies wholly within Canada.[1]

The small lakelet at the foot of the cliff at the head of the gorge is clearly a waterfall pool, analogous to Green lake near Syracuse. The lower lakelet at the eastern end of the gorge, where the valley widens out into a depression of more ancient date, appears to be due to the choking of the valley at the eastern end of the lakelet as if a powerful stream reaching this point was checked and forced to drop its load. At the lower margin of the upper lakelet there is a heap of angular blocks of the Potsdam sandstone showing the action of the turbulent currents once active within the pool.

The rock on either side of the brink of the gorge and particularly along the southern side is stripped bare of drift and displays

[1] "The Gulf" is most easily reached from the south by driving from Mooers to Armstrong's Bush in the northwest corner of the quadrangle, thence to Covey Hill postoffice and westward over the top of the hill to Mr Donnelly's or farther on to Mr Sutten's place, from the latter of which a private road leads to the head of the gorge and the bare rock of the channel above the abandoned waterfall.

all the characters of the so called Flat rock or spillway so well shown about Altona. On the west the old stream bed springs as out of the air across the swamp near the crest of the col. Nothing else than the front of the Wisconsin ice sheet, pressed against and around the northern slope of Covey hill and the northern flanks of the Adirondacks to the westward, could have held up to this elevation the waters which discharged eastward through "the Gulf" to the lower levels of the Champlain valley. The present investigation has not determined the precise origin of these waters—whether they came from the ice itself, from the large streams which, descending the northern slopes of the Adirondacks, discharged against the ice front; or whether any part of the water passed along the front of the ice to this point from the northeastern extension of some stage of Lake Iroquois, a large fresh-water lake retained over the site of present Lake Ontario by the western extension of the same ice dam which is here invoked for the anomalous drainage feature of "the Gulf."

The facts at "the Gulf" warrant the conclusion that, at the time the ice sheet stood along the boundary so as to hold the drainage up to this col, there was a free run off for the water from at least the upper lakelet at an elevation as great as 830 feet above the present sea level. This, as will be shown later, precludes the idea of a glacial lake existing above this level at this particular time over the Champlain valley. The same remark holds true for the bottom of the gorge at the lower lakelet: while the water still flowed through this gorge at the latest stage a glacial lake could hardly have existed to the south and east at a higher level than the 645 foot level. [*See* p. 41 for further bearing of facts at Covey hill on water levels]

"The Gulf" is a witness also against the presence of the sea within the range of its elevation and shows that the deltas and shore lines within these levels southward along the slopes of the Adirondacks are not of marine origin.

Small rock exposures

The small rock exposures shown on the map—care has been taken to show all that were observed—fall into two groups, artificial and natural exposures. The artificial exposures are in this district almost entirely in road and railway cuttings, but many along these lines of travel are also natural exposures, particularly in the zone of wave action.

The natural exposures are mainly due to the sweeping away of the drift and beach materials along the beds and banks of streams, and in the low grounds from elevations of 600 feet downward, to the scouring action of waves. Their distribution serves to show that over most of the area the covering of glacial deposits and the wave-modified drift derived from them are on the whole thin. Where these small exposures are crowded, the surficial deposits are thinner than in regions where the outcrops are widely scattered.

LATE AND POST-WISCONSIN LAKE AND MARINE DEPOSITS

The complicated course of events attending the disappearance of the ice sheet from the northern slope of the Adirondacks can perhaps be understood if it is remembered that, while the torrents which produced the spillways were discharging along the ice front over the district from the south side of Covey hill to the Little Chazy, the ice sheet was gradually receding from this position, that over the site of Lake Champlain a glacial lake was expanding northward foot by foot with the recession of the ice front, and that standing water crept in between the ice front and the eastern margin of the flat rock areas. As the ice still further withdrew, an open lake existed for a time with an ice barrier for its northern shore, stretching in an ill defined line from Covey hill to the northern versant of the Green mountains. It was still the Wisconsin glacial epoch. The ice next disappeared from the entrance to Lake Champlain, and the sea came in and began a new series of processes. The Wisconsin epoch locally had closed, and a new epoch with essentially nonglacial processes of change had been introduced. This epoch is the only true "Champlain" epoch of the Pleistocene period. The sea did not apparently stand as high against the land as did the earlier lake shores. The beaches of both series are preserved on the Mooers quadrangle, and it is difficult to distinguish between them as one traverses the wave-modified belt from the lowlands near Lake Champlain to the upper limit of beach ridges at the eastern margin of the bared rock areas denominated spillways.

In the low grounds there are other deposits—beds of gravel, sand, and clay sometimes in the form of deltas, often occurring as flats. Marine fossils occur well up toward 350 feet in the area from Plattsburg northward and shells afford decisive evidence of marine submergence up to 340 feet near Mooers.

In general, the glacial deposits which have been worked over by waves occur in three fairly well defined belts or zones, viz:

1 A cobbly beach zone, several miles in width and ranging from an elevation of over 700 feet on the north to 640 feet on the south and thence down to about 250 feet.

2 A sandy zone looping up into the area of the first zone but lying mainly lower and somewhat farther east; and often characterized by glacial erratics of small size not definitely arranged by wave action.

3 Nearer the shore of Lake Champlain a clay zone more or less overlapped by the eastward extension of the sand zone. This clay zone lies almost altogether to the east of the Mooers quadrangle, but ramifications of it extend up the valleys of the rivers as high as the 250 foot level as near Mooers.

Shore lines of the area

The area covered by this atlas sheet displays the greatest array of abandoned and elevated beaches to be seen anywhere on the New York side of the Champlain valley. In the vicinity of West Chazy, unquestionable wave action can be traced up to an elevation of 675 feet above the present sea level. Along the international boundary unquestionable wave action can be traced within the limits of the map, from 280 feet up to about 540 feet. Above this hight in the northwest corner of the area in the district known as Armstrong's Bush, probable wave action appears at 620 feet to 630 feet, and again at 720 feet above the present sea level.

The accompanying map [pl. 26] shows the beach ridges where they have been seen. Except near the larger streams, where sandy deltas are developed, the slopes between the 450 foot contour and the 360 foot line are thickly beset with wave marks. The beach lines, in the form of low ridges, often crowded closely together, are particularly numerous northwest of the English river along the international boundary between 360 feet and 500 feet. I counted 25 such ridges between the 365 foot and the 450 foot contour lines. From Bullis brook south of Mooers to the southern limits of the sheet, the surface is ribbed with beaches almost everywhere apparent, from 500 feet down to 320. Higher wave marks also occur in this part of the sheet. Lower wave marks are seen on the Rouse Point quadrangle to the east.

The location of the numerous beaches shown on the map and their position with reference to the contour lines were determined by eye estimates in traversing the areas where they occur. Any single beach ridge can seldom be traced satisfactorily for any distance; it may fade away, merge into other lines, or become lost in second growth timber, where its slight relief, added to the other difficulties named, would make the detailed mapping of the many similar beaches on this area hardly worth the expenditure of time and money. I have reason to believe that many of the short beach lines shown on the map are really more extended. Careful leveling would also, I believe, show a greater divergence between the beach lines and the contour lines. It is to be presumed that the contour lines are correctly drawn. It is noticeable however that they are drawn to follow the prominent beach lines; but the evident decline of the principal wave zone from north to south appears to indicate very clearly that the beach lines are not level lines, yet no beach as before noted proved sufficiently distinct and continuous to make the test of walking one out across the area available for determining the degree of tilting.

The principal object of the study and mapping of the beaches has been to determine if possible the upper marine limit in this field, and the question at once arose whether all the beaches were marine or whether some of the higher ones were formed in a fresh-water lake in front of the retreating ice sheet. It has been seen how "the Gulf" would place the marine limit below 645 feet of elevation.

The lower beaches up to at least 340 feet above the present sea level are shown to have been made by the sea by the existence of marine shells in the contemporaneous deposits. There appear to be no characteristics by which marine beaches as such can be discriminated from lake beaches. As will be shown in more detail in a report now in preparation on the whole question of the marine invasion in the Champlain and Hudson valleys, certain reasonable assumptions may be made with regard to the distribution of beaches, by means of which, when the expectations are met, the marine beaches in this area above the fossil shells and below the level of the Gulf may be distinguished from those made in glacial dammed lakes. In the first place, elevated marine beaches may be expected to be traceable with more or less continuity throughout the entire borders of low ground to which the sea must have had access; the beaches may be expected to succeed each other at any given place without very noticeable breaks in the vertical succession, as a consequence of the rather uniform nature of the elevation of the land above the sea. Glacial lake beaches, on the contrary, would be expected to end where they met the ice front, they should not therefore be continuous where sea beaches would be continuous; the sudden lowering of a glacial lake by the uncovering of a new outlet would cause noticeable intervals in the vertical succession of these beaches; and particularly might an interval be expected between the lowest lake beach level and the upper marine limit.

