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THE PHYSICAL GEOGRAPHY OF NEW YORK STATE.

PART I.—GENERAL PHYSIOGRAPHIC FEATURES.*

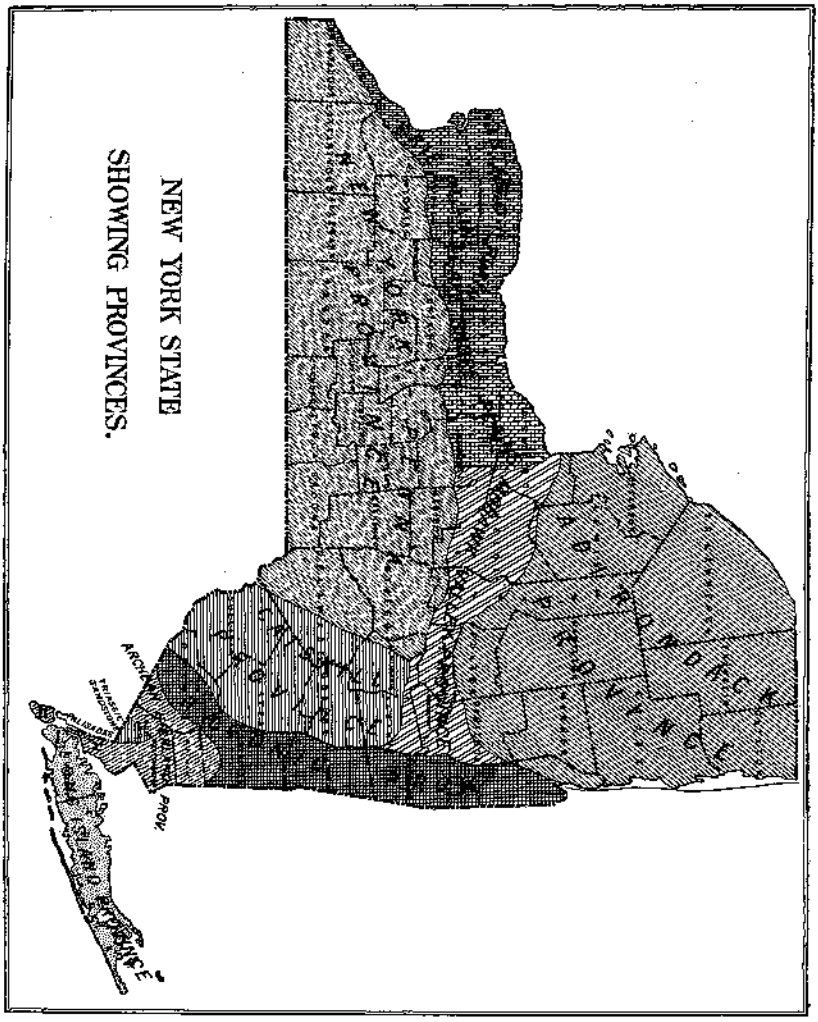
* In later pages references are made to special discussions of individual features. General descriptions are found in the following: Eaton, Geological and Agricultural Survey of the District adjoining the Erie Canal in the State of New York, Albany, 1824.

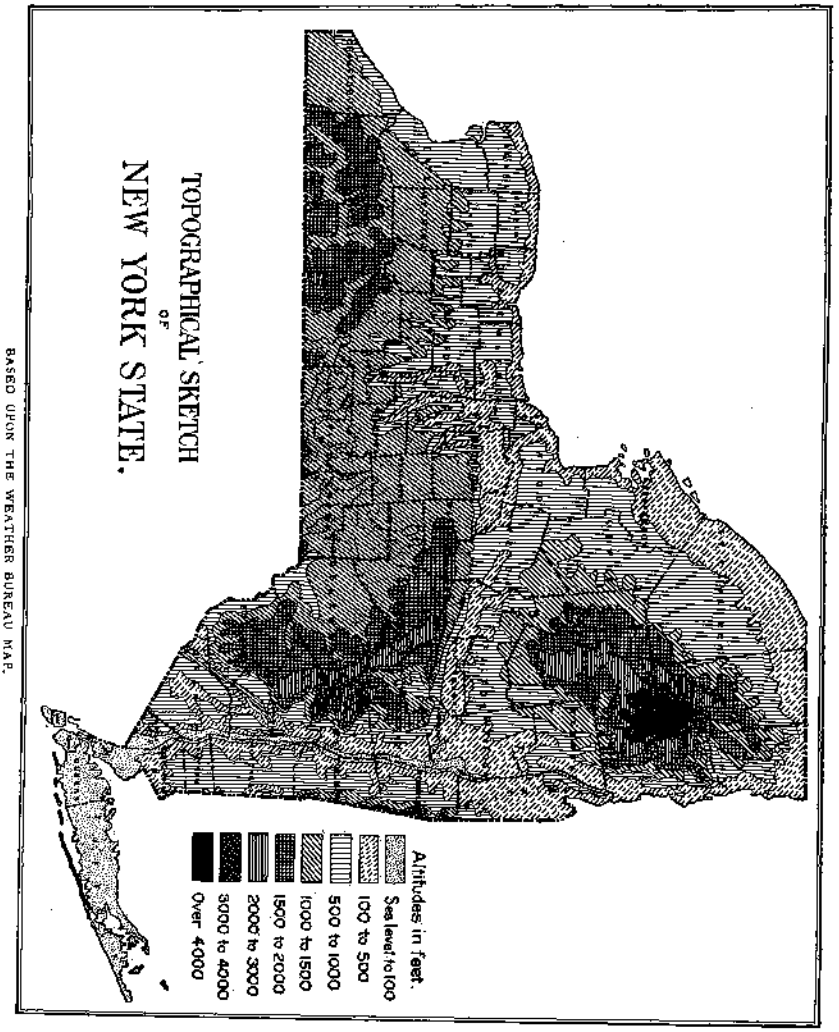
Henry, Trans. Albany Inst. I, 1830, 87–112.

Natural History of New York, Geology, Part I, Mather; Part II, Emmons; Part III, Vanuxem; Part IV, Hall, 1842–3.

Emmons, Natural History of New York, Agriculture; Vols. I–IV, 1846–1851.

New York State Museum, Report 47, 1894, Albany.


NEW YORK STATE
SHOWING PROVINCES.
ADIRONDACK
PROVINCE


TOPOGRAPHICAL SKETCH
OF
NEW YORK STATE.
BASED UPON THE WEATHER BUREAU MAP.
Altitudes in feet.
Sea level to 100
100 to 500
500 to 1000
1000 to 1500
1500 to 2000
2000 to 3000
3000 to 4000
Over 4000

Physiographic Provinces.

General Division.—On its northern side the State of New York is very naturally bounded for the greater part of its distance; but nearly everywhere else the boundaries are purely artificial. In consequence of this, most of the physiographic provinces of the State are merely portions of larger areas which extend into it from the neighboring States. Viewed broadly, and excluding the New England border, there are two highland areas and one branching area of lowlands. If the sea should rise only a few hundred feet, it would extend up the Hudson valley and across the divide into the basin of Lake Champlain, thence into the St. Lawrence and Lake Ontario. At the same time, it would reach up the Mohawk and meet the waters of Lake Ontario, passing across the divide at Rome. So the Adirondacks would become an island, separated from the Green Mountains of Vermont by a narrow channel, from the Highlands of Canada by a broad strait, and from the Catskills and the plateau of central and southern New York by a strait of intermediate width. As a result of this change the Long Island province would be entirely submerged in the sea.

Long Island Province.—Examining the topography of the State in a little more detail, we find these highland and lowland areas capable of considerable subdivision. There is first the sandy lowland of Long Island, barely separated from the mainland, yet quite distinct from it in its general features of outline and in its rock structure. The highest elevation is about 380 feet, and the plains average only about 70 feet above sea level.* It is really a northward extension of the coastal province of New Jersey, but its surface is considerably modified by deposits of glacial drift.†

Gneissic Highland Province.—Passing to the mainland, there commences a province of complex structure, and one in which, in the main and most typical part of the province, the rocks for the most part are very much folded and disturbed metamorphic strata of ancient date. These rocks are really an extension of the Highlands of New Jersey,‡ which reach across the southern angle of New York, extend northward and enter Connecticut. Besides

* Am. Journ. Sci. XIII, 1877, 235.

† Upham, Am. Journ. Sci. XVIII, 1879, 81–92; 197–209; Mather, Geol. of New York, Part I, 1843, p. 161; 248–278.

‡ Chiefly described in New Jersey Geological Survey Reports. See also Pierce, Am. Journ. Sci. II, 1820, 181–199; same V, 1822, 26–33; Eaton, same V, 1822, 231–235; Shepard, same XXI, 1832, 321–334.

these Archean gneisses, there is some sandstone* and a black diabase or trap, which forms the Palisades,† besides extensive layers of limestone, gneiss and schist, which extend across the region occupied by the City of New York.‡ This whole series of strata is intricately associated.

Excepting at the very seashore line, the province is a moderate highland, with rather rough topography and with hills rising in some places to an elevation of 1,000 or 1,200 feet above sea level. Where there is limestone or sandstone in this area, there is usually a lowland, while highlands occur wherever the hard gneiss comes to the surface not immediately at the seashore. This is extremely well illustrated in Rockland County, where the gneissic Ramapo Mountains are faced at their south-eastern base by a lowland, a somewhat rolling plain, which, however, is bounded on its eastern margin by another highland where the trap of the Palisades rises close by the Hudson River. At many points along the eastern boundary of this highland region the Ramapo Mountains rise to a height of 1,100 or 1,200 feet above sea level, while the average elevation of the hills on the sandstone plain at its base is not more than one-half this; but the highlands of the Palisades in some places rise to 700 or 800 feet above the sea.

It would be possible to subdivide this second province; and indeed this would be necessary if we were to extend this examination of the surface into minute details. There are: (1). The low hills and highlands of the immediate coast, including all of New York County and a part of Westchester County. There is then: (2) the Palisade range of trap rock, and (3) the small angle of Triassic sandstone which extends from New Jersey into New York as a wedge-shaped area of undulating plain—a low hilly province in the apex of the angle between the Palisade and the real gneissic highlands. West of this is: (4) the gneissic highland proper in western Rockland, eastern Orange and a large part of Putnam Counties. This portion of the province forms the western member of the general highland area. The Hudson River crosses it,

* Mather, Geology of New York, Part I, 1843, 285–294; Russell, Annals, N. Y. Acad. Sci. I, 1879, 220–254; Russell, Bull. 85 U. S. Geol. Survey, 1892.

† Mather, Geology of New York, Part I, 1843, 278–85; 465–487; 534–541. Wurtz, Proc. New York Lyceum Nat. Hist., I, 1870, 99–105.

Darton, Bulletin 67, U. S. Geol. Survey, 1890.

‡ Mather, Geology of New York, Part I, 1843, 441–464; 525–534; Gale, in same, 581–604; Britton, Annals N. Y. Acad. Sci., II, 1882, 161–184; Transactions of same, VI, 1886, 12–18. See also references for Taconic Province (p. 104). Kemp, Trans. New York Acad. Sci., VII, 1887, 49–64.

cutting the strata diagonally and so trenching the highland area throughout its width. The axes of the folds, which prevail in this complex region, are almost uniformly northeast and southwest and the folding has been extremely complex.

*Taconic Province.**—West of this gneissic highland is an area of folded rock, which, compared with the gneissic highland in the southern part, is itself a lowland. It extends as a broad valley northward from Pennsylvania, across New Jersey and into Orange County, New York, then, crossing the Hudson, it skirts the boundaries and extends into the States of Connecticut, Massachusetts and Vermont. The rocks are mostly shales, slates, schists and limestones; but in the northern portion some of the strata are durable quartzite and even gneiss. While the topography is that of a valley in the southern portion, this province in the northern part becomes transformed into a region of highlands, and indeed of real mountains. This is true of the Taconic range, on the boundary between Massachusetts and Rensselaer County, which rises to an elevation of more than 2,800 feet above sea level. This same range extends along the axis of the Green Mountains, and passes across the Canadian line at the boundary with Vermont.

Throughout its entire extent the rocks of this province are folded, and the topography hilly; but in the southern part it is a gently undulating, broad valley between two highlands, because its rocks are softer and more easily denuded than the bounding strata. Towards the northeast, near the Massachusetts and Vermont boundaries, metamorphism has altered these strata until they are harder than the surrounding rocks; and hence they form true mountains, sloping on the one side toward the valley of the Hudson and

* The Taconic area has served as the basis for an extremely prolonged controversy. The reports of the Geological Surveys of Vermont, Massachusetts and Connecticut contain facts upon this province. Besides these, reference may be made to the following: Dewey, Am. Journ. Sci. II, 1820, 246–249. Barnes, Am. Journ. Sci. V, 1822, 8–21. Dewey, Am. Journ. Sci. VIII, 1824, 1–60; 240–244. Emmons, Geology of New York, Part II, 1842, 135–164. Mather, Geology of New York, Part I, 1843, 366–438. Dana, Am. Journ. Science, XIV, 1877, 37–48; 132–140; 202–7; 257–64; XVII, 1879, 375–388; XVIII, 1879, 61–64; XIX, 1880, 153–155 (contains a Bibliography); 191–200; 236–237; XX, 1880, 21–32; 194–220; 359–375; 450–456; XXI, 1881, 425–443; XXII, 1881, 103–119; 313–315; 327–335. Dwight, Am. Journal Science, XVII, 1879, 389–92; XIX, 1880, 50–54; 451–453; XXI, 1881, 78–79. Dale, Am. Journal Science, XVII, 1879, 57–59. Ford, Am. Journ. Sci. XIX, 1880, 225–226. Dale, Thirteenth Annl. Rept. U. S. Geol. Survey, 1893, 291–340. Pumpelly, Wolff and Dale, Monograph XXIII, U. S. Geological Survey, 1894, Washington, D. C.

on the other toward the Connecticut. After passing the latitude of the boundary between Vermont and Massachusetts, this province is almost entirely within the State of Vermont; for the Lake Champlain depression marks the western boundary. From near Catskill, northward to Glen's Falls, the Hudson may be considered as the approximate western boundary of this area. South of Catskill the Hudson turns away from the boundary, enters the area and crosses it, then enters and extends across the gneissic highlands. While, especially in the north, the rocks in the Taconic area are considerably metamorphosed, sometimes even past recognition of their original condition, in the south they become less and less changed; and there (as well as in a few places to the north) we are able to see that they are members of the Cambrian and Lower Silurian periods. On page 118 it is shown that the rocks of this area were all folded at one time; and hence the area may be properly separated from the complex gneissic province.*

Catskill Province.†—The folded rocks of the Appalachians enter this State in western Orange and eastern Sullivan Counties; and in this region the folds have determined a series of ridges which make this part of the State a truly mountainous section, notably in Shawangunk Mountain, where a tilted conglomerate rock caps the ridge.‡ West and north of this the strata are less disturbed, and are for the most part in a horizontal position.

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* Some may question the value of a separation of these eastern folded sections into two provinces; and, so far as New York is concerned, the division would not be warranted. Really the folding of the Taconic rocks involved the eastern gneissic highlands also, and the rocks of Westchester County are mostly of this age. The true Taconic Province therefore divides in Putnam County, one portion passing southwards into Westchester County (see articles by Dana referred to on p. 104. See also Prosser, Trans. New York Acad. Sci. XI, 1892, 132–149). The place of division is the older Archean and younger sedimentary areas. One might therefore speak of the whole eastern margin of the State, exclusive of Long Island, as the Taconic area, which extends eastward at least as far as the Connecticut. This could then be subdivided into (1) the eastern, Westchester County Taconic, (2) the Palisade range, (3) the Triassic sandstone, (4) the Archean Highlands, and (5) the main Taconic area, mountainous in the north and lowland in the south.

† Dwight, Am. Journ. Sci. II, 1820, 11–29. Barton, Am. Journ. Sci. IV, 1822, 249–251. Pierce, Am. Journ. Sci. VI, 1823, 86–97. Vanuxem, Geology of New York, Part III, 1842, 186–194. Mather, Geology of New York, Part I, 1843, 299–316. Hall, Proc. Am. Assoc. Adv. Sci. XXIV, 1875, Part 2, 80–84. Guyot, Am. Journ. Sci. XIX, 1880, 429–451. Julien, Trans. New York Acad. Sci. I, 1881, 24–27; Newberry, same, 28–31. Darton, Report 47, New York State Museum, 1894, 485–566.

‡ See Mather, Geology of New York, 1st District, 1843, pp. 355–7.

Darton, Nat. Geog. Mag. VI, 1894, 23–34; New York State Museum Report 47, 1894, 485–566.

Being in this place made of durable sandstones and conglomerate, and being very much carved by denudation, this plateau region has the appearance of real mountains; and some of the peaks are more than 3,500 feet, and one even 4,205 feet above the sea level. In the southeastern part of the province, where the rocks are really folded, the hard strata stand up in the form of mountain ridges. In this province the rocks are sandstones, conglomerates, shales and limestones of the Devonian age; and where there are folds* they are essentially like those of the plateau west of this province, excepting that they are more intense. Both in the north and in the west, they gradually disappear, and the mountainous region in both of these directions is gradually replaced by a plateau. The western boundary of the Catskill province is not easily drawn with definiteness; but the eastern boundary is marked by a quite continuous highland overlooking the lower region of the Taconic province, and the north by a strongly developed escarpment, the Helderberg (see pages 107, 124).

This province might also be subdivided. It is the only truly mountainous portion of the State made out of rocks later than the lower Silurian. It might be divided into (1) the folded, southeastern portion and (2) the deeply dissected Catskill plateau area.

New York-Pennsylvania Plateau Province.†—West of this, and occupying fully one-third of the State, is a great plateau region, often deeply dissected by numerous broad river valleys. It is made entirely of Devonian rocks, mostly upper Devonian shales and sandstones, in which, however, there are some strata of limestone. The strata of this province are in a nearly horizontal position, in this respect differing from the previous province, with the exception of a part of the Catskills.‡ This fact of the horizontality of the rocks determines the extensive plateau character of the province, a feature which extends southward, across the Pennsylvania line, along the western base of the Appalachians. Throughout the New York section of the plateau, the hill tops quite commonly rise to elevations of 1,500 to 2,000 feet, and the average elevation above the sea level cannot be less than 1,000–1,200 feet. From the valleys this does not resemble a plateau, but rather a mountainous

* Hall, Am. Assoc. Adv. Sci. XXIV, 1875, Part 2, 80–84.

† Mather, Geology of New York, Part I, 1843, 317–365; Hall, same, Part II, 1843. Also Williams, Bull. 80 U. S. Geol. Survey, Washington, 1891.

‡ There are some gentle folds and faults. See Hall, Geology of New York, Part IV, 1843, 163; 213; Williams, Proc. Am. Assoc. Adv. Sci. XXXI, 1882, 412. Some of these undulations may be due to removal of beds of salt from beneath.

country; for the hills often rise to heights of 1,000–1,200 feet above the low valleys. Upon the tops of the hills one is able to see that this is really a plateau region very much cut by stream action, and carved by denudation, into a maze of hills, many of which are capped by the harder layers of nearly horizontal rocks.

Considered as one great dissected plateau, its surface undulates somewhat. Where the branches of the Susquehanna head against the headwaters of the Finger Lake streams, the plateau level is somewhat depressed.* It sags in the middle, being higher near the western base of the Catskills and lower in the Finger Lake region; then, rising again, it reaches a high elevation in Cattaraugus County, in western New York. Beyond this, in Chautauqua County, and westward in Pennsylvania, the plateau level again descends. Excepting near the Catskills, the highest portions of this plateau are in Cattaraugus and Allegany Counties in New York, and the adjoining counties of McKean and Potter in Pennsylvania.

On its northern face the plateau ends in an escarpment, which, though irregular and somewhat serrated, is commonly quite pronounced. Its position in the east is determined by the hard Helderberg limestone;† but in the extreme west it is determined by the two sets of shales, the upper and more durable ones and the lower fragile beds. Along the Erie shore, near the boundary between New York and Pennsylvania, the escarpment is about two or three miles from the lake; but going toward the east the escarpment recedes from the lake. In some cases it is very abrupt, and in Chautauqua County, it ascends to a height of 500 feet in a very short distance. The escarpment is less distinct in Erie County, but becomes more and more pronounced toward the east, and in Seneca and Cayuga Counties, it is a distinct escarpment, while east of this it becomes sufficiently high to form the Helderberg Mountains. Therefore, for the greater part of the distance, the northern boundary of the Catskill and Plateau provinces is a single deposit of limestone, which in some places rises 1,000 feet above the plain below.

Lake Shore Plains Province.‡—At the base of the escarpment, north of the plateau, there is always found one or more plains. In the west, on the Erie shore, the escarpment is bounded at its base

* See Lincoln, Am. Journ. Sci. XLIV, 1892, 290.

† Vanuxem, Geology of New York, Part III, 1842, 24; Darton, Report 47, New York State Museum, 1894, 394–396; 427–428.

‡ Hayes, Am. Journ. Sci. XXXI, 1837, 241–247; Vanuxem, Geology of New York, Part III, 1842, various pages; Hall, Geology of New York, Part IV, 1843, various pages.

by a very narrow strip of plain, which gradually descends below the lake level. This plain widens toward the east, extending from the escarpment south of Buffalo to Lewiston and Lockport. The Niagara River, from Lake Erie to the Falls, crosses on the surface of this plain, then, dropping over the Falls, the river courses along in a gorge which has been cut into the plain.* Here and elsewhere we find that the strata are horizontal.† This plain crosses the Niagara River into the Province of Ontario,‡ and indeed extends beneath the waters of Lake Erie; for the bottom of this lake is really only a part of this plain.

Along the western shore of Lake Ontario, the plain just described is terminated on the northern margin by a rather abrupt escarpment, sometimes two or three hundred feet in height. This has its position determined by the very durable stratum of Niagara limestone, upon which the Falls are now situated, and by which their height and position are determined. In the east this escarpment gradually disappears and the two plains merge into one. This province may best be seen from the heights of Queenstown and Lewiston (called "The Mountain") on the Niagara River. There, stretching eastward toward Lockport, and westward into the Province of Ontario, is the Niagara escarpment; south of this, toward Buffalo, is the nearly level upland plain, the Erie plain; and northward, stretching from the very base of the bluff, is another remarkably level plain, which, extending along the shores of Ontario, may be called the Ontario plain. Its width varies from 4 to 9 miles. Beyond this, to the north, the level descends rapidly beneath the lake waters, and ten miles from the shore, the depth is 500–600 feet. In the east these plains become more hilly, and as a distinctive province, it disappears at about the longitude of the eastern end of Lake Ontario. Northward from this the plains extend into a series of hills which face the western base of the Adirondacks; and eastward they extend into the valley of the Mohawk, which is made the next province.

Mohawk Valley Province.§—East of Oneida Lake and Rome, there is a good-sized valley between the Adirondack Mountains on the north and the Plateau and Catskill Provinces on the south. It

* For a geological section in well-borings in this plain, see Ashburner, American Inst. Mining Eng., VII., 1888–89, 398–406.

† In a few places local folding is detected. See Hall, Geology of New York, Part IV, 1843, 295–298; Gilbert, Proc. Am. Assoc. Adv. Science, XL, 1891, 249–250.

‡ See Hunt, Am. Journ. Sci. XLVI, 1868, 355–362.

§ Vanuxem, Geology of New York, Part III, 1842, 20–21; 203–211. Darton, Report 47, New York State Museum, 1894, 603–623.

is a broad, well-developed valley, irregular and hilly, and cut out of shales and limestones for the most part, though in one or two places the river has cut down into gneiss. While commonly horizontal, the rocks of this district are somewhat disturbed in places, particularly on the northern boundary, where they merge into the Adirondack Province. It is in such places, as at Little Falls, that the river, cutting into an uplifted portion, has reached down to the gneiss which probably underlies the entire valley as a subterranean continuation of the Adirondack region.

This province is the least characteristic of all that are named. Its boundaries are often indistinct, merging imperceptibly into the neighboring provinces; but there are parts of the valley which are distinctly separated from either of the bounding areas; and hence, for the sake of defining the topographical features, it may be classed as a separate province, although with the distinct understanding that it is not equal in value to some of the other divisions. On the east the Hudson River forms the natural boundary, and on the south, the escarpment.

*Adirondack Province.**—This, which is nearly as large as the Plateau Province, is second in size of the several divisions proposed. It is a nearly circular area of metamorphic and igneous rocks, mainly gneisses, granites, gabbros, norites and other plutonic or very much metamorphosed rocks. The area of metamorphic rocks is skirted by a collar of sedimentary strata of Lower Silurian and Cambrian age, which, though not so much metamorphosed, nor so greatly disturbed in position, are nevertheless to be considered a part of the Adirondack Province. In this area is then included the hilly, though lower land bordering the St. Lawrence and the western base of the Adirondacks along the shore of Ontario, as well as the hilly section on the southern boundary and along the shores of Lakes George and Champlain. The central and typical part of the province consists of a series of grand mountain masses, usually with flowing outlines and rising, in several

* Steele, Am. Journ. Sci. IX, 1825, 1–4. Finch, Am. Journ. Sci. XIX, 1831, 220–228. Redfield, Am. Journ. Sci. XXXIII, 1838, 301–323. Emmons, Geology of New York, Part II, 1842, various pages. Vanuxem, Geology of New York, Part III, 1842, various pages. Guyot, Am. Journ. Sci. XXXI, 1861, 157–187. Kemp, Trans. New York Acad. Sci. XII, 1892, 19–24 (Bibliography). Van Hise, Bulletin 86, U. S. Geol. Survey, 1892. Smyth, Trans. New York Acad. Sci. XII, 1892, 97–108. Kemp, Report 47, New York State Museum, 1894, 625–666; Cushing, 667–683; Smyth, 685–709.

places, to a height of over 5,000 feet, while Mt. Marcy,* the highest peak, reaches an elevation of 5,379 feet above sea level. The eastern central portion is a central divide region, from which the streams radiate outward in all directions. In their course they are often very much disturbed by glacial deposits, and hence lakes are extremely abundant in these mountains.†

Summary Statement of Geographic Provinces.—Thus New York may be divided into eight provinces, every one of which except the last two, is only partially in this State. These are:

(1) The Long Island area, which is the northeastward continuation of the Tertiary and Cretaceous plains of New Jersey, and is composed of soft rocks covered by thick deposits of glacial drift. (2) The Gneissic Highland Province, which typically is made of highly metamorphosed rocks, folded into complex positions and with a general north-east and south-west strike. This may be subdivided into (*a*), the low hilly coastal portion; (*b*) the Palisade range; (*c*) the Triassic sandstone plains; (*d*) the true Gneissic Highlands, each of which extends from New Jersey into New York, while the main Gneissic Highland area passes north-eastward into New England. East of this is (3) the Taconic Province, a region of soft shales, slates, schists and limestones forming a valley in the southern part, but rising in the form of true mountains in the northern more highly metamorphosed part. This province also crosses the southern part of the State, entering it from New Jersey and passing into Connecticut, Massachusetts and Vermont.

West of this is (4) the Catskill Province, which is the northeastward extension of the Appalachian folds and the high Appalachian plateau on the western base of these mountains. While in some places the rocks are tilted, in others they are nearly horizontal, in each case being sandstones, conglomerates, limestones and shales. This province is bounded on the north by the Mohawk Valley area and on the west by (5) the New York and Pennsylvania Plateau Province, into which it gradually and imperceptibly merges. In the plateau region the rocks are all Devonian, and mostly upper Devonian, while their position is horizontal or nearly so. This is faced on the north by an escarpment, at the base of which lies the (6) Lake Shore Plain Province, in which the rocks are also horizontal; but, instead of being a deeply dissected

* See Emmons, Geology of New York, Part II, 1842, 218.
Colvin, Trans. Albany Inst. IX, 1879, 11–26.

† Emmons, Geology of New York, Part II, 1842, 171, 213–214, 415–416, 422–427.

plateau, they are in the condition of a remarkably level plain, rising to no great height above the surface of the lakes. In the west this province is double, consisting really of two plains separated by an escarpment; but in the east it becomes less like a plain, where the plains of the two levels are joined as one by the disappearance of the escarpment. This then becomes more and more hilly toward the east and finally disappears in (7) the Mohawk Valley Province, which is a hilly valley region, set between the Catskills and the great Plateau Province on the one side and (8) the Adirondack Province on the other. This latter province is the most mountainous and the highest portion of the State. It may be fairly considered to be entirely within the State, although a very small part of its northern border really extends into Canada, across the east and west portion of the New York-Canada line.

The most typical provinces are the Adirondack and the Plateau areas. Omitting Long Island, one might with simplicity divide the State into but four provinces: (1) the Eastern folded region, extending from the Sound to the base of the Catskills; (2) the New York-Pennsylvania Plateau Province, including the Catskills proper; (3) the Lake Shore Plains; (4) the Adirondacks, using the Mohawk River as a boundary line between the second and fourth provinces.

We then have two areas of folded and contorted rocks (1 and 4), making considerably more than one-third of the State, and two areas (2 and 3) of nearly horizontal strata. In the folded parts the scenery is beautiful, the rock structure complex and the topography quite irregular, particularly in the Adirondack portion. In the two areas of nearly horizontal strata, the scenery is usually less varied, though sometimes quite mountainous, notably in the Catskills and in Cattaraugus County. With decrease in ruggedness, the value of the land for agricultural purposes increases; and so the best of the agricultural land is situated on the plateaus and plains, particularly in the lower and more level lands near the lakes.

Drainage of the State.

Lakes.—The drainage of the State is very much interrupted by lakes, some of which present very interesting and even remarkable features. The lakes vary in size from Ontario, whose greatest length is over 180 miles with a width of 50 miles, to tiny ponds; and they vary in depth from mere shallow pools to Ontario, which in one place reaches a depth of 491 feet below sea level.* There are

* Being 738 feet deep and the surface being 247 feet above sea level.

various types of lakes, but the prevailing feature throughout the State is the linear form, so typically illustrated in the group of Finger Lakes* which occupy the central depressed portion of the great Plateau Province, though not less so in Lakes Chautauqua, George, Champlain, and many of the Adirondack lakes. For the most part these lakes are plainly river valleys in which water has been made to collect because of their local transformation to basins.

While the lakes of the State are well scattered over its entire area, they are, excluding Lakes Erie and Ontario, bunched with especial abundance in three parts of the State, namely, (1) the Finger Lake region of the Central Plateau, (2) the Adirondacks and (3) the mountainous and hilly southeastern part of the State, including the Catskills. In these areas, and particularly in the Adirondacks, lakes are present in great numbers. Among the Adirondacks alone, there are many hundreds of lakes, great and small, besides a great number that have been filled and changed to swamps and meadows.

The St. Lawrence. — The water that falls within the boundaries of New York passes outwards in all directions.† Not far from one-half of the State, and more than one-half of the Adirondacks, is drained through the St. Lawrence River. The divide between the St. Lawrence and southern drainage passes irregularly east and west from the northeastern part through the middle of the State, passing out of it in only one place, namely in the middle western portion, where the Genesee rises in Pennsylvania and flows northward entirely across the State, entering Lake Ontario. The part of the State that drains into the St. Lawrence system sends its waters to that river through numerous streams, most of which are very small. There are many hundreds of these that enter the Great Lakes or Lake Champlain or the St. Lawrence directly. The only two that are of good size are the Genesee, which rises in Pennsylvania, and flows northward, entering Ontario near Rochester, and the Oswego, which carries the waters of the Finger Lakes of central New York. The divide between the St. Lawrence and the southern drainage area is very irregular, being sometimes far from the St. Lawrence or from the Lakes; but in one place, in Chautauqua

* Vanuxem, Geology of New York, Part III, 1842, 237–242. Hall, Same, Part IV, 1843, 321, 405–408. Lincoln, Am. Journ. Sci. XLIV, 1892, 290–301. Brigham, Bull., Am. Geograph. Soc. XXV, 1893, 16. Tarr, Bull. Geol. Soc. Am. V, 1894, 339–356.

† Ballou, Am. Nat. XIV, 1880, 139–140.

County, in western New York, it is within sight of Lake Erie and at a distance of not more than ten miles from it.

Not only are the tributaries of the St. Lawrence system fre quently interrupted by lakes, but the main portion of this river has the same features even more markedly developed. The main valley is a series of lakes, the Great Lakes, of which two, Erie and Ontario, are partly within the boundaries of New York. In the case of Ontario the valley is made into a lake for a distance of more than 180 miles, with an average breadth of not far from 40 miles. Connecting Lakes Erie and Ontario is the Niagara River with its wonderful falls and gorge. At the other end of Ontario, the waters emerge through a region almost as remarkable as the gorge through which they enter it. The lake gradually merges into a river, its channel being clogged and dotted by hundreds of islands. The outlet of Ontario is at first a great bay, gradually becoming a river only after passing over a distance of many miles, dividing and ramifying between the Thousand Islands.*

The Hudson.—Next in area is the Hudson drainage, including its single great tributary, the Mohawk, which enters from the west. The eastern boundary of this river system is very nearly the boundary between New York and New England, now entering these border States, again entering New York. A considerable part of the Catskills and the Adirondacks are drained into the Hudson. This is the single large stream which is really a New York river. Unlike any other, it rises in the State, flows entirely within its area and enters the sea within the State boundaries. With the exception of a very little water received from the bordering States of New Jersey, Connecticut, Massachusetts and Vermont, the Hudson obtains all of its supply from New York.

The Hudson is notable for its remarkably straight course from the rectangular turn at Sandy Hill to the Sound, and also for its deep valley with steeply rising rock walls. The influence of the tidal rise and fall is felt as far as Albany, while navigation is possible even beyond this city. Above the mouth of the Mohawk the river is small and unimportant; and if it were not for the fact that the tide holds back the water of the Hudson, it would never have become the important commercial artery that it now is.

Other Drainage Systems.—The Delaware River rises in New York State, draining part of the Catskills, and the neighboring region,

* Bigsby, Phil. Mag. Ser. IV, Vol. v, 1829, 1–15; 81–87; 263–274; 339–347; 424–431.

into the Atlantic through Delaware Bay; and further west the Susquehanna tributaries have their headwaters on the southern side of the St. Lawrence divide. These drain very nearly one-fourth of the State, competing with the St. Lawrence for the greater part of the central plateau. By the time the Susquehanna leaves the State of New York, it has become a large river and the waters are carried southeastward into Chesapeake Bay. Farther west, in Cattaraugus and Chautauqua Counties, the Allegheny River enters New York; and, after a short course within the State, it re-enters Pennsylvania, thus draining a small corner of the State into the Gulf of Mexico, through the Ohio and Mississippi.

So the State of New York is a great divide region contributing water to no less than five well-known river systems, the St. Lawrence, Mississippi, Susquehanna, Delaware and Hudson, only one of which enters the sea in the State, or is even in large measure within its boundaries. A very little of the drainage of the State enters the sea through small streams in New Jersey and Connecticut. Therefore the water that falls on various parts of the State may enter the St. Lawrence, or it may pass over a much longer journey to the southward, possibly, even into the Gulf of Mexico.

Gorges and Waterfalls.—In many of the Northern States, waterfalls and gorges are notable and common features; but of none is this more true than of New York. Many of the streams, particularly those of the central plateau region, flow for a part of their distance in gorges and are interrupted by falls and rapids. Niagara is a type of these, which, though larger and more wonderful than its fellows, finds its counterpart in hundreds of places in other parts of the State. Among the Adirondacks and Catskills the streams are also tumbled into rapids or falls and are often found racing through gorges. A consideration of the causes for this peculiarity, as well as of the other physiographic features of the State, will be deferred until later papers.

Peculiar Importance of the New York Drainage.—Leaving out of question the æsthetic aspect of the drainage, for which the lakes, gorges and falls of New York are justly noted, and the commercial value of the water for power, there are several features of New York drainage which have had a unique influence upon the development of the State. A navigable river, the Hudson, reaches into the heart of the State, extending far up toward Lake Ontario. Indeed, with a canoe but a short portage is needed to reach this lake. As soon as the Indian obstacle was removed, these natural waterways

served as a pathway into interior New York, and indeed to the west.

As the necessity for transportation to and from these interior colonies increased, because of the great natural facilities, it became possible to add to the readily navigable Hudson and the large lake a system of artificial waterways, the canals. So New York is ramified by these, the most remarkable of all being the Erie, which, emerging from Lake Erie near Buffalo, passes along the upper member of the Lake Shore Plains Province and extends with a remarkable levelness over this plain to the divide at the head of the Mohawk, down the valley of which it extends to the Hudson. This canal and its tributaries have done more to develop the resources of the State of New York than almost any other feature; and both the main canal and the branches depend for their location upon the peculiar configuration and drainage of the State.

By means of the natural and artificial waterways, it is possible to reach into the very heart of the country. For a while it seemed as if railways had done away with the necessity and value of canals; but by enlarging them, and particularly by the use of electric power for movement, the future of the great canals seems more promising than ever. No canal in this country offers better facilities for enlargement and greater need of this improvement than does the Erie, and it may safely be predicted that this will be done.

Physiographic Features Illustrated in New York.

About New York as a centre it would be possible to build a complete physical geography. Within the boundaries of the State there are illustrated very nearly all of the important groups of physiographic features. Among rivers there are various forms and types, and of lakes there are both an abundance and a variety of kinds. Of coastline features illustration is furnished not merely along the sea shore of Long Island and the very southernmost angle of the State, but also along the shores of the Great Lakes, and, in a smaller way, along the shores of the smaller bodies of water. Mountains find illustration in several types; and although volcanoes are absent, lava rocks are found in the Palisades of the Hudson and in various other parts of the State.* Plateaus and plains cover more than one-half of the State and they exhibit varied features, while instances of cliffs and escarpments abound.

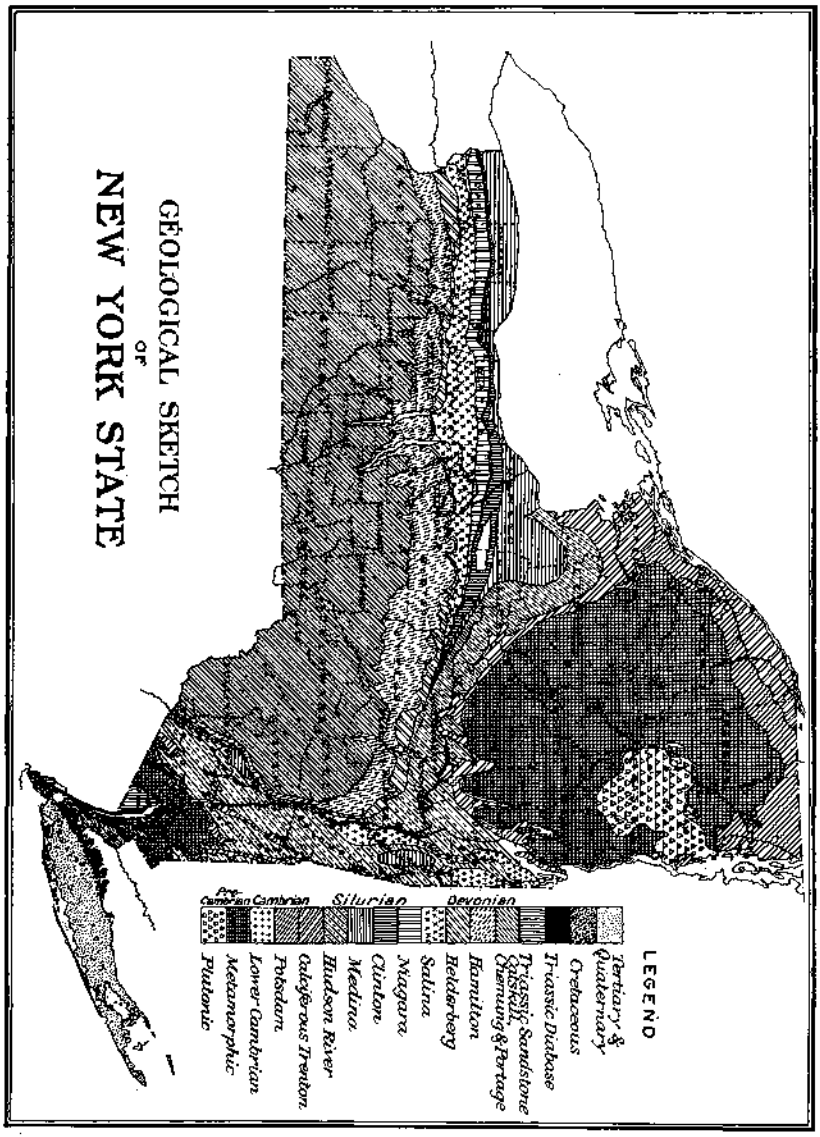
* See references on p. 103. Also, Kemp and Marsters, Trans. New York Acad. Sci. XI, 1891, 13–23.

Besides these greater earth features, there are many smaller ones, perhaps the most notable of which are those that have resulted from glacial action. There are terraces, ancient shore lines, various kinds of glacial hills and, indeed, illustrations of most of the features of the earth. In later pages of this discussion, these will be taken up for consideration. There are few States that offer within their own boundaries so rich an assemblage of physiographic illustration.

Geological Development of the State.

Deposit and Folding.—The Adirondacks are distinctly the oldest large area in the State, the only possible competitor being the crystalline highland region of the southwestern corner of the State (the real gneissic part of the Highland Province), where the Archean rocks of the New Jersey Highlands extend across the New York boundary. At the beginning of the Palæozoic, both of these areas of crystalline rock were mountainous lands facing the sea, which stretched away to the westward, and beneath which all the rest of the site of New York State was submerged. The southwestern highland mountains extended northward into New England; and toward the east they probably reached seaward beyond the present coast line. This mountain range also extended southwestward along the eastern part of the sea-coast States, and west of it was a great sea in the present Mississippi Valley. Whether the Adirondacks and this highland mountain range were ever connected, and what was the actual former extension of the two areas, cannot be told in the present state of geological knowledge. The record of much of the early history has been hidden beneath the strata of later age.

However, in the very early Palæozoic the waves of the sea beat at the western base of the southern highlands and these were then at least separated from the Adirondack area, which was at this time an island in the Palæozoic sea. This is shown to be true by a ring of early Palæozoic sedimentary rocks, which practically surround the mountains and in which fossil beaches can now be plainly detected. Later folding has probably affected the Adirondacks, and it is also quite probable that parts of these mountains have since that time been submerged; but the main post-Archean history of the Adirondacks is that of long-continued denudation, as a result of which the elevation has been greatly reduced. Throughout much of the Palæozoic, and apparently throughout all of the post-Palæozoic time, these mountains have been subjected to constant denudation. The structure and detailed history of the Adirondacks are very


GEOLOGICAL SKETCH
OF
NEW YORK STATE
LEGEND
Tertiary & Quaternary
Cretaceous
Triassic Diabase
Triassic Sandstone
Chemung & Portage
Hamilton
Helderberg
Salina
Niagara
Clinton
Medina
Hudson River
Calciferous Trenton
Potsdam
Lower Cambrian
Metamorphic
Plutonic
Pre-Cambrian
Cambrian
Silurian
Devonian
BASED UPON THE STATE MUSEUM MAP.

obscurely understood, and little except the most general facts are at present known concerning it.

Next in the development of the State came a great overturning of the rocks along a line parallel to and near the crystalline highlands of the southwest. Indeed, these were undoubtedly involved in this folding, which profoundly influenced the southeastern portion of the State and all of western New England and eastern New York. Indeed, from the neighborhood of Quebec, southwestward as far as Virginia, and apparently beyond, this period witnessed the growth of a great mountain system, which has been called the Taconic system by reason of the fact that the Taconic Mountains, of the New York-Massachussetts boundary, have furnished good evidences of this system of folding. The rocks involved in the overturning are the older, crystalline pre-Palæozoic rocks and the Cambrian and Lower Silurian sedimentary strata; and, as a result of the mountain growth, these have been extensively folded and even broken or faulted. Since the rocks of the Upper Silurian age rest unconformably upon the sides of these uplifted strata, the age of the Taconic Mountain uplift is placed near the close of the Lower Silurian. By the folding the rocks were also extensively metamorphosed, the limestones often being changed to white marble, the sandstones to dense quartzite, the shales to slates, etc.; and in some places the metamorphism has gone so far that the original rocks are now changed to schists and even gneisses.

The folding and faulting were more intense in the northern part of the State than near the New Jersey line, and more in the east than in the west; and hence the rocks are more metamorphosed, and therefore more durable in the northern than in the southern counties. In the south, in Orange County, the folded rocks are bounded on both the east and the west by harder strata, and hence denudation has lowered them into the condition of a valley. The real Taconic ranges, near the New York-Massachusetts boundary, and their continuation along the Green Mountains of Vermont, furnish illustration of good-sized mountains. This is especially true of those, which, like Mount Graylock in Massachusetts, consist partly of a very durable quartzite. Since their formation these mountains have been very much worn, and there is every indication that they were once very lofty ranges. Among them the folds are very often overturned, and there are numerous illustrations of overthrust faults where the rocks have broken along a nearly horizontal plane, and the upper beds have been moved bodily over the lower. Some of these faults are of great extent.

Toward the west the mountain folding disappeared; but how far it extended cannot be told, for later rocks cover the folded strata. It certainly extended as far west as Little Falls, for the folds on the southern margin of the Adirondacks are of this age.

During the remainder of the Silurian and Devonian times, the condition of that part of New York which lies outside of the Adirondacks and the two southeastern provinces of folded rocks, lay beneath the sea, at least for the greater part of the time. This sea was on the average a shallow one, and it received contributions of sediment from the Adirondacks, the Taconic ranges, and also probably from the Canadian highlands. Shallow water conditions are almost everywhere indicated among these central New York strata, and the very coarseness of the deposits among the Catskills shows that land was near by at the time these were deposited. During these geological periods, there was deposited in this sea a depth of sediment which in the Catskills is fully 10,000 feet, in central New York, in the Genessee River valley, not less than 7,000 feet, and in the highlands of Chautauqua County, some 6,000–6,500 feet.* During this time, the straits that had connected the inland sea with the ocean north of the Adirondacks became filled and closed. The beginning of the St. Lawrence valley along the northern border of New York had been determined very early by a depression into which the sea entered.

While the Silurian and Devonian sediments were being laid down, there were evidently numerous minute changes in the land and water; but the average condition was one of slow subsidence of the general area which was beneath the sea. Beds of shale and limestone were being deposited over much of the State, although sandstones and conglomerates were formed in some places near shore lines. During the Salina of the Upper Silurian, conditions prevailed over central New York as a result of which extensive beds of rock salt were accumulated between the beds of shale, the total depth of the salt strata often being from 50 to 150 feet.† The reason

*Communicated by Prof. C. S. Prosser. For records of sections in New York, see Prosser, Proc. Am. Assoc. Adv. Sci. XXXVI, 1887, 208–9; Am. Geol. VI, 1890, 199–211; Proc. Rochester Acad. Sci. II, 1892, 49–104; Bull. Geol. Soc. Am. IV, 1893, 91–118. Fairchild, Proc. Rochester Acad. Sci. I, 1891, 182–186; 215–223.

†Eaton, Am. Journ. Sci. VI, 1823, 242–243; Smith, Am. Journ. Sci. XV, 1829, 6–12; Phil. Mag. VII, 1830, 198–201; Vanuxem, Geology of New York, Part III, 1842; Hall, same, Part IV, 1843; Gibson, Am. Journ. Sci. V, 1873, 362–369; Newberry, Trans. New York Acad. Sci. IV, 1887, 55–57; Wright, Science, VIII, 1886, 52; Newberry, Trans. New York Acad. Sci. IX, 1889, 39–45; Hall, Luther and Clark, Report 47, New York State Museum, 1894, 203–383.

for these salt beds is apparently a shallowing of the New York sea accompanying a broad general uplift in Ohio, and neighboring States, which has been called the Cincinnati arch. Before this the conditions had favored the deposit of the thick Niagara limestone in clear and perhaps moderately deep water. By the shallowing of the sea this part of the State may have become a great salt vat, reached by the sea and subjected to evaporation so that beds of salt were precipitated and later covered by beds of very fine mud. After this the sea again entered this portion of the State, becoming clear open water, perhaps of considerable depth, and certainly free from land sediment. During this time another series of limestone-beds, the Helderberg and Corniferous, which extend from near the Hudson to Buffalo, were accumulated in the sea.

After this, throughout the Devonian, the conditions favored the deposit of extensive beds of shale, which in central New York often reached more than 3,000 feet in depth. These vary from fine textured clay rocks to sand layers, and from real clay to impure limestone and even to pure beds of limestone, a few of which occur in the series. In the east, along the line of the Taconic, the deposits in this sea were mainly sandstones and conglomerates, evidently because this was near the coast line. Here, in the region of the Catskills, the sandstones are between three and four thousand feet thick, and this is the main determining factor for the existence of the Catskill Mountains. Their location therefore depends primarily upon the existence of a shore line supplied with quantities of sand and pebbles. In some places these Catskill beds are conglomerates.

Conglomerates are also found in the extreme southwestern part of the State, these being remnants of a bed of upper Devonian conglomerate. They have attracted considerable attention because of their supposed resemblance to ruined cities, which has given the name "rock cities"* to these conglomerate rocks which have broken along the joint planes and then tumbled apart as a series of huge blocks. These have been undermined by the action of denudation which eats away the softer underlying shales and allows these huge blocks to assume various attitudes. It is probable that this layer has recently extended over a considerable part of the high southwestern plateau; and perhaps it has been the cause for the great height of this section, the overlying conglomerate cap protecting the soft shales from rapid denudation.

Whether the Carboniferous ever extended into New York State or not; and, if it did, how far it extended, are questions now impos-

* Hall, Geology of New York, Part IV, 1843, 284–285. Ashburner Penn. Geol. Survey, Report R., 1880, 49–78.

sible to answer; but there seems little reason to doubt that the Carboniferous rocks did extend for at least some distance into the State. Since the Carboniferous time, throughout the entire State, there has been an almost uninterrupted condition of land exposed to the air; and during this time much rock material must have been removed. Throughout the higher parts of the central plateau the rocks are of the upper Devonian age; and, unless some Carboniferous strata existed there, having since been removed, we must marvel at the minute amount of work done by denudation throughout all of the post-Palæozoic time. Therefore the fairest supposition is that the Carboniferous did extend well into New York, perhaps covering the entire plateau.

Final Uplift.—Perhaps early in the Carboniferous time, certainly before the close of that period, the entire State of New York was raised above the sea, a position which, so far as we know, it has since uninterruptedly maintained, excepting perhaps in some very limited localities and for a short time, as for instance along the Champlain* and Hudson River depression. This elevation was associated with the uplifting of the Appalachian Mountains; and although within the State of New York there was no excessive mountain folding at this time, the great area of rocks forming the State were raised as a general plateau uplift with some minor folds. The rocks of the plateau itself, and of the Lake Plains to the north of it, are so upraised as to dip very gradually to the south. Near the central part of the plateau, along the shores of Lake Cayuga, and elsewhere within the State, the strata were thrown into gentle undulations with east and west axes. Near the boundary of New York and Pennsylvania, east and southeast of Binghamton, the effect of the plateau folding is plainly seen in the rocks; and at the angle of junction of New York, Pennsylvania and New Jersey, the mountain folds are quite pronounced. Among the Catskills, while there is some folding, the real cause for the ruggedness of the mountains is the presence of the very massive and durable sandstone, which in some places has a depth of not less than 3,000 feet. Because the upper Devonian in this part of the State is sandstone rather than shale or sandy shale, the Catskill region rises in a series of prominent elevations which are carved into very mountainous outlines. There has also been greater uplift in this section and some folding; but denudation is the really potent cause for the carving of these mountains.

* Emmons, Geol. of New York, Part II, 1842, 127–134; 283–284; Kellogg, Science, XIX, 1892, 341.

There are no means of telling in what form the uplift of the State left the surface. However, from the dip of the rocks it seems probable that the greatest elevations were in the north and east. The Adirondacks seem to have continued, as they had previously been, as a great central divide, from which, as from a highland, the streams radiated out in all directions. The Taconic ranges must have served to prevent the flow of New York waters toward the east, just as they do at present. The greater uplift of the Catskill area may have determined some of the drainage approximately along the course of the Hudson valley, while in the trough between the Catskills and the Adirondacks, the Mohawk naturally developed. If the St. Lawrence valley in its present line existed early in the history of the State, there must have been drainage toward it, and there is very little reason to doubt that some of the water of the State thus found its way northward.

However, the tilting of the rocks to the south must have determined this as a direction to be pursued by much of the drainage. Before we can be certain of what has happened to the rivers of the State we must first learn more about the early history of the streams in the Pennsylvania region. What has led the Delaware and Susquehanna waters across the Appalachians through their remarkable water-gaps? Was the tilting of the rocks beneath the plateau of central New York accomplished at the same time as the uplift of the Appalachians, or has it been a later development? If the former, then the greater part of the drainage of the western half of the State must have been toward the south; if the latter, this does not of necessity follow. It seems that the topography and drainage indicate the first rather than the second. North-flowing streams have an advantage in cutting their valleys in rocks that dip to the south.* By the law of monoclinal shifting,† as the country wears down, the divides should gradually retreat to the south; and so the north-flowing streams would constantly gain territory at the expense of those which were flowing toward the south. As a matter of fact, the north-flowing streams of New York have not pushed their headwaters very far back into the plateau, apparently not so far as they

* Of course this applies to any streams heading in a tilted region and flowing in opposite directions.

† This is, briefly, that in the settling of the surface of a country under the action of denudation, if the rocks are inclined, the divides will migrate in the direction of the dip. See Gilbert, Geology of the Henry Mountains, Washington, 1880, pp. 129 and 134; also Tarr, Elementary Physical Geography, p. 274.

would have done if they had been north-flowing streams at the beginning of the uplift of the plateau.

Another question is whether the country was also raised to its present height. Here again the answer must be somewhat doubtful but apparently in the negative. Had it originally been elevated to its present height, it should be denuded vastly more than it has been. Even granting a complete covering of Carboniferous rocks for the central plateau, the time that has elapsed since the close of the Carboniferous would have allowed more than 10,000 or 15,000 feet of strata to be removed. Besides this, the drainage systems indicate later elevation, as do other facts from outside of the State.*

The history seems to have been that of an uplift at the close of the Carboniferous, continued now and then, so that considerable denudation has in the meantime been possible; and then, in the mid-Tertiary, there came a decided uplift which allowed all the rivers of central New York to cut deep valleys, and which occurred long enough ago to admit of sufficient broadening of the valleys to produce a mature type of topography. With this uplift something like the present condition of drainage was introduced, although in the details many changes have been introduced by the ice invasion.

Post-Palæozoic Denudation.—As a result of this extensive denudation, any rocks that overlaid the Devonian have been removed; and, in a great part of the area, the Devonian and older strata are trenched deeply by valleys, so that the plateau is very much dissected by deeply-cut valleys, particularly near the divides. Although these are fairly well rounded, there remain great hilly masses between, and so only a mere beginning has been made toward the removal of the Devonian and older rocks.

In the progress of the denudation there has naturally resulted an attack upon the plateau, not only by the streams that have trenched it, but also by wasting away from the north. If, as seems evident, there existed parallel to Lake Ontario a river with an east and west extension, from this valley as a base there would naturally be an attack upon the rocks of the plateau which lies to the south. The strata of this plateau, dipping toward the south, exposed their outcrop edges towards the north. The hard rocks protected the soft; but, as these were undermined, the hard strata retreated in the direction of the dip, but always with a tendency

* Notably the fossil faunas of Mesozoic and early Tertiary ages, which seem to prove the existence of lowlands in the north-eastern part of the country. Also in the valley of Lake Champlain, deposits of Tertiary age prove a depression for this region.

to maintain an elevated position. An excellent example of this is seen between Rochester and Lewiston, especially near the latter place, where the hard Niagara limestone is covering soft shales and determining the position of the bold Niagara escarpment. Where the hard Helderberg limestone outcrops, the same tendency exists, and here again an escarpment results. This very marked influence of the rock structure on topography, producing so precipitous a slope in a region whose elevation is not great, could only result when the action of denudation had produced moderate effects during its present cycle.

The time is not yet ripe for the announcement of the complex histories of New York rivers, and hence for the elucidation of the development of many of the main topographic features of the State. The remarks made above are merely suggestive and are thrown out only as hints. However, it seems very certain that rivers with different kinds of valleys, and perhaps even with different courses, existed before the Tertiary uplift. Then the streams cut down through the rocks and carved their mature valley forms, perhaps not always in the courses which they formerly pursued.

Ice Invasion.—Then, as a last step in the development of the features of the State, came the Glacial Period, which came later than the Tertiary uplift, and during which practically the entire State of New York was covered with a thick sheet of ice. Why this came, how long it remained and why and when it disappeared are questions that do not now admit of definite answer. For some reason, possibly the elevation, from some source in northeastern Canada, an ice sheet spread out over New York, covering it as effectually as Greenland is covered by ice to-day. When this went away the surface of the land, though in many particulars hardly affected, was nevertheless in many respects strangely transformed. Over the surface was strewn a sheet of glacial deposit of variable thickness;* some of the hills were planed down and rounded, others were built up; some valleys were deepened, others were more or less completely filled; some streams were turned completely out of their valleys, some partly so interfered with, and many were locally transformed to lakes. The hundreds of lakes that dot the State were thus created, and even Lakes Erie and Ontario had their birth at the close of the ice period. The Falls of Niagara, and many other gorges and waterfalls, have also had their beginning as a result of

* Mather, Geology of New York, Part I, 1843, 158–228; Hall, same, Part IV, 1843, 318–341. Chamberlin, Third Annl. Rept. U. S. Geol. Survey, 1883, 347–379.

the ice action. With the withdrawal of the glacier, the form of the lakes varied, finally assuming their present condition. The sea also rose higher than it does at present, and parts of the Hudson-Champlain depression were submerged; and then, finally, the conditions of the present came about. Many of the details of the physiography of the State are a result of this ice invasion, and some of these subjects will serve as special topics for discussion.

Climate of the State.*

Throughout the State of New York there is abundant though not excessive rainfall; but, as in the other eastern States, there is liability of occasional drought. The total precipitation in inches varies from 25–30 in the northwestern part of Niagara County, and in some places north and east of the Adirondacks, to 60 inches near the coast and on the slopes of the Adirondacks. The rainfall probably amounts to more than this on the tops of these mountains. Over the greater part of the State the rainfall ranges from 35 to 50 inches. There is a greater percentage of cloudiness near the Lakes than at a distance from them, and over nearly one-half of the State the sun is obscured for more than 60 per cent. of the time during which it is above the horizon. In the southeastern portion of the State there is the least cloudiness.

The mean annual temperature ranges from 50° near the coast and 48° near Lake Erie, to less than 40° in the Adirondacks. The mean temperature for July ranges between 72° on the coast and 70° near Lake Erie, to less than 64° in the high Adirondacks. In January it ranges between 30° at the coast and 26° on the Lake Erie shore, to considerably less than 16° among the high Adirondacks.†

In the distribution of the isotherms there is much irregularity, for the influence of topography is very marked. It will be seen from this statement of temperatures that New York is peculiar in having high summer and low winter averages. However, it is not nearly so extreme as some of the interior States. For instance, St. Paul, Minnesota, has an average temperature of 72° in July and 8° in January; and St. Vincent, Minnesota, has an average of 65° in July and — 10° in January. On the other hand, San Francisco has a summer temperature of 69° and an average winter temperature of 50°, choosing single months for the averages.

* There is an admirable discussion of this subject in the Fifth Annual Report of the State Weather Bureau of New York, Department of Agriculture, Albany, N. Y., 1894, pp. 345–448, written by Mr. E. L. Turner.

† For the upper portions of the Adirondacks there are no reliable data.

Since New York has such low winter and high summer temperatures, the climate of the two seasons corresponds with climates in widely differing latitudes. This has been so well stated by Mr. Turner* that I quote from his description as follows :

"The isothermal line of 70 degrees, which will be observed on the chart for July to pass from the Great Lakes over northern New York, extends thence eastward through New England to the vicinity of the coast, where it again turns toward the southwest, meeting the line of 70 degrees which appears over eastern Long Island. This isothermal then passes directly eastward over the Atlantic near parallel 40 degrees, intersecting the coast of Europe in northern Spain. Reaching the warmer land surface, it tends somewhat north of east through Central France, Austria, Central Russia and Siberia. Near the eastern coast of the latter country it turns southward through 20 degrees of latitude and passing to the Pacific over the Island of Japan, continues nearly eastward, meeting the coast of America in Central California. Thence it follows the meridian of 120 degrees west well northward into British America before again turning to the southeast in the direction of the Great Lakes and northern New York.

"The line indicating 74 degrees in July passes from New York directly southward over the ocean until opposite Virginia; thence slightly south of east to Morocco in North Africa, where it turns northward to France; thence passes through Southern Europe (north of the Italian peninsula) to the Black Sea, through Central Asia at latitude 50 degrees, and near the coast turns southward to Japan. Diverging somewhat from the isotherm of 70 degrees, in its course over the Pacific, it touches America in Southern California, follows the Rocky Mountains northward to British America and thence takes a southeasterly direction to the Great Lakes and New York.

"In January, New York is to be classed with quite different regions of the globe from those named above. The isotherm of 15 degrees, which appears near the northern boundary of the State, passes thence over Labrador, the southeastern coast of Greenland and the Arctic Ocean. When well to the northward of Scandinavia it turns southeastward through Central Russia (passing north of St. Petersburgh) to the northern border of the Caspian Sea. Proceeding eastward to Northern Japan and northeastward over the Pacific it reaches the southern coast of Alaska, when it again trends

* 5th Annual Report, New York State Weather Bureau, 1894, pp. 361–2.

southward to South Dakota and finally passes north to the Lake Region to the St. Lawrence valley.

"The mean January temperature of 30 degrees (that of New York City) is found also in southern Newfoundland, Iceland and northern Norway. This isotherm turns sharply southward in the latter region and passes to eastern Germany, Austria and the northern border of the Black Sea, when its course becomes eastward to the Pacific. Like all the preceding lines it intersects Japan and thence passes northeastward to the Aleutian Islands. Following the American coast line to the border of the United States it turns southeastward to Missouri and thence passes to the southern shore of the Great Lakes."

There are several interesting climatic peculiarities in the State of New York. In general, the climate is that of an interior land area, though it is near enough to the seashore to be somewhat influenced by the ocean. The prevailing winds are from the west* and the alternations of weather conditions are due to the passage of successive areas of high and low pressure from west to east, carrying with them alternate conditions of clear, dry weather and cloudy, rainy weather.

In these respects New York is not unlike the other States of the north. During the clear anticyclonic times of high pressure conditions, cool or cold winds blow over the State from the north and the northwest, in winter spreading a blanket of cold air over the land. While the stormy conditions of the low-pressure areas prevail, air is drawn over the State from the south. It then comes either from the Atlantic or the Gulf (the latter particularly in the western portion), and so brings moist, warm conditions to the State. With the coming of the south wind, rain and snow often fall because the air in moving northward passes into colder regions and also rises over the plateau, thus being cooled down to the dew point, when precipitation must follow. When rain does not fall, the weather becomes warmer, in winter producing thaws, in summer causing heated terms.

These normal conditions of weather change are somewhat interrupted by the topographic features of the State, only a few of which can be mentioned. Long Island and the vicinity of New York City is distinctly the region most under the influence of the ocean of any part of the State; hence the winters are warmer, and on the seashore the summer heat is more moderate. The mean annual tem-

* This is often well illustrated in orchards, where the trees are all seen to incline towards the east.

perature is higher and the range in temperature less than in other portions of the State. Also in this part of the State the rainfall is greater than in other portions, with the probable exception of the high Adirondacks. During the summer the heat of the land is frequently tempered by the cool sea breezes that blow in from over the ocean.

The coldest and most variable portion of the State is the high Adirondacks, which, though cool in summer, become very cold in winter. Here there is much snowfall and the climate is distinctly that of mountains.

An influence very much like that of the ocean is exerted upon the climate of New York by the waters of the Great Lakes. They serve to temper the summer heat and to moderate the winter cold. When a cold wave overspreads the region, the temperature of the United States side of Lake Ontario is often 10° or 20° higher than it is on the Canadian side. This influence of the Great Lakes holds back the spring-time development of plants by the presence of the cold water; and hence vegetation is not liable to suffer from