ART. XXXI.—*Terminal Moraines of the North American Ice-Sheet;* by WARREN UPHAM.

[Continued from page 92.]

BEYOND Block Island the extreme terminal moraine does not rise above sea-level for 35 miles, at which distance in a direction a little to the north of east it reäppears in No Man's Land and Gay Head. Heights of it here and in its farther extent are as follows: No Man's Land, about 150; Gay Head, 100 to 145; about one mile east, near the church, 185; Prospect Hill, the highest on Martha's Vineyard, 295; Peaked Hill, a mile south from the last, 290; other hills, reaching from these five miles to the northeast, 200 to 250; Indian Hill, 245; Sampson's Hill, on Chappaquiddick Island, about 100; highest part of Tuckernuck, about 50; Macy's or Pole Hill, the highest of Saul's Hills, 91; Folger's Hill, a mile east from the last, 88; and Sankaty Head, the highest point of Nantucket Island, 105. The cliffs of Gay Head, at the west end of Martha's Vineyard, expose a section four-fifths of a mile long, composed at the top of the unstratified terminal moraine, five to forty feet thick, filled with abundant bowlders of all sizes up to twenty feet in diameter. This rests on fossiliferous beds,* probably of Miocene Age, which dip from 20° to 50° northerly throughout the section, and present a most striking succession of brightly-colored clays, sands and gravel, varying from black to red, brown, gray and white. Gay Head township, reaching three miles to the east, has a very uneven surface of glacial drift in small elevations and depressions, strown with frequent bowlders, but apparently underlain by Tertiary clay and sand at no great depth.

In the next eight miles this moraine forms high parallel ranges of hills, very irregular in contour, which extend northeastward through Chilmark and the northwest part of Tisbury, occupying a width of one to three miles. Their surface is generally till, with very abundant bowlders; but occasionally, as at the top of Prospect Hill, it is modified, consisting mainly of water-worn gravel and sand. The black, red and white Tertiary clays underlie these deposits in the hills, and are exposed in the cliffs along the northwest shore to the east side of Lumbard's Cove, eleven miles from Gay Head. Upon the south side of Prospect and Peaked Hills they extend to heights 225 and 250 feet above the sea.

The southeast half of Martha's Vineyard consists of modified drift without bowlders, lying in extensive level plains, twenty-five to fifty or sixty feet above sea. Along the south shore

* Described in Hitchcock's Geology of Massachusetts, 1833 and 1841; in Lyell's Travels in North America in 1841–2, vol. i, pp. 203–206; and in this Journal, I, vol. xlvi, pp. 318–320.

these plains are indented by numerous ponds, which are only separated from the ocean by a beach, and the shores of the ponds are again indented by long and narrow arms or coves, from the head of which dry channels, similar to those described on Long Island, extend across the plains in a northerly course. The road from West Tisbury to Edgartown crosses several of these depressions, one of which, known as Quampachy Hollow, may be taken as an example. This starts from the head of Oyster Pond, a narrow arm of the sea, which stretches two miles north from the beach by which it is now shut in. The dry hollow, diminishing from twenty-five to ten feet in depth, and from 300 to 100 feet in width, prolongs this valley at least three miles to the north. Near Vineyard Haven and Oak Bluffs, north of these plains, and on Chappaquiddick Island, the modified drift, sometimes sprinkled with bowlders, is heaped in gently sloping hills, 50 to 100 feet high, which appear to have been formed at the margin of the ice-sheet.

Thence the line of terminal moraine is continued in Muskeget and Gravelly Islands, which however are only low banks of gravel and sand. On Tuckernuck Island it appears again in small hills, which in part are unstratified, with plenty of bowlders, the remainder being modified drift. Nantucket is composed almost wholly of stratified gravel and sand. The line at which the ice-sheet appears to have terminated is marked in the west part of this island by gently undulating hills, forty to fifty feet high, composed of stratified drift, which, however, differs from that of the plains on the south in having here and there bowlders up to ten feet in diameter embedded in it or lying on the surface. The course of this line is from Eel Point, north of Maddequet Harbor, by Trot's Hills to the town. Eastward it continues on the same course in the Shawkemo and Saul's Hills to Sankaty Head. The portion of this series called Saul's Hills, two miles long and a half mile wide, is of very irregular contour, with steep and abruptly changing slopes, forming hills, ridges, mounds and small enclosed basins, some of which contain ponds. The material is stratified gravel and sand, upon and in which are scattered bowlders, varying up to ten feet in diameter.

Sankaty Head, at the east shore of the island, affords a section across this range.* A quarter of a mile south from the light-house, the order of deposits, beginning at the base is as follows: brown sandy clay to about twenty feet above sea; ferruginous sand and gravel, four feet; white sand, four feet; yellow sand enclosing masses of blue clay, one foot; ferruginous gravel and sand, with abundant shells, two feet; a bed of

* The Post-pliocene beds at the base of this section, and their fossils, are described by Professor A. E. Verrill and Mr. S. H. Scudder, in this Journal. III, vol. x, pp. 364–375.

serpula, mixed with sand, about two feet; gravel and sand again, thickly filled with shells, two feet; fine white sand, about ten feet; the common yellow sand and fine gravel of the modified drift, about forty-five feet, its top being at ninety feet; coarse gravel, three feet; ferruginous sand, one foot; changing above into a former surface soil, one foot thick; overlain by three feet of dune sand, which forms the present surface, ninety-eight feet above sea. The highest part of the bank is midway between this and the light-house. From a comparison of the species contained in these two shell-beds, Professor Verrill estimates that the temperature of the sea at this place was lowered 15° between the times in which they lived. The layer of coarse gravel which occurs here at the height of ninety feet, is continuous for a half-mile from this point both to the north and south, varying from three to eight feet in thickness. About half of its rock-fragments are rounded, these being of all sizes up to one foot through; the rest, which are rough and angular, range up to two feet, and rarely to four feet, in diameter. This bed has its greatest thickness and is coarsest at the highest portion of the bluff, where it closely resembles till. The old surface of black soil and the present surface of dune sand are also continuous along the same distance. An eighth of a mile south from the shell-beds, the bluff falls to a hollow about sixty feet above the sea, and in this depression the blackened layer becomes a bed of peat, two feet thick, containing numerous stumps and roots of trees and covered by two feet of sand. The rocky stratum, the old surface soil, and the overlying sand thus cap the bluff for more than a mile, in which its height falls from 105 feet at the middle to about 35 feet at each end. Below the rocky layer it consists of fine modified drift and pre-glacial beds. This succession tells of a period when the sea had about its present temperature; next it becomes much colder; sand and fine gravel are accumulated to a depth of more than fifty feet, probably brought by rivers from the summer-meltings of the ice-sheet; this finally reached its outmost limit, overspreading the north half of the island; at its retreat the coarser materials which it held were dropped; forests sprang up, as the climate became mild again; and, lastly, the sea has eaten away the east portion of these deposits, while the sand of its shore has been swept by the wind over their top.

The whole south side of Nantucket Island consists of nearly level plains of gravel and sand, twenty to sixty feet above the sea. This expanse, reaching more than ten miles from west to east, with a width varying from one to three miles, is broken by frequent hollows which extend approximately from north to south, like those already noticed on the similar plains of Long

Island and Martha's Vineyard. Narrow ponds, to the number of a dozen or more, having the same height with the ocean, fill the entire course of these depressions, or occupy their lower end next to the south shore.

The Second Terminal Moraine.—A later series of morainic hills extends along the north shore of Long Island for forty-five miles eastward from Port Jefferson to its extremity at Orient Point. Their heights are approximately as follows: Strong's Neck, close east of Port Jefferson, 100 to 200 feet; Mount Sinai, at school-house, and Miller's Place, each about 150; Noah Jones' Hill, 1½ miles east from Miller's Place, 200; Pine Hill, one mile farther east, 175; Blue Point Hills, one mile southeast from last, 150; hills near Wading River village, 150 to 200, the highest of which, at Mr. D. M. Tuthill's, a mile east from the village, commands a very fine view; hills, partly of dune sand, north of Baiting Hollow, known by the names of "Horse in the Bank," Horton's Bluff, and Friar's Head, about 150; at Northville, 125; Jacob's, Cooper's and Mattituck Hills, 125 to 150; Manor Hills, extending east from Mattituck Inlet, 100 to 150; Horton's Point, 70; highest points for the next seven miles, extending by Greenport, about 50; Brown's Hills, north of Orient, 110 and 160. East from the light-house on Horton's Point, these deposits, though not rising in prominent hills except at Orient, are in many places unstratified, with an abundance of large angular bowlders, which are of all sizes up to twenty-five feet in diameter. This terminal moraine overlies stratified gravel, sand and clay, which contain no bowlders; as is well shown in the bluffs, 50 to 100 feet high at the north side of Brown's Hills, where the very coarse morainic till is five to twenty feet thick, and forms the entire surface of these hills. The last two miles of this shore from near Brown's Point east to Orient Point, are all stratified gravel and sand twenty to forty feet high, strown in only a few places with bowlders; being a part of the plains which skirt the south side of the moraine. Its hills probably once existed here at a little farther north, but they have been washed away by the sea. The same action is apparent throughout the whole extent of this series on Long Island, so that many of these hills have lost more or less from their north side, and stand as half-eroded barriers which are still falling slowly before the encroachment of the waves. The greater portion of this series, extending more than thirty miles from Port Jefferson to Horton's Point, is composed, like the extreme moraine on the south, of obliquely stratified sand and coarse gravel, with occasional bowlders, which are sometimes of enormous size. One of these, about thirty feet long, lies at the north side of the road, 1½ miles west from Wading River. Two

others of equal size are seen close to the road in Setauket village. The largest block yet found on Long Island lies much farther west, at about a mile southeast from Manhassett, and is, according to measurement by Mr. Lewis, fifty-four feet long, forty feet wide, and sixteen feet high.

This later moraine is separated six to ten miles, on Long Island, from that formed at the extreme line reached by the ice-sheet, and the area between them is occupied by extensive plains, the Peconic Bays, and Shelter Island. This series of plains resembles that of southern Long Island, in that both slope southward from terminal moraines on their north side, and are alike crossed by ancient water-courses which are now dry. The plains associated with the second terminal moraine begin at Syosset, about twenty-five miles west from Port Jefferson, and it is not improbable that the second moraine may be represented in the irregularly scattered hills, composed of modified drift with bowlders here and there, which lie at their north side along this distance. For the first ten miles the plains vary from one to two or three miles in width, having a height from 100 to about 150 feet above sea. Their greatest altitude appears to be at East Northport station. Here they pass beyond the north spur of the Dix Hills and expand to the south, attaining a width of five miles, which continues without much variation to Riverhead. In Smithtown considerable portions of these plains have been removed by the erosion of streams since the Glacial period. Their height along their north side here and in Brookhaven is 150 to 100 feet above sea, from which the general slope southward is about ten feet to the mile. Near the east line of Brookhaven is a notable series of ponds, reaching four miles, and lying in depressions of one of the old lines of drainage. These are called the West Row Ponds, and are known in their order from north to south as Long Pond, Big and Little Tar-kiln, Pease's, Duck, Sandy, Grass, and Jones' Ponds, extending to the Peconic River at a mile west from Manorville. Two miles eastward in Riverhead are the East Row Ponds, a similar series, including in the same order the two Jackson Ponds, Ice, Worthington and Fox Ponds. Northeast from Fox Pond is a tributary series, including Sand, Mud and Cranberry Ponds. Several other valleys, not containing ponds and of similar character with those of the southern plains, extend southward from the vicinity of Baiting Hollow and Northville. On the north branch of the island these plains diminish from four miles to about one mile in width, their height being sixty to thirty feet at the north, from which they slope to the shores of Peconic and Gardiner's Bays. The hilly character of Shelter Island, which varies from 50 to about 180 feet in height, being composed of stratified sand and gravel

with occasional bowlders, indicates that it was of similar origin with the hills of modified drift in the two moraines between which it lies. During the retreat of the ice-sheet it would appear that exceptionally large deposits were accumulated by its rivers here and at Gardiner's Island.

The continuation of the second moraine beyond Orient Point is to the east-northeast in Plum and Fisher's Islands, and from Watch Hill through the south part of Westerly, Charlestown and South Kingstown in Rhode Island, to near Point Judith. On Plum Island it forms hills about 100 feet high, abundantly covered with bowlders; but a considerable tract on the south side of this island is a low plain of modified drift, free from bowlders and sloping southward. Gull Island is a remnant of this plain which was formed in front of the terminal moraine. Fisher's Island, about seven miles long, is a conspicuous remnant of the moraine, being composed of the same coarse glacial drift with Brown's Hills and Plum Island. Its elevations vary from 100 to nearly 200 feet in height, the most prominent being Mount Prospect, North Hill, and Chocomount. Portions of the low plains are preserved on its south side for a mile from its west end, and again for a third of a mile between two ponds near the middle of the island.

In the State of Rhode Island this moraine is well developed for seventeen miles, and its whole course may be finely seen from the carriage road in going from Watch Hill through Charlestown and Perryville to Wakefield. After the first three miles, which are mostly on the north side of the range, this road lies for fifteen miles at the south foot of these hills, which are so irregular and broken in contour and so rough with their profusion of bowlders that they cannot fail to impress the observer with the remarkable features of an entirely unmodified terminal moraine. The width of this series of deposits is from one to two miles, and some of its highest points, not noticeable from this road, consist of stratified gravel and sand without bowlders. Such are Chin and Cranberry Hills in Westerly, and the tops of Indian Burying and Sand Hills in Charlestown. These rise 100 to 150 feet above sea, and probably no points of the range reach to 200 feet. Fort and Village Hills in Westerly, the "Old Mountain" and Bunker Hill in Charlestown, and Broad Hills in South Kingstown, are unmodified portions of this series. The margin of land on its south side, averaging perhaps a mile in width, consists mainly of gently undulating modified drift, with occasional bowlders, its only expanse in plains being for about three miles in the southeast part of Charlestown. Within one to two miles northeast and east from Perryville, several ponds occur among the hills, ridges and knolls of the moraine. At this part of its

course it appears to turn to the southeast, passing into the sea two miles west of Point Judith. This angle corresponds to a similar one which was probably formed in the extreme moraine at Block Island, whence it also seems to have extended first to the southeast, in which direction very rocky fishing-ground is found at a distance of ten miles from that island.

The next appearance of the northern moraine is in the Elizabeth Islands, where the position of Cuttyhunk, Penikese and Nashawena Islands corresponds to that of No Man's Land, Gay Head and the hills of Chilmark in the southern moraine, indicating that angles occur again in them both, respectively at Penikese and at Gay Head. Heights of the later moraine on the Elizabeth Islands and Cape Cod, are as follows: highest portion of Penikese, about 100 feet; of Cuttyhunk, Nashawena, Pasque and Naushon Islands, about 175; the Quisset Hills, west of Falmouth village, about 150; station of the United States Coast Survey, a mile east of West Falmouth, 198; the Ridge Hills, extending thence to the angle of this series near North Sandwich, 150 to 200 feet; southwest from Sandwich village, about 225; Bourne's Hill, a Coast Survey station, two miles south-southeast from Sandwich, the highest point of the whole series, 297; the Discovery Hills, including the last and extending eastward, 250 to 150; Shoot Flying Hill in Barnstable, about 200; German's Hill in Yarmouth, 138; Scargo Hill in Dennis, 166; railroad summit at Brewster station, 125; and Mill Hill in Orleans, about 150.

This moraine forms the entire chain of the Elizabeth Islands, fifteen miles long, with an average width of one mile. Their contour throughout is very irregular in roughly-outlined hills and ridges of variable height, enclosing many crooked and bowl-shaped hollows, which often hold small ponds. Their material is glacial drift with abundant bowlders of all sizes up to twenty or thirty feet in diameter. The surface exhibits all the characteristic features of the upper till, being loose, yellowish in the color of its detritus, and with its bowlders almost invariably angular. This deposit also appears to form the greater part of the cliffs upon the shores of these islands. At the northeast end of Naushon, however, in deepening an old well from forty-five to sixty-seven feet, only the dark and compact lower till, or ground-moraine, was found.

The trend of this chain of islands is about east-northeast, but on the peninsula of Cape Cod the same belt of hills, continuing with its width, contour and material unchanged, bends within a few miles to a course nearly due north. A railroad cutting thirty feet deep in these deposits near Wood's Hole, and shallower sections on the Quisset Hills, show two or three feet of yellowish till at top succeeded below by light gray till, equally

coarse but apparently more compact, with some of its fragments planed and striated. The latter was probably accumulated beneath the ice-margin, while the former was dropped by its melting. After holding its way northward ten or twelve miles, reaching to a point about a mile south of North Sandwich, the range turns at a right angle to a course a few degrees south of east. Some portions of it in this vicinity are strown with bowlders, but mainly, as shown on the roads which cross these hills southwest and south from Sandwich village, at the highest portion of the entire series, they consist of stratified gravel and sand, with bowlders rare or entirely wanting. There is also a change to a more simple contour, with fewer irregular hills and hollows. From its angle the range extends about thirty-five miles to the east shore of the cape. Through Sandwich and Barnstable it lies about a mile south of the railroad, consisting in the latter town of hills 100 to 200 feet high, apparently formed of modified drift, with frequent bowlders embedded in it and scattered upon its surface. In Yarmouth the series is somewhat broken, and the railroad crosses it upon a sand plain a little west of German's Hill. South of Dennis Pond and for one and a half miles northeast from German's Hill to Follin's Pond, it is very well shown in exceedingly rocky, low hills. Next it appears to suffer an offset of about two miles to the north, being represented by Scargo Hill, which is modified drift with only few bowlders. Thence it runs a little north of east six miles to Brewster station, where it is again crossed by the railroad. Through most of this distance it is very rocky, some of its blocks being twenty to thirty feet or more in diameter. Its further course is mostly modified drift with occasional bowlders, passing east-northeast to Mill Hill, Orleans village, and the southeast side of Town Cove, beyond which it is concealed beneath the ocean.

The angle of this range at North Sandwich shows that the portion of the ice-sheet on the west and that on the east pushed against each other here, the motion and slope of each being directed toward its line of frontal moraine. The medial moraine produced where their slopes came together north from the angle of their terminal line, is presented in Rocky, Manomet and Pine Hills, which form a gigantic ridge in the east part of Plymouth, four miles long from north to south, with a continuous height 300 to 400 feet above the sea. Abundant angular bowlders of all sizes up to twenty feet in diameter strow its surface. At the north end of this ridge the sea has undermined its base, forming a steep slope sixty feet in height. A section here showed twenty feet of upper till, yellowish, with abundant large and small bowlders, nearly all of them angular, underlain by lower till, dark bluish gray, with small glaciated

stones, exposed for twenty feet vertically but concealed below. The bed of bowlders which forms the shore at this point came mostly from the upper stratum, and their sharp corners and edges have since been worn away by the waves.

On Cape Cod, as on Long Island, Martha's Vineyard and Nantucket, we find south of the line of morainic hills an area of stratified gravel and sand without bowlders, forming extensive plains which slope very gently southward. These are fully ten miles wide from north to south in Sandwich, Falmouth and Mashpee, and thence to the east they have an average width of five miles. From the southwest limit of this area at Falmouth village, the traveler who follows the road along the south side of the cape for thirty miles sees only level plains, twenty-five to forty feet above the sea, with occasional hollows and valleys, most of which are occupied by ponds and brooks. The north edge of this area, next to the terminal moraine, consists of more elevated plateaus, 50 or 75 to 200 feet in height. From this line there is a continuous slope southward, scarcely perceptible, but declining in the five to ten miles of its extent to within twenty-five to forty feet above sea. This north portion of the plains is marked by frequent hollows of large extent, which contain ponds 50 to 100 feet below the general surface. A fine idea of the slope of this deposit of modified drift is obtained in a journey from Sandwich to Greenville, Ashunet Pond and Falmouth. The ascent of 200 feet or more from sea-level to the highest point of the road is accomplished in two miles, bringing us to a point where Bourne's Hill, the highest on Cape Cod, is within a half mile to the east; while close at the west is the Great Hollow, about 100 feet deep and perhaps a half-mile wide, enclosed on all sides by the hills and high plains. Without descending more than twenty feet below its highest point, the road next enters on a plain of gravel and sand, and thence extends seven miles before crossing the first hollow which is at Ashunet Pond. Beyond this point it crosses numerous depressions that are or have been water-courses; but there is no break in the continuity of the plains, which in about twelve miles descend by a gradual slope from the height of 200 feet to sea-level.

These plains of Cape Cod are also like those previously described in being indented by narrow arms of the sea which reach one to two miles inland, filling the lower end of long depressions that continue across the plains to the north, being either dry or occupied by small streams. These channels are best shown on Cape Cod in Falmouth and eastward to Cotuit harbor, being in the region directly south from the angle of the terminal moraine and from its highest hills, which in this portion of its course are composed mainly of modified drift;

in other words, they occur most abundantly where the drainage from the melting ice-sheet must have been greatest, including all the floods poured down from the ice-fields along the line between Falmouth village and North Sandwich, those that converged toward the angle of the ice-margin, and those which brought down its vast frontal hills of gravel and sand along several miles eastward.

Extensive portions of the terminal moraines were deposited, as we have seen, by rivers which flowed from the surface of the melting ice when a warmer climate returned. On the south side of these the plains have their greatest width and height, while on the north we also find extended areas of modified drift, which show that the glacial floods continued to be poured down to the same portions of the ice-margin during its retreat. Thus on Long Island the area north of the extensive moraine from the Narrows to Roslyn consists almost wholly of undulating unmodified drift with abundant bowlders, while farther eastward it is stratified gravel and sand with few bowlders. Wherever angles occurred in the terminal front of the ice its surface had converging slopes, which would be likely to produce extraordinary fluvial deposits. This may explain the origin of the thick beds of stratified drift which form nearly the whole of Block Island, and of the plains in South Kingstown, R. I., which extend six miles north from the angle of the second moraine, reaching from Tucker's and Worden's Ponds to the north line of the township. The plains south of the moraines at their angles near Vineyard Haven and North Sandwich are notably due to the debouchure of glacial rivers at these points; and when the ice-sheet retreated from its second moraine, the floods which it discharged formed a most irregular belt of gravel and sand in ridges, hills, plateaus and hollows of every shape, but generally with a north-to-south trend, through a distance of nearly twenty miles to the north and north-northwest, reaching from its angle at North Sandwich through Plymouth to Kingston. West and north from these kames, the greater part of Plymouth County consists of nearly level or moderately undulating deposits of modified drift, 50 to 150 feet above sea, which reach continuously from the angle of the terminal moraine on Cape Cod more than thirty-five miles to Hingham, on the south shore of Massachusetts Bay. Another and perhaps more remarkable series of fluvial deposits was supplied from the melting ice-sheet to form Nantucket, the hills which rise 75 to 125 feet above sea in Chatham, the southeast township of Cape Cod, and the north portion of this peninsula beyond Orleans, which consists entirely of modified drift from 50 to 175 feet above sea.

The first recognition of the terminal moraines of southeastern

Massachusetts was by Mr. Clarence King,* who examined Naushon Island and pronounced it, with the similar formation continuing on Cape Cod, to be a series of deposits accumulated at the margin of the continental ice-sheet. The same conclusion has been announced by the geologists of Wisconsin and New Jersey respecting the series which cross those States. At these lines the border of the ice appears to have remained nearly stationary through a long period, in which the materials that it contained were being continually brought forward and deposited.† In many places these would be pushed into very irregular heaps and ridges by slight retreats and advances of the ice-margin. At the same time we should also expect that thick beds of ground-moraine would be gathered beneath the ice near its termination. The withdrawal of the glacial sheet would then leave these deposits as upper and lower till, one overlying the other in a long but broken and undulating range. In many parts of these series, however, the materials brought by the ice have been covered by modified drift brought by glacial rivers; so that the three divisions of the drift join to form the terminal moraines. No similar series of drift deposits seems to have been discovered north of the second here described, and we may conclude that in general the retreat of the ice-sheet did not admit sufficient pauses for their formation.

* Proceedings of the Boston Society of Natural History, vol. xix, p. 62.

† In Long Island and throughout New England, the materials that make up the drift are uniformly derived from the north, the greater part of them being from the nearest formations in that direction, while nearly all the rock-fragments are represented by ledges within fifty miles. The most remote origin required by any bowlders or pebbles found in the drift of New Hampshire during the recent geological survey of that State is about eighty-five miles. Respecting the origin of bowlders at the north end of Manomet Hill in Plymouth, Dr. Edward Hitchcock, the State Geologist, reported that this locality shows nearly every variety of granite, syenite and porphyry, found along the coast northward as far as the extremity of Cape Ann. Dr. C. T. Jackson, in his report on the geology of Rhode Island, says that the greater part of the bowlders found on Block Island are porphyritic granite such as occurs in place at Point Judith and Kingston, twelve and twenty miles distant at the north. Sir Charles Lyell, in his "Travels in North America," quoting in substance from one of Professor Mather's annual reports, says of Long Island: "At its eastern extremity the bowlders are of such kinds of granite, gneiss, mica slate, greenstone and syenite, as may have come across the Sound from parts of Rhode Island, immediately to the north. Farther westward, opposite the mouth of the Connecticut River, they are of such varieties of gneiss and hornblende slate as correspond with the rocks of the region through which that river passes. Still farther west, or opposite New Haven, they consist of red sandstone and conglomerate, and the trap of that country; and lastly, at the western end, adjoining the city of New York, we find serpentine, red sandstone, and various granitic and crystalline rocks, which have come from the district lying immediately to the north."

Excepting the pre-glacial deposits which have been mentioned, and a small area of gneiss and hornblende schist at Long Island City and Astoria, the whole of Long Island, Block Island, Martha's Vineyard, Nantucket, the Elizabeth Islands, and the peninsula of Cape Cod, consist of drift deposits which owe their accumulation, as has been here shown, to the action of the ice-sheet and its rivers in amassing them at its termination.

It remains for us to notice briefly the probable extent and equivalency of these terminal accumulations of the ice-sheet, both to the east and west. Agassiz believed that the fishing banks or submarine table-lands, which lie at a distance of 100 to 200 miles east and southeast from Cape Cod, Nova Scotia and Newfoundland, are such glacial deposits. On the other hand, it has been recently learned that fragments of fossiliferous rock,* apparently of Miocene age, are brought up from the sea-bottom on George's Bank, Banquereau and the Grand Bank, by the coralline growths attached to them becoming entangled with fishermen's lines. These indicate that this coast, 1,000 miles in extent, is bordered by submerged Tertiary formations, similar to those that occur above sea-level in the Southern States, as had been already suggested by Professor C. H. Hitchcock,† before this discovery. Although it now seems likely that these older deposits form the principal basis of the fishing banks, it is clear that the opinion of Agassiz was part of the truth; for besides the fossiliferous fragments many of granites and schists are also obtained by the fishermen. Furthermore, the course of the extreme terminal moraine that crosses New Jersey, Long Island, Block Island, Martha's Vineyard and Nantucket, has its line of continuation in these remarkable submarine banks. It is probable, therefore, that they consist, somewhat like Gay Head, of Tertiary strata covered with their own and foreign detritus brought by the ice-sheet.

The later moraine of Cape Cod, the Elizabeth Islands, southern Rhode Island and the north shore of Long Island, was formed after the ice had retreated from its farthest limit, but while it still terminated eastward beyond the present coast-line. This halt in its departure was extended along the entire margin of these ice-fields to the west for a distance of more than 2,000 miles. In the interior of the United States the extreme limit of glacial action has not yet been found to be generally marked by extraordinary deposits, but a most notable series of terminal moraines north of this line and probably contemporaneous with that of Cape Cod is found, as recently shown by Professor Chamberlin,‡ stretching across Ohio, and represented in southern Michigan, in the Kettle Moraine of Wisconsin, and the Leaf Hills of Minnesota; while its farther continuation seems to be in the Coteau des Prairies and the Coteau de Missouri of Dakota and British America, reaching northwestward, according to Mr. G. M. Dawson,§ to the North Saskatchewan

* Described by Professor Verrill in this Journal, III. vol. xvi, p. 323.

† Appalachia, vol. i, p. 13; and Geology of New Hampshire, vol. ii, p. 21.

‡ "On the Extent and Significance of the Wisconsin Kettle Moraine," in Transactions of Wisconsin Academy of Science, 1878, with maps.

§ Quarterly Journal of Geological Society, vol. xxxi, pp. 614–623, with map.

River, 350 miles west of Winnipeg Lake. These deposits, like the moraines of southern New England, are made up entirely of drift materials, partly unstratified with abundant bowlders and partly stratified gravel and sand, in hills 100 to 300 feet high, of very irregular contour, with many enclosed hollows, and occupying a width of from one to thirty miles. They lie upon the uneven surface of the rocky strata, being continuous across valleys and ranges of highland, which in Wisconsin undulate 800 feet in vertical height; while the elevation of this entire series of terminal moraine varies from sea-level in the region that has been here described to 2,000 feet above it at the north line of Dakota.

In the Western States the front of the ice-sheet is shown by Professor Chamberlin to have been lobed, producing acute angles in its terminal moraine, with medial moraines extending northward from them; corresponding to which, we find a deflection of ninety degrees in the series of morainic hills on Cape Cod, with the massive medial moraine of Manomet and Pine Hills a few miles farther north. The same lobed character appears also to have marked the ice-sheet at its greatest extent, making angles similar to those of a later period in its frontal line, and even enclosing a large driftless area in Wisconsin. It is now possible to draw two pictures in our mind of this glacial sheet: the first, when it reached its farthest boundary, probably coinciding nearly with the course of the Columbia, Missouri and Ohio Rivers, and the south coast of New England, while a part of Wisconsin and adjacent States was an oasis of verdure surrounded by its desert of ice; the second, when it had yielded a portion of its ground, but rallied again to a sturdy resistance before being fully put to flight.