There are other minor differences with regard to the development of lake and marine beaches which may be expected in the Champlain district. In the making of marine beaches, the strength of the wave action at any place depends in part on its exposure, and that on the fetch of the winds across the water body. Where the topography and materials to be wrought by the waves are essentially the same from higher to lower levels in a given portion of the area traversed by the regression of the sea, a like strength of beaches is to be expected.

In the case of deep waters along an ice front, the heaviest wave action may be expected to occur independently of the conditions which control normal marine waves. It will take place at or near the junction of the shore line with the ice front; for there the calving of the ice front in the production of icebergs will set up heavy waves, the force and direction of whose action will be independent of the prevalent winds and the more remote geographic conditions of the lake or fiord seemingly protected coasts are thus rapidly waveworn, an observation which Dr Gilbert personally communicated to me from his experience in Alaska. In a glacial lake such wave-made beaches would frequently occur as worked over morainal deposits recently abandoned by the retreat of the ice sheet. Such wave action would cast up materials higher than waves would reach along the shores removed from the ice front.

The magnitude and power of berg-made waves in situations where wind-made waves can hardly reach any considerable size, has been vividly described by Dr Isaac L. Hayes[1] from personal experience in the Sermitsialik fiord on the west coast of Greenland in the voyage of the steamer *Panther*. The calving of the front of the glacier which enters the sea in this fiord produced a wave of vast proportions. "The wave," states Hayes, "occasioned by an earthquake only can be compared with it in magnitude and force. . . Waves of considerable though not dangerous magnitude followed, and it was quite half an hour before the waters were at rest."

Upper limit of beaches

The upper limit of beaches or to be more concise the upper limit of wave action on the Mooers quadrangle appears to be found in the northwest corner of the area at 720 feet according to the local contour of the map, but west of the area mapped a possible higher deposit occurs at the corner of the road to Covey Hill postoffice. This 720 foot deposit is a coarse cobblestone bar ending on the south with a spitlike hook just north of Kellas brook. Beachlike ridges also occur to the south along the road at 720 and 725 feet, and again at Cannon Corners on either side of the English river as shown on the map. Possible wave marks occur on the south of the English river as high as 750 feet according to the contours of the map. Still farther south along the western border of the quadrangle and north of Deer pond, what appears to be weak wave action is indicated by the configuration of the ground and rounded gravel at about 705 feet. On the hillside west of this locality water-

[1]Hayes, Isaac L. A Visit to a Greenland Glacier. Harper's New Monthly Magazine. January 1872. 44:212-13.

worn cobbles form a steep slope nearly to the 800 foot contour line but I have not been able to distinguish this deposit from waterworn material deposited in the presence of the glacier and worked over by it. It is not discriminated from the general local drift coating on the accompanying map.

South of Deer pond and thence southeastward along the curving contour of the flanks of the Adirondacks I have not been able to find traces of wave action above 680 feet along the northern margin of the Altona flat rock or spillway, above 670 to 675 feet in the region west of West Chazy, and above 640 feet at the southern limit of the map.

Water may have stood at a higher level with waves beating against the flat rocks but these bared surfaces would have yielded little material for making recognizable beaches. The 680 foot level is very indistinct or locally wanting along the eastern margin of the Altona flat rock area in the southern part of Pine ridge where the stripped rocks descend to lower levels than usual. The absence of definite beaches therefore between Deer pond and Altona does not necessarily mean the absence of wave action within the zone at which it might be expected if it is granted that these supposed wave-made deposits marked a former water level now tilted to the southward.

The falling off in level of this tracing of highest beaches is as much as 110 feet at least between Cannon Corners and the southern margin of the quadrangle. In an air line in a northwest and southeast direction this amounts to a rise on the north at the rate of about 6.5 feet to the mile, or if we neglect any possible eastwest tilting, and compare the two localities in a north and south direction, the rate of tilting is about $7\frac{1}{3}$ feet to the mile.

The rather persistent beach at the 680 foot contour on the north side of the Altona flat rock extending in an east by south direction for about 3 miles lies at a very large angle to the evident direction of tilting and this fact will account for the approximate uniformity of level which the water lines there show.

These estimates of the degree of tilting involve the supposition that the highest lines are parts of one water level. There are good reasons for thinking this not the case. It is evident that they are the traces of successive stages of water action along the border of the ice. In a later part of this report the attempt is made to correlate them with different levels of a glacial lake which has left more definite traces over the southern border of the quadrangle, but whose tilting does not exceed 4.5 feet to the mile to the south. In fact there is no very definite upper limit to the signs of water action in this field and certainly none that can be traced continuously across the area. Far above this field to the west as the ice withdrew from the district, streams of water coursed along the ice border, building stream bars and plains of gravel and sand wherever space was provided for temporary lakes; gradually as the form of the ground favored the process larger lakes ending in one large lake came into existence and this extended northward over the Champlain valley as the ice front retreated. With regard to the beaches and signs of wave action in the quadrangle, the following account groups them roughly in two series.

Upper series of beaches

The upper series of beaches on the Mooers quadrangle comprise those higher water level traces of the area of which no satisfactory evidence has been found extending beyond the limits of the map around the northern slope of Covey hill on the Canadian side of the boundary line. These water levels are believed to be mainly the margins of successive lower and lower stages of a glacial lake which gradually extended northward in the Champlain valley with the northward recession of the Wisconsin ice sheet. The evidence on which the upper beaches are distinguished from a lower group of marine origin is such as to make what is apparently an arbitrary division of the beaches in this particular area.

Along the northern edge of the quadrangle at the international boundary, the upper series as here defined includes those traces of water action which appear above 450 feet. It will be noted by an inspection of the map [pl. 26] on the rather steep slope between the 380 and the 520 foot levels, averaging about 140 feet to the mile, the beach ridges are well developed and closely crowded. Above 538 feet no traces of beaches in the northern part of the map are shown till the 620 foot level is reached, where scanty evidences of possible beach action have been seen at one place in the northwest corner. A second higher interval without definite traces appears between 620 and 720 feet at the upper of which elevations a beachlike ridge of cobblestones terminating southward in a recurved spit or hook is found at the head of Kellas brook. Southward from this point isolated traces appear at mainly higher levels up to 750 feet south of the English river which are tentatively regarded as the work of waves rather than of running water. About half a mile west of the Mooers quadrangle, where the road south of the boundary line turns northward toward Covey Hill postoffice, at an elevation by the aneroid of about 820 feet, there is a repetition of the cobblestone deposits at the 720 foot level. These upper deposits at 620, 720 and 820 feet along the international boundary are not certainly beaches; they may be the products of streams of water coursing along the ice margin where it met the confronting slope of the land at these respective levels. The association with the spillways suggests this relation. Nevertheless if they are not true water levels they appear to fall in certain planes of tilted water levels shown farther south.

In the southern part of the area in the latitude of West Chazy beach phenomena are nearly continuous from about 675 feet down to the eastern limit of the area. Beginning at the top, the most conspicuous example is found at the locality which I have named Cobblestone hill.

Cobblestone hill beaches. The highest distinct wave marks in the southern half of the Mooers quadrangle lie, as nearly as I have been able to determine by the aneroid and a comparison of the contoured map with the ground, between the 640 foot line on the extreme south and the 680 foot contour line near Altona. This line of wave action can be traced with some breaks from a point on the northern margin of the Flat Rocks 1 mile southeast of Altona along the margin of the Flat rock area to the series of beaches which form the eastern face of the high morainal wall stretching off to the south from Pine ridge and terminating at the Little Chazy river. South of the Little Chazy, the beach ridge reappears on an elongated hill at an elevation according to the local contour, of 675 feet, and reappears farther south between the upper branches of Ferrel brook at about the

View looking north along the eastern slope of Cobblestone hill, just below the crest

Plate 13

View looking north along Cobblestone hill, a lower beach than that in plate 12

Plate 14

The crest of Cobblestone hill, showing strong wave action on boulders and large cobbles. Looking west. Elevation 650 feet same level. I was not able to recognize any distinct beach at or near this level farther south on this area.

At the point of beginning near Altona the beach is distinctly ribbed and contains many angular blocks along with water-worn cobblestones. The deposit is raised some 3 or 4 feet above the surface of the bare flat rock whose surface, following the local dip, shelves steeply beneath the beach.

At Bert Waitman's berry camp, a locality 1.1 miles distant in a n.n.e. direction from Dead Sea, the bare rock extends a few rods below and north of a line of subangular boulders, whose elevation according to the aneroid measurement is 680 feet, a deposit which taken by itself is not suggestive of a beach. Glacial striae were observed here on the rocks (n. 31°e.).

At a berry camp on the margin of the rock, reached by a road going southwestward from Sciota, no trace of wave-strewn cobbles or blocks was observed at 680 feet, and, as noted above, the bare rock descends nearly to the 620 foot contour line. It is conceivable that along this part of the line the wave action was such as to remove rather than deposit longshore drift.

South of the locality last mentioned, the partly wooded surface of the stripped rock shows here and there a block or group of blocks of sandstone in positions suggesting wave action. No trace of a water level at or near the 680 foot line was detected on the northern part of the morainal spur composed of very large sandstone blocks, which joins the southeastern point of Pine ridge. Wave action appears however at a somewhat lower level, in the most pronounced manner on the extension of this morainal ridge, which forms a detached mass somewhat to the south and east, named, as before noted, Cobblestone hill on the map which accompanies this report [pl. 12-14].

Apparently this hill was originally a morainal wall laid down along the ice margin at the southeastern extremity of the Altona flat rock area. It is one of a series of elongated drift ridges which extend *en échelon* from the southern end of Pine ridge along the eastern base of Rand hill in Beekmantown approximately between the 600 foot and 700 foot contour lines. Its form on the atlas sheet is imperfectly shown. The northwestern part rises above what is here termed the crest of wave-heaped cobbles.

The hill is composed altogether of blocks and cobbles of the Potsdam sandstone. On the wave-heaped crest and the western landward slope the blocks are still prevailingly angular, and there are no signs of strong water action other than the bare flat rocks. But from the crest down the eastern wave-washed slope the blocks are often well rounded, and are particularly so at lower levels. The fragments decrease in size from the crest, and near the 600 foot level are coarse gravels. The larger blocks are between 3 and 4 feet in length, but blocks yet larger occur. Ovoid masses of this size in the upper zones of beach action attest the strength of the waves which reshaped this side of the hill.

The eastern slope exhibits a number of benches of these boulderets and cobbles arranged in the manner peculiar to regressive wave action. The crest, tolerably uniform in elevation, is a narrow ridge, about the northern and southern ends of which the cobbles of the shelf next below are extended in well formed recurved hooks.

The third level below the crest extends northward along the slope of the ridge, which is there lower and, like the continuation of the beach on the second level, loses its beach aspect near the northern end of the hill.

I was not able to identify any signs of this wave action at similar levels on the equally strong morainal ridge just north and west of the hill.

The southern end of Cobblestone hill falls off to a lower level with signs of wave action along the crest of this extension, and about halfway down its eastern slope. Below 600 feet the surface of the main ridge is heavily covered with coarse gravelly deposits forming an even slope characteristic of the zone just below strong wave action.

In a subsequent report it is planned to give a sketch map and more detailed account of this deposit.

Neither north nor south of Cobblestone hill, within the zone of abandoned beaches to which this group of strand lines belongs, are there indications of such strong and long continued wave action. The extreme localization of the effects has seemed to me possibly explicable on the view advanced on a previous page, viz, that the ice front for some time stood near this hill on the north, and that the waves set up by bergs forming along the ice front were the cause of the phenomena. With the surface of static water as high as the 640 foot contour line at this locality, there would have been a depth of water of 140 feet at a distance of 1 mile, of 240 feet at a distance of 2 miles, 340 feet at 3 miles, depths far less than those in Greenland fiords, but not as I conceive it, incompatible with the idea of berg-made waves of a magnitude greater than wind-made waves in an open body of water in the same position.

Against the view of berg-made waves, it is to be noted that Cobblestone hill stands out in a more exposed position than the similar ridges immediately north and south of it; and that the benches of cobblestones on its wave-washed face range through over 30 feet of elevation, as if the cause persisted through a change of water level.

The highest beaches detected south of Cobblestone hill appear to be along the same water level, falling off gradually in elevation as the shore line is traced southward. The elongate hill which rises to the 700 foot contour line between the Little Chazy river and the north branch of Ferrel brook is decidedly ribbed on its eastern face at about 670 feet. In the flat at the eastern base of the hill, in the woods, at 630 feet (aneroid) there is a stony belt suggesting brief wave action.

Still farther south, between the branches of Ferrel brook from about 670 feet down to 625 feet (by contours of the map) there are four wave marks, the uppermost of which is traceable for about $\frac{3}{4}$ of a mile.

Between the southern branch of Ferrel brook and the northernmost branch of Silver creek, faint wave marks are distinguishable from 650 feet down to 590 feet.

Southward of these indications to the southern limit of the map (44°45′n.lat.) the steep slope of the base of Rand hill, between 600 feet and 630 feet at least, is smoothened with rubble which appears to have been deposited under water or under the action of light waves as the water surface passed from higher to lower levels of the hillside.

At the extreme southern limit of the sheet and south of the road to Dannemora, a strong ridge appears delimited on the atlas sheet by the 640 foot contour line. The loose rubble which mantles its surface, particularly on the east, is strongly suggestive of wave action. From this locality westward up the slope of Rand hill the surface is till-covered, becoming morainic in character, with kettle holes indicating the deposition of much glacial drift in the presence of melting ice.

Throughout the entire length of the Mooers district but few positive traces of wave action occur between the 500 and 600 foot contour lines. Along the road parallel with the international boundary, in the district locally known as Armstrong's bush, there are no marks between 540 and 620 which can be attributed to wave action, nor are any phenomena of the sort observed except for the slight indications below noted till one passes south of Bovington brook near West Chazy. The possible exceptions are the weak signs of wave action north of the English river between 510 feet and 515 feet, the weak beaches on the hill midway between Sciota and West Chazy at elevations of 540, 550, and a possible case at 590 feet. This ridging of the drift at 590 feet occurs also about a mile and a half west near the margin of the Altona Flat Rock area, with a 600 foot ridge immediately west of it.

On the road from West Chazy to Cobblestone hill, possible wave marks occur at 540 feet, 545 feet, and again on the eastern and northern slopes of the low hill marked by the 580 foot line. Along the eastern base of Cobblestone hill and northward toward the edge of the Flat rock area, there are beach levels continuous in series with the Cobblestone hill group from 610 feet down to at least 590 feet.

South of the Little Chazy river, there is an apparent beach north of the main branch of Ferrel brook at about 530 feet (from the map). Another narrow beach ridge with a hook at its northern end occurs along the road going south from West Beekmantown at about 550 feet according to the local contour; and southwest of this town the 500 foot contour line apparently follows the crest of an offshore bar.

Between Silver creek and the south branch of Ferrel brook, there is a marked sandy bar rising on its eastern face from the

480 to at least the 560 foot line, but I am not certain that it is wave-made.

When one compares the rather marked shore lines between 590 feet and 680 feet on the south, and between 620 feet and 720 feet on the north of this area, with this indistinctly marked zone between, extending down to about 500 feet on the south and to 540 feet on the north, it is evident that the sinking of the water level or the rise of the land in relation to the wave zone was rapidly accomplished. The greater number of the wave marks in this interval on the south, both as regards the cases mapped and their broader distribution in the vertical space, is taken to indicate that water action lasted there longer than on the north of the Corbeau. It is to be noted also that the large streams which traverse the northern part of this field have no deltas between 500 feet and 600 feet. They apparently extended their mouths from the deltas above the 600 foot line to those below the 500 foot line suddenly. The English river has no delta immediately below the 500 foot line, as the Big Chazy has just south of it, unless we regard that delta as partly formed also by the English river. The English river has however a delta at about 450 feet.

From a comparison of these shores lines and deltas southward throughout the Champlain valley with certain spillways and outlets between Fort Edward and Stillwater it appears that a glacial lake must have existed for a long time over the region, held in on the north by the retreating ice front and thus overflowing southward. The earliest stage of this lake is apparently marked by a spillway over the west bank of the Hudson gorge between Schuylerville and Quaker Springs. This stage of the lake is probably not represented on the Mooers quadrangle by lacustrine deposits or shore lines. The ice appears still to have covered the district.

Later the excurrent stream cleared out a drift-filled side channel of the Hudson west of Schuylerville and joined the Hudson gorge at Coveville. By this time the glacial lake appears to have extended into the Mooers district. The upper line of wave action on Cobblestone hill, and the signs of wave action rising northwestward to the 720 foot line at Armstrong's bush are believed to have been formed at this time.

Gradually the waters at the outlet cleared out the main gorge of the Hudson and finally came to a lower level with an outlet just north of Fort Edward, establishing a level over the lake about 100 feet lower than that of the Coveville stage. At this time the shore line stood somewhere near 550 feet at the southern end of the Mooers quadrangle and at about 620 feet at the northern end of the area.

This glacial lake, which it is proposed to call Lake Vermont, endured for some time longer when the ice sheet melted out along the northern border of the Green mountains and allowed the waters to fall to the level of the sea. On account of the then low stand of the land the sea at once came in and spread as far south as Whitehall.

Before the sea came in, however, there appears to have been a stage in which the lake waters gradually fell below the Fort Edward outlet, presumably by reason of the weakening of the ice barrier on the north allowing the more or less gradual escape of the lake waters. The crowded beaches in the northern part of the quadrangle from 540 feet down to the upper marine limit near the 450 foot contour line are referred to this stage. I have described their correlation with what appear to be stream-cut terraces on the northern side of Covey hill in another paper on the ancient water levels of the Hudson and Champlain valleys.

It has been suggested by Mr Warren Upham that the ice front receded from the Champlain valley in such a manner as to allow a connection between the glacial lake in this field and one extending over the upper St Lawrence valley into Lake Ontario, previous to the invasion of the district by the sea. These beaches and possibly some of the lower ones referred to the marine stage would be thus explained but not so the cut terraces at Covey hill and the occurrence of marine shells on Mt Royal at an elevation of about 550 feet.[1]

The average inclination of these old water levels to the south is assumed to be parallel to the upper marine limit. An attempt to trace some one line of beaches proved unavailing as a test of

[1] Sir William Dawson gives both 540 and 560 feet for the elevation.

Plate 15

View of the beach at 500 feet elevation in Mooers, 3 miles northwest from Mooers Forks. Looking south

View looking west by north on the shore bar at 500 feet, on the headwaters of Bullis brook

Shore bar cut through by headwaters of Bullis brook at 500 feet. Looking north their attitude. There are certain lines of water level, for instance that at about 500 feet between the English river and the west branch of that river, which at first sight appear to be without tilting. On going south of Wood Falls one finds the fragments of a beach at practically the same level and again farther southeast near the road from Sciota to Altona there is a large bar at this level. But when the line is followed along the international boundary, favorable slopes of the ground show equally good wave marks going up to 540 feet. The beaches are not continuous.

A conspicuous bar first noted by Dr Gilbert occurs at 450 feet on Bovington brook near West Chazy, quite well enough formed to have been made by strong waves in the sea, but it does not appear to demand stronger wave action than that formed on the face of Cobblestone hill just west of it at a much higher elevation and undoubtedly by glacial lake waters.

Lower series of beaches

The lower series of beaches on the Mooers quadrangle comprise those levels of former wave action which can be traced northward beyond the limits of the map around the northern slope of Covey hill in Canada. These wave marks are presumably marine. The data from Covey hill beyond the northern limits of this area are briefly presented in this paper under another heading. The highest level of clear wave action at that point is 450 feet above sea level. On the Mooers quadrangle wave action is traceable on the northern margin of the area in closely set ridges forming a distinct group from 540 feet down to 370 feet at the base of the hill just east of Armstrong's bush. Eastward over the area, beaches occur on exposed places, mainly low ridges or hillocks, at levels from 350 feet down to 340 feet and again near Perry Mills at 250 feet (by the contour of the map) [pl. 15].

This group of beaches can be traced from the northern limits of the map to the vicinity of the English river. Between the English river and Bullis brook west of Sciota, recognizable beaches are fewer and much less distinct as the accompanying map shows. About a mile southeast from Wood Falls the highest beach seen occurs at 500 feet according to the local contour by the map. There is a bar [pl. 16, 17] partly thrown across one of the head branches of Bullis brook at this level. East of Bullis brook and southward to the southern limits of the map, beach ridges rib the slope at Sciota from 495 feet down to 250 feet according to the contours of the map. Beach ridges and waterworn gravels occur either side of the state road from Sciota to the vicinity of Tracy brook. At 450 feet Bovington brook, as noted by Dr Gilbert, cuts through a well formed bar with a typical under water beach slope in front of the bar. Above this level along the road to Cobblestone hill there are faint parallel lines with rather angular washed material indicative of wave action at 530, 545 and 580 feet (by the map). These higher water lines are apparently traces of the water body which sank stage by stage from the 570 foot level in this latitude to the lower series of beaches. South of West Chazy stronger and broader bars than appear on the north come into existence in a slightly overlapping or offset arrangement, which is fairly well shown by the contouring of the map just above the 420 foot line. These broader ridges are marked by minor beach ridges. East of West Beekmantown, these larger bars take on the form of definite offshore bars, inclosing back swamps. Silver creek winds its way in rectangular adjustment down the slope running part way between the bars and part way transverse to their extension where they become depressed and exhibit their offsetting. Another broad wave-heaped ridge of this character occurs south of West Beekmantown at about 500 foot elevation. West of this beach wave marks appear at about 545 feet. There is a distinct group of half a dozen beach ribs on the slope south of Silver creek from 315 feet up to 340 feet. This group of minor beach ridges extends northward and merges into the broader belt of greater vertical range north of West Chazy.

The beaches of this lower series, as a whole, are composed of highly angular materials, often flat slabs of Potsdam sandstone or angular polygonal blocks dependent apparently on the manner of fracture of the nearby underlying Potsdam sandstone derived either from ledges or the glacial drift worked over by the waves. In the northern part of the map near the international boundary, rolled and rounded pebbles aside from those in the deltas near streams as at 420 feet east of the English river, first appear at an elevation of about 350 feet on the western slope of a low modified drumloidal hill about 2 miles northwest of Mooers Junction. The underlying glacial materials are angular rock fragments peculiar to glacial till. It is evident that long continued and effective wave action took place on the western slope of this hill. The eastern slope is occasioned by a few large boulders but without waterworn materials and without any definite signs of a beach. Another similar ridge about 1 mile southeast of that above described shows similar features except that its crest is wave-heaped inclosing a shallow lagoon between low beach ridges. Its eastern slope is wave washed. The crest is approximately at the 350 foot level.

From Sciota southward to near West Chazy there is much subrounded beach gravel along the state road at levels from 380 to 400 feet. There are also heavy beaches [pl. 18-21].

Summarizing, none of these ridges has been found sufficiently continuous and distinct from those above and below it to enable one to trace it out by walking across the area on what appeared to be a deposit made at any one time across the limits of the sheet. The attempt to show whether the beaches are still level or are tilted from their original position appeared to demand a more general consideration involving a study of the beaches north and south of the area. Similarly the distinction between beaches made by waves in the glacial lake which it is believed covered the district before the sea came in and those made by the waves of the sea has not seemed possible by means of evidence found within the Mooers quadrangle. Though as shown below there are certain details in the strength of wave action which fit in with facts farther south and confirm the view that the upper marine limit is approximately determinable.

Evidence at Covey hill, Canada. Fortunately for the geologist in this field, the critical area for the study of the shore line problems which arise on the Mooers quadrangle lies just over the international boundary in Canada. Immediately north of the abandoned Niagara known as "the Gulf," the northeastern prolongation of the Adirondacks terminates in Covey hill, whose elevation according to the United States Geological Survey is 1030 feet above mean tide level.[1] Within about 3 miles from the boundary line the ground falls off to less than 300 feet, as at

[1] Information supplied by Dr G. K. Gilbert.

Vicars. The northern slope of this hill thus stands as a self-registering nilometer of the water levels which have existed in the St Lawrence valley in contradistinction to glacial lake levels in the Champlain on the east of the Adirondacks and in the upper St Lawrence valley and over the Lake Ontario basin on the west.

The crest of Covey hill is till covered. It has already been pointed out that "the Gulf" at the western base of the hill indicates the path of a powerful torrent flowing across this spur of the mountains at the time when the ice front had receded locally as far as Covey hill, but had not retreated from its northern slope. These torrential waters held up by the ice formed a waterfall, whose cliff is now at 870 feet, and whose pool stands at 830 feet; below this is a second pool in the bottom of a chasm 160 feet deep precisely on the international boundary line. The surface of this pool, according to Dr Gilbert's observation, is 645 feet. From this point the valley opens out, the small, spring-fed stream which escapes from the lakelets turns northeastward, thence north past Covey Hill postoffice and, joining the English river, falls into the Chateaugay and thence enters the St Lawrence river at a point almost directly north of Covey hill.

From the facts shown at "the Gulf" it is evident that, when the ice front rested against the northern slope of Covey hill, the drainage at its southern base found open-air conditions of flow at a level as low as that of 645 feet. About 2 miles southeast of this lakelet, something like shore line phenomena appear on the Mooers quadrangle at 620 feet to 630 feet, a level which would not have drowned the waterfall action at "the Gulf." At an earlier stage water levels appear 100 feet higher in the northwest corner of the Mooers quadrangle; water at this level would have penetrated the chasm at "the Gulf" and entered part way between the lower and the upper lakes. At a still earlier stage there appears to have been formed a cobblestone bar with spits just west of the Mooers quadrangle at an elevation of about 810 feet (aneroid); waters at this level would have come nearly to the upper lake.

At the time the waters were flowing out of the lower lake at "the Gulf," the discharge must have taken place eastward and thence southward to the Mooers quadrangle along the 620 foot to 640 foot level, being held to this line of flow by the ice on the north and also for the reason that the ground south of "the Gulf" along the line of the Stafford's and Blackman's rock spillways was much higher than the path opened up as the ice retreated from the Potsdam escarpment to the east of "the Gulf."

That certain shore lines on the Mooers quadrangle and the area west of it are contemporaneous with the drainage through "the Gulf" notch and thus with the ice sheet frontage against the northern slope of Covey hill, is shown by the absence of such distinct wave marks on the northern slope of the hill between the levels of at least 900 feet and 600 feet. An almost unmodified slope of till in the most favorable position for rearrangement under the action of waves or lateral glacial streams covers this important interval. The phenomena of "the Gulf" demand an ice barrier on the north to hold up the extraglacial waters so as to cause them to flow over a col in the divide between the head waters of the Chateaugay river. The water levels on the south of "the Gulf," whose range is the same as that of the depth of "the Gulf," are, it has been shown, also contemporaneous with the ice frontage in that field and therefore, I think, are demonstrated to be independent of the sea in the Champlain and St Lawrence valleys.

The intervals between signs of water level on the Mooers quadrangle thus appear to be associated with a glacial lake, sudden falls in which might arise from the opening of new spillways as a consequence of the continued retreat of the ice sheet.

There is, according to my observations, something like a periodic recurrence in the vertical interval between these water levels; thus there is, above the continuous series of lower beaches which stop off between 520 feet and 540 feet, an interval up to 610 to 620, another interval from that level to that of 720 to 725, followed by another up to 810 or 820 feet, intervals approximately 100 feet. This is I believe to be attributed to the nature of the ground about the southern end of this glacial lake in the region of its outlet.

Determination of the upper marine limit, benches and beaches on the north slope of Covey hill. The accompanying sketch map gives a general idea of the Covey hill district [*see* pl. 11]. The roads and position of villages have been traced from Walling's *Atlas of Canada*. The contour lines are mere approximations based on aneroid readings made by myself in traversing some of the roads and the railroad shown on the map. The elevation of the top of Covey hill has been furnished me as noted by Dr Gilbert.

The crest of Covey hill is devoid of marks of water action attributable to waves or glacial streams. Toward the base of the northern slope of the hill, unmistakable evidence of water action begins to appear at about 570 feet, and from that level down to the rather rolling low ground at its base there is first a succession of benches and then of distinct beaches. These are encountered in going from Covey Hill postoffice to Vicars, from the top of Covey hill to the main road west of Stockwell, and in descending the hill by the northwest road which enters Franklin Center.

On the road to Franklin, just beyond the fork in the roads, there is a small sand flat or delta on a little stream at an elevation of 720 feet (aneroid); and again, on the same road just south of Franklin and above the point where a "dug road" comes in from the northeast, there are low, flat ridges sloping westward at an elevation between 700 feet and 800 feet (aneroid reading discredited). These are the only exceptions I noted to the general absence of water levels on this hillside above 570 feet, and these cases are of the discontinuous kind which may be attributed to temporary conditions attending the drainage along the margin of the ice sheet as the front retreated from the northern slope of the hill.

Dr Gilbert, in his manuscript notes, records a well marked beach on the road from Covey hill to Vicars at an elevation of 450 feet. He states that he noted ridges above that level, but that they lacked the element of horizontality and were hence thrown out of the evidence he sought for the determination of the upper marine limit.

In going over the hill to the west and down the road toward Stockwell, a shelving terrace is encountered at 580 feet which drops off in the form of a low cliff to a shelving flat, which joins the cliff base at 570 feet. No signs of water action in the way of waterworn pebbles are noticeable, but some form of erosion has evidently taken place at this level. Going farther down this road, the till is cut back in the form of a good bench with a cliff. The road from Stockwell to Franklin Center runs on this bench at an elevation of about 540 feet (aneroid). This is the highest of a group of strongly developed benches which can be traced along the northern base of Covey hill for several miles. Their surfaces are frequently strewn with coarse angular blocks of sandstone, though half a mile east of Stockwell postoffice a bar at 520 feet shows coarse, waterworn material. Gravelly beaches begin in this direction at 450 feet. Above this line the materials are coarse stones. The road follows the upper ridges at least as far as Rockburn.

At Franklin Center, as indicated on the adjoined sketch map, which is designed only to show the general orientation of the roads, the 570 foot bench with a cliff cut in the till is distinctly shown. North of the main road is a succession of beaches and ridges down to at least 396 feet. All readings are aneroid compared with the top of Covey hill. First and just north of the crossroads is the crest of a bar at 480 feet, with waterworn pebbles on the base of the beach slope at 450 feet. At a slightly lower level and farther north is a weak beach ridge. North of the crossroads there is a beach ridge 430 feet at top, with waterworn gravel down its northern slope to 400 feet. This beach is confronted by a flat whose surface is at 396 feet. The upper stony ridges become stronger and more distinct toward Rockburn, beyond which point within Canada I have made no attempt to trace them.

Dr Gilbert, in his manuscript notes, placed the upper marine limit at Covey hill at 450 feet. With this decision I agree.

Taking the 450 foot line as the upper marine limit at Covey hill, the rude terraces above that level would appear to be of the nature of stream cuts partly made in the till of the hillside at the time the ice front still pressed against the base of the hill. As soon as the ice began to melt back from the hill the water which had been heretofore forced across "the Gulf" spillway would find a lower pathway about the northern base of the hill and thence into the Champlain valley. The rude beach deposits along the international boundary on the Mooers quadrangle from 540 feet downward to and even below the 500 foot contour line are the local equivalent of this state of affairs, but there probably was open water in that field.

Accepting the evidence at Covey hill for placing the upper marine limit at 450 feet, it would further appear that the beaches in this region above that level are those of a glacial lake. The evidence found in the southern part of the Plattsburg quadrangle about Port Kent seems to indicate that the upper marine limit is there to be placed at an elevation not more than 330 feet above sea level of today. On this basis plate 25 has been prepared exhibiting the shore line as it is presumed to have stood at the time the sea was at its maximum extension in the Champlain valley. This line it will be noted makes an arbitrary division of the crowded beach lines in the lower series.

As stated in another place the marine shells which occur near Mooers at 340 feet, and on the Saranac above Plattsburg at approximately the same elevation, 342 to 346 feet, prove that the sea stood as high as 340 feet at least over the northern part of the district. It is to be presumed that shells may be found as high as the marine limit in beach deposits. As yet shells have not been reported in the beaches of this district.

The upper marine limit as here placed coincides with a tilted plane passing through the 450 foot beach at Covey hill and just above the 550 foot marine shell deposit on Mt Royal. This plane intersects the delta of the Big Chazy at Mooers Forks, and the heavy beaches south of Sciota [pl. 18-21] at about 400 feet; it also passes beneath the rock cliffs from the waste of which these beaches are in part built [*see* pl. 22-24].

Marine invasion

It has long been known that on the disappearance of the ice sheet from the St Lawrence and Champlain valleys the sea covered the floors of these valleys at least as high as the localities at which marine shells have been found in the clays and sands laid down at that time. Opinion has differed among geologists only as to the depth to which the land in various parts of this portion of the continent was then submerged. The character of the fossil shells, the fact that many of the species are still living in the St Lawrence gulf or in the adjacent waters of the Atlantic coast show that these animals found their way into the Champlain valley from the north or northeast. The

View looking north along the uppermost beach ridge shown in plate 19 south of Sciota

Plate 19

Looking east over the coarse beach ridges built along the shore south of the Sciota cliff

Landward slope of one of the coarse beaches, 2½ miles south of Sciota

Plate 21

View looking north along the less developed beach lines south of Sciota

Plate 22

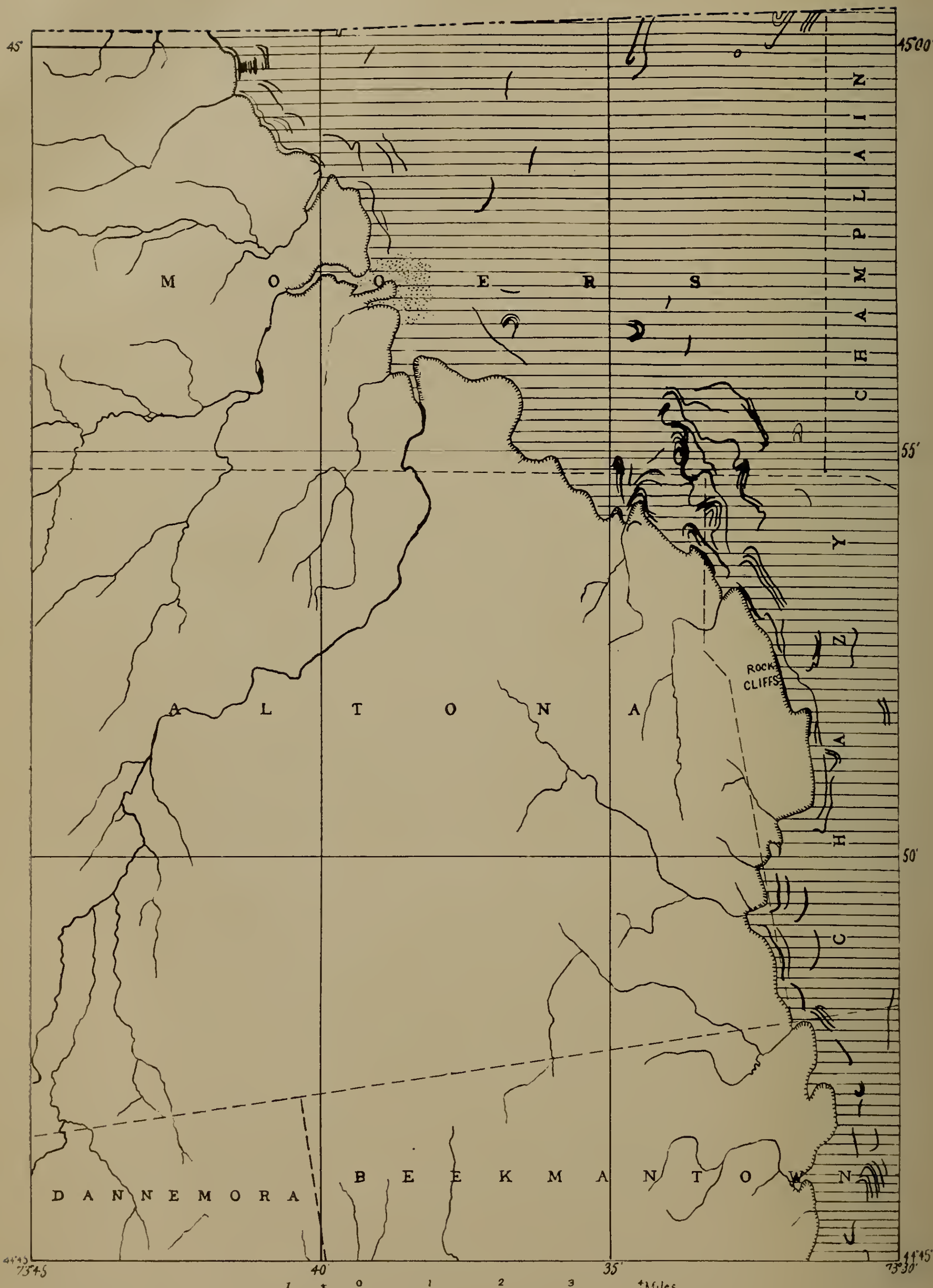
Abandoned sea cliff in Potsdam sandstone, 2 miles south of Sciota, showing blocks fallen from cliff. Looking west

Upper part of the old cliff south of Sciota shown in plate 22

Plate 24

Looking south along abandoned sea cliff in Potsdam sandstone, 2 miles south of Sciota

Plate 25



Sketch map of Mooers quadrangle showing extent of submergence beneath the sea (horizontally lined). The curving lines in submerged area represent beaches and bars made during the regression of the sea fossil shells are found along the New York side of Lake Champlain at least as far south as the ruins of the old French fort on Crown Point peninsula. The marine waters probably extended as far south as Whitehall; and as will be shown in another report on this special subject that there was no connection by the marine waters southward through Wood creek with the sea at the mouth of the Hudson river at this time, the land on the south being elevated very much in the same proportion as the land in the upper St Lawrence valley was depressed below sea level.

Marine deposits

There is difficulty in distinguishing the marine deposits of this area from those made by the waters of the glacial lakes. The sole satisfactory local criterion is the presence of marine shells or other fossils in the oceanic series. As already indicated these deposits occur in the low grounds. On plate 25 the shaded area shows the horizontal extent of the marine deposits according to the determination of the upper marine limit which has been made in this report. In general the marine deposits on this area are stony modifications of the glacial deposits, largely modified till, worked over by waves and currents. The effect of wave action has been to arrange the drift in the form of beach ridges, and waves and currents together have produced bars of gravel or flats of sandy materials frequently changing to gravels or coarse, bouldery deposits. The accompanying map [pl. 26] is not made to show the distinctions between these various phases other than to delineate the recognizable beach ridges. Here and there a plain of sand or gravel marks the delta of a stream as at Mooers and Mooers Forks. The deposits of undoubted marine origin within the area are only a few feet in thickness. Some parts of the submerged area exhibit morainal deposits apparently without alteration as north of Mooers and east of Sciota. The finer waterworn deposits are best developed along the courses of the streams and are thus to be regarded as rehandled detritus alternately deposited in deltas and thus carried downward about the mouth of the stream as the land rose above the sea.

Deltas at old sea margins. The larger streams have at certain levels well marked deposits of gravel and sand along their courses, evidently deltas built during the time of submergence.

The English river exhibits such a deposit about 2 miles northwest from Mooers Forks. The stream now makes a turn about the northwestern margin of this deposit. At one time, the stream passed to the east of the delta making a deep trench shown by the contours on the map.

The Big Chazy river has a small delta above Mooers Forks mainly developed in the triangular area between this stream and its north branch. The sands of this deposit extend up the valley to about 500 feet above sea level. Along the eastern margin of the delta from 400 feet to about 440 feet the surface is faintly marked by beach and wave-cut lines.

At Mooers there is another delta on the Big Chazy, whose surface is at 280 feet.

Bullis brook exhibits a slight delta at 300 feet on the south of Mooers and Shedden brook, also has a slight delta at about 280 feet elevation.

The small streams on the south to the limit of the map show no marked signs of their former local entrance into the sea.

Clays. The area mapped on this quadrangle lies mainly to the west and above the typical zone of marine clays which borders the present shores of Lake Champlain. The clays however appear along the course of Big Chazy river at Perry Mills in the northeast corner of the area and are said to underlie some of the swamps in the low grounds, probably as high as the 240 foot contour line in the region north and east of Mooers. Clays also appear in the banks of Bullis brook near its junction with the Big Chazy river. There is another locality on the north bank of the river about 1½ miles east of Mooers. At this locality clay has been worked in recent years in a small way for brickmaking. The clay is decidedly sandy and is overlain by sands representing the outer margin of the Mooers 280 foot delta, a deposit of which the clays are probably an essential part. They are not generally exposed at the surface west of Perry Mills. For an occurrence of early stratified pebbly clays *see* note on p. 53.

Marine fossils. Postglacial marine fossils were found during the course of this survey at only three points within the area of the map. The excavations made for the State road from West Chazy to Sciota in 1903 gave numerous shallow sections in the beach gravels between the 300 foot and 400 foot contour lines, but no fossil shells were seen in several thousand feet of such exposures. A few shells of *Macoma groenlandica* were found however in a borrow pit in the sand hill on the west bank of Tracy brook, where the road crosses that stream at 300 feet of elevation.

An excellent exposure of fossiliferous sands and some clay was found at the bend of the Big Chazy about 1¼ miles below Mooers Forks. The marine deposits here rest on an arenaceous boulder clay without the interposition of barren sands or clays which might be attributed to a glacial lake. The deposits are exposed on the west side of the neck of land near a large outcrop of the Potsdam (Saratogan?) sandstone lying in the middle of the stream. The bank is gradually receding here under the attack of the river. At about 340 feet above tide, 3 or 4 feet of fine marine sands, including a thin, underlying clay, contain numerous shells of *Saxicava rugosa, Leda arctica,* a few valves of *Yoldia* sp., and shells of *Balanus* sp. Many of the molluscan shells show both valves in the attitude of growth. The deposit is overlain by coarse gravels, evidently a part of the old river bed when the Chazy flowed at a higher level.

Fossil shells, apparently *Macoma groenlandica,* were also seen in a trench in gravels at a house by the spring west of the schoolhouse which stands about 1 mile west of Perry Mills, at about 300 foot elevation.

Mr William D. Stevenson, United States customs officer at Mooers Junction, stated that some 15 years ago he saw shells taken from a well on the McDowell place at the depth of about 8 feet. This locality is at the railroad junction, where the surface of an ancient delta of the Big Chazy is approximately at 280 feet.

The lack of recent excavations prevented undoubtedly the finding of shells in many parts of the low ground along the eastern part of the area.

Just over the international boundary, north of Mooers Junction and about 1½ miles south of Hemmingford, Can., at an elevation determined by the aneroid barometer to be 270 feet, abundant shells of *Saxicava rugosa* were found in a fine state of preservation in gravel at depths from 18 inches to over 3 feet below the surface. Many of the shells were standing in attitudes of growth in the spaces between the pebbles. The deposits were very rudely stratified.

The discussion of the bearing of these and other shell deposits on the New York side of Lake Champlain is given in full in my report on the marine submergence.

RECENT CHANGES

Since the glacial deposits were strewn over this district and the old shore lines marked out by waves, it is evident that the land has risen in relation to the sea. According to the data gathered in this survey, this elevation amounts to about 450 feet along the international boundary, being somewhat less in the southern part of the area because of the tilting to the south. There are reasons for believing that this change of level is still in progress but no local evidence of it has been observed.

The exposure of the rocks to the atmosphere in postglacial time has produced a slight amount of weathering and consequent disintegration. In many places over the flat rock spillways the Potsdam sandstone has broken down, affording loose white sand or white quartz pebbles but always in very small quantities. A more noticeable effect in this area has arisen from the action of frost in prying loose the angular joint blocks or slabs of the rock. On the whole the drift strikes an observer from the southern part of the glacial field as little altered by weathering but the resistant character of the Potsdam sandstone which forms so large a part of the coarse material tends to highten this impression. The amount of work done by glacial torrents and by waves gives in this region a far longer vista of late glacial and postglacial time than does the degree of weathering.

Streams and stream deposits

All of the streams of this quadrangle, except the brooks flowing down the south slope of Rand hill in Beekmantown, discharge across the zone of abandoned and elevated beaches. The courses of the streams thus present that irregularity which arises from their having been extended from low to lower grounds with the recession of the ice to the northeast and the withdrawal of standing bodies of water from the ancient shore lines. The streams have thus been compelled to find their way from point to point by flowing over and out through the lowest path in the surface materials. The head waters of the north branch of the Big Chazy and the English rivers appear to flow in rock valleys older than the last ice epoch.

The 500 foot delta on the north branch of the Big Chazy river received contributions from both of these streams. By a shallow trench about ¾ of a mile in length the English river might now be diverted into the north branch of the Big Chazy river across the upper part of this delta. Two miles northwest of Mooers Forks, the English river has cut its channel around the northwestern margin of what was probably a delta at the 420 foot local water level. First the stream appears to have escaped eastward by a dissection of this deposit.

The Big Chazy river also exhibits evidence of having shifted its course during the changes of level which have raised the old ocean bottom above the sea level. From Thorn there is a broad stream channel from 20 feet to 40 feet deep, leading northeastward to the Sperry brook depression about half a mile west of Mooers Junction. The contours of the map fail to show this channel. At Thorn the bottom of the channel is about 20 feet above the present bed of the river. When this channel was used, the Big Chazy must have flowed north of Mooers Junction along the northern side of the 280 foot delta at that place.

The river appears also to have flowed temporarily along a course half a mile north of its present channel at Mooers Forks, as is shown by the swampy channel north of the railroad curve near that place.

In many places as on the road along the eastern bank of the river from Altona to Wood Falls, the Big Chazy river bed, with characteristic torrential deposits, extends widely on either side of the present channel. The same remark is applicable to portions of the north branch of the river and to the English river. The streams are evidently in the process of lateral shifting, and at the same time they are sinking deeper into the drift deposits over which they flow. In several places, as at Wood Falls, the rivers have become fixed in rock gorges; in other places, where recent shifting has caused them to cut deeply into the banks, the streams are on or near the bed rock and are soon likely to become fixed in their course. The bank at the sharp bend between Thorn and Mooers Forks on the Big Chazy is being undercut on the north side, but the stream is here partly on bed rock.

Bovington brook, near West Chazy, presents a good example of a small stream which has been extended as the land rose above the old water levels with their beach barriers. At about 450 feet the stream passes by a small cut through a barrier beach thrown across its path. Corbeau brook, where it traverses the beaches on the 400 foot contour line, has swept these deposits away for several yards south of its present channel.

Wind-blown sands

Wind-blown deposits of sand in the form of ancient dunes of small extent occur south of the Big Chazy river in the southeastern corner of the town of Mooers at an elevation between 240 feet and 260 feet above sea level. They appear to have accumulated from the deflation of the surrounding sandy tracts. Two such areas of blown sand are shown on the map. That on the boundary line between the towns of Mooers and Champlain is the more conspicuous dune; it has been resorted to as a source of fine sand. Except for the blowing of sand about the artificial openings in the soil covering of the deposit, the sand appears not now to be blowing, and it does not seem likely, with the generally thick grass coating of this region, that these deposits will prove detrimental to farm lands by their extension.

Dunes have not been recognized in association with the ancient shore lines at higher levels within the area, nor are ancient or existing dunes observable about the sandy deltas along the Chazy river and its branches.

Swamps

The fresh-water vegetal accumulations within the area are extensive, particularly in the low grounds and as narrow strips between and behind the low gravel and shingle ridges in the zone of beaches. Besides those shown on the map there are scores of narrow swampy strips too small to be mapped. Considerable tracts belong to the group of wet woods rather than swamps. About 1 mile east of Wood Falls there is a depression occupied by a dense growth of tamarack with the usual swamp conditions. Shallow swamp growths margin many of the streams in northern Altona and Mooers; particularly are these swamps noticeable at the elevation of 500 feet. Abandoned stream beds also give rise to small narrow swamps, as in the example parallel to the Rutland Railroad tracks northeast of Mooers Forks.

Most of the larger swamps in the low grounds appear to occupy the broader depressions in the old sea bottom, where the slopes are too gentle for the existing streams effectively to drain the area. Whether or not the tilting of the district in postglacial times has had any effect on the formation of swamps, does not appear from an examination of their development in relation to north and south flowing streams. The fact that the smaller swamps are mainly shallow, and that they exhibit the habit of climbing the slopes of stream bottoms, offsets perhaps the effects of a displacement of the surface. It should be noted however that a large swamp tract appears along the course of the Big Chazy river on the eastern border of the area mapped just where the river turns to a northward course. The valley is broad and open here and becomes narrower near Perry Mills.

Peat. The swamps on this eastern margin in the town of Champlain, including a large one on the adjacent Rouse Point map to the eastward, are said to be underlain by extensive peat deposits.

SUMMARY OF PLEISTOCENE HISTORY OF THE AREA

Definite traces of glaciation anterior to the latest or Wisconsin epoch have not been recognized. Earlier glacial deposits might well have been scoured away in a region which received the brunt of ice action as the Wisconsin ice sheet pressed on and rose over the northern slope of the Adirondacks. A small deposit of very fine grayish sandy clays, with whiter bands of a more silicious character in the north bank of the Big Chazy, about 1 mile above Mooers Forks and now overlain by boulder clay is the only as yet discovered deposit intermediate in age between the clearly recognizable Wisconsin drift and the ancient Paleozoic rocks. These clays are evidently nonglacial, but whether they are Pleistocene or not is undetermined. The clays contain Potsdam pebbles up to 3 inches in diameter, of angular shapes and free from striae of any sort. Floating ice appears to be demanded for the distribution of such pebbles in stratified clays, and it is possible that the deposit is Pleistocene in age. The top of these clays is approximately 400 feet above the present sea level.

The principal surficial glacial deposits of the region pertain to the latest stages of the ice sheet and were formed at a time when the country to the southward was free from ice. They are undoubtedly contemporaneous with many of the deltas and lake beaches about the southern borders of the Adirondacks, and with the water levels in the upper Hudson valley.

As the ice front receded from the foothills of the Adirondacks, recessional frontal moraines were formed, and, when the ice had receded far enough to permit of the existence of northward flowing streams having a considerable volume of water, this drainage as well as that from the ice became organized in torrential streams, escaping along the ice margin toward the east into a glacial lake covering the site of the present Lake Champlain. These waters flowed across the "flat rock" or spillway at "the Gulf" on the international boundary. As the ice retreated, but before it retreated from the north slope of Covey hill, it seems to have opened a passage just north of the boundary and east of "the Gulf," so that the waters passing through "the Gulf" for a time entered a glacial lake near the mouth of "the Gulf." Eventually the ice melted out from the St Lawrence valley so as to permit the ingress of sea water, whereon strong wave action took place at what is now an elevation of 450 feet on the north slope of Covey hill. Southward wave action is found above and below this limit. That above is referred to a glacial lake, that below mainly to the sea. On the Plattsburg quadrangle, to the southward, there is a cliff with strong delta building at about 330 feet, phenomena which are taken to mark the marine limit at that place. The marine limit fixed in this manner is interpreted to indicate a rise of the old sea level on the north at the rate of 4.41 feet to the mile. This would place the marine limit on the northern margin of the Mooers quadrangle at about 450 feet and on the southern margin of the area at about 370 feet.

Such a tilted plane agrees very closely with the rate of falling off in elevation of the fossil shell localities from Montreal to the southernmost localities known on the New York shore of Lake Champlain.

The land in this district was at an undeterminable elevation during the time it was ice covered. When the ice began to disappear from the region a glacial lake formed along its front in the Champlain valley and it is evident that the land in the southern part of the State was higher than it is now in relation to the Champlain district. During the existence of this glacial lake, changes of level apparently were in progress, but they can not well be discussed without more detailed reference to the glacial retreat on the south than can be given in this local report.

After the sea came in from the north, the land at least began or perhaps continued to rise gradually, causing the sea to retreat from the area. As the land rose, the streams extended their courses, building noticeable deltas at particular levels; and gradually the existing state of physical features of the area was established. There are some reasons for believing that the changes of level are still in progress, though no local measurement of such a movement has been detected.

The general discussion and a more complete account of the glacial lakes and the marine submergence in this area and throughout the Hudson and Champlain valleys will be found in Museum Bulletin 84.

EXPLANATION OF THE MAP OF THE MOOERS QUADRANGLE

The southwestern part of the Mooers quadrangle everywhere above the elevation of 900 feet, and in many places from about 700 feet upward is more or less thickly coated with typical till, here and there taking on a hummocky aspect where thickened in the manner indicative of recessional moraines. There is but one stratified sand deposit in this field, that near Alder Bend.

The mapping of the general sheet of surficial deposits below the limits of this clearly demonstrable unmodified glacial drift must be regarded as provisional. After the work was begun what at first sight on the basis of long familiarity with glacial drift in other districts was taken to be unaltered glacial till was ascertained to be till partly modified by the action of waves or currents. Thus near Norwood, on the west of this field, marine shells occur at the depth of over 2 feet in what at the surface has all the appearance of glacial till, but which in section shows that it must be regarded as a rubbly layer worked over without distinct stratification or even rounding of the constituent rock particles. Usually the action of the sea on these stony tills has been to leave the surface of the deposit strewn with many small blocks of rock, which appear to have accumulated on the surface as the result of the washing away to lower grounds of the finer sands and clayey particles of the superficial layer in which the stones were originally embedded. The larger glacial boulders are seldom moved far and often project from the soil as in the case of ordinary till areas.

The area mapped as "Undifferentiated glacial deposits superficially worked over by waves and currents" is of the above described character. Beach lines, and bars of wave-heaped rubble are common in the district as shown on the map. This belt rises to a somewhat higher elevation on the southern border of the area than it does on the north.

Lying above this wave-modified district there are in the northwestern part of the area very similar deposits only less distinctly reworked except along certain ancient water levels. The distinction between the two areas is difficult to make and there are large areas in both fields which I am sure are identical in topography, in composition of the drift, and in structure; yet one distinctly gets the impression in passing from the low grounds to the upland portion of the district on going above an elevation of from 450 to 500 feet, that he is passing from a zone of largely water-laid materials to a region of till. The demarcation in the field between these two areas of more or less modified deposits is usually very vague. I have drawn it on the map at about 500 feet in elevation in the northern part of the map because above that line the chief characteristic of the lower belt of materials—the presence of beaches—is usually wanting.

Another plan of mapping would have placed the area covered by glacial lakes under one color and that later covered by the sea under a different color but this would have resulted in an equally arbitrary division of the deposits of the area.

The pattern for beaches and bars has been applied equally to the belts of rounded pebbles and angular stones, to the coarse bouldery deposit of Cobblestone hill and the sandy beaches. Some of the lines of supposed water level above the 500 foot line in the northern part of the area are also marked by the same pattern and color.

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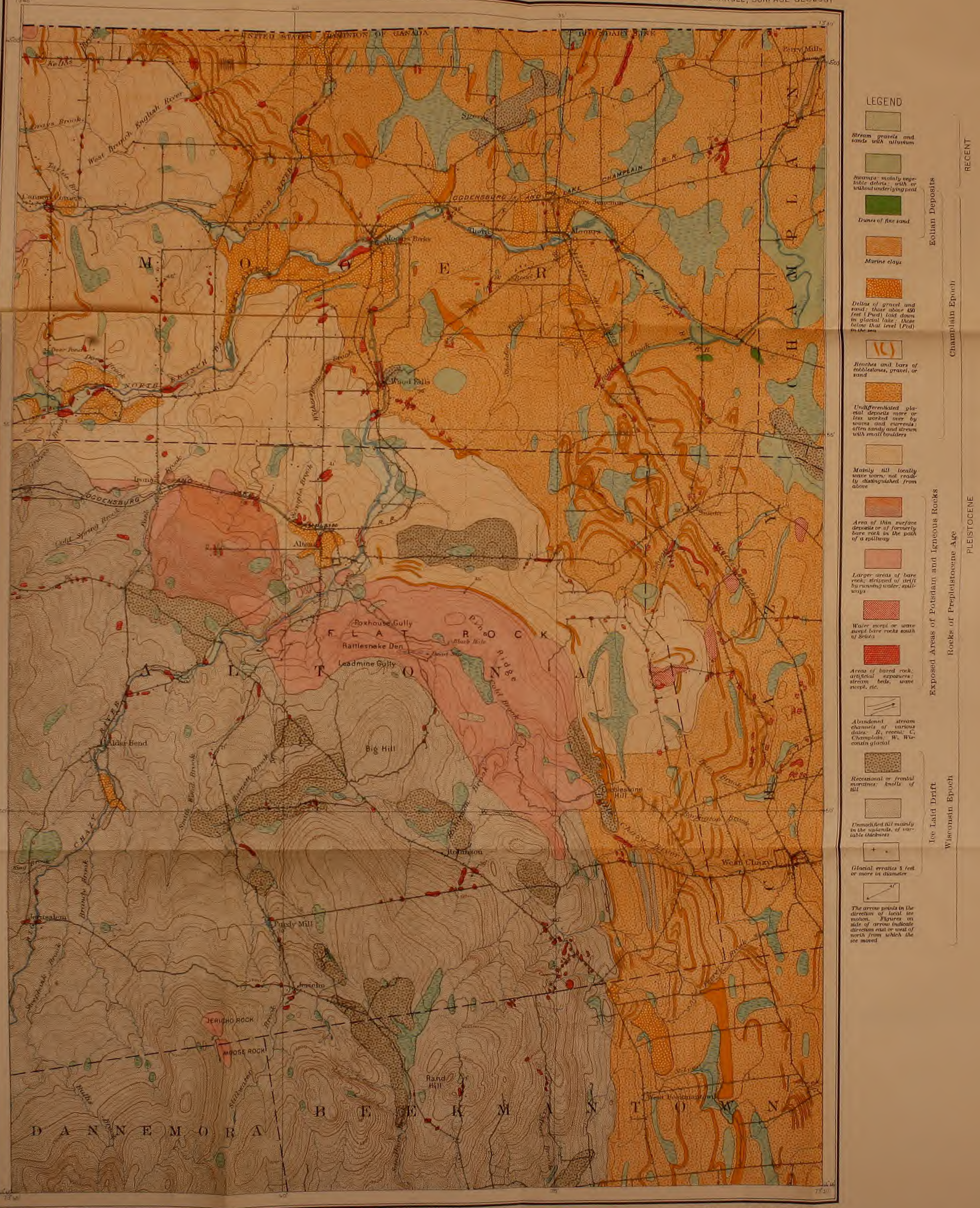

BASE by U. S. GEOLOGICAL SURVEY
Surveyed in 1893 in cooperation with the State of New York.
Campbell W. Adams, State Engineer and Surveyor.

Barnard
McCormick

Scale $\frac{1}{62500}$

Contour interval 20 feet.
Datum is mean sea level.

Pleistocene Geology by J. B. Woodworth
1902–1903.

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New York State Museum

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Geologic map of the Mooers quadrangle

New York State Museum

The New York State Museum as at present organized is the outgrowth of the Natural History Survey of the State commenced in 1836. This was established at the expressed wish of the people to have some definite and positive knowledge of the mineral resources and of the vegetable and animal forms of the State. This wish was stated in memorials presented to the Legislature in 1834 by the Albany Institute and in 1835 by the American Institute of New York city and as a result of these and other influences the Legislature of 1835 passed a resolution requesting the secretary of state to report to that body a plan for "a complete geological survey of the State, which shall furnish a scientific and perfect account of its rocks, soils and materials and of their localities; a list of its mineralogical, botanical and zoological productions and provide for procuring and preserving specimens of the same; etc."

Pursuant to this request, Hon. John A. Dix, then secretary of state, presented to the Legislature of 1836 a report proposing a plan for a complete geologic, botanic and zoologic survey of the State. This report was adopted by the Legislature then in session and the governor was authorized to employ competent persons to carry out the plan which was at once put into effect.

The scientific staff of the Natural History Survey of 1836 consisted of John Torrey, botanist; James E. DeKay, zoologist; Lewis C. Beck, mineralogist; W. W. Mather, Ebenezer Emmons, Lardner Vanuxem and Timothy A. Conrad, geologists. In 1837 Professor Conrad was made paleontologist and James Hall, who had been an assistant to Professor Emmons, was appointed geologist to succeed Professor Vanuxem, who took Professor Conrad's place.

The heads of the several departments reported annually to the governor the results of their investigations, and these constituted the annual octavo reports which were published from 1837 to 1841. The final reports were published in quarto form, beginning at the close of the field work in 1841, and 3000 sets have been distributed, comprising four volumes of geology, one of mineralogy, two of botany, five of zoology, five of agriculture, and eight of paleontology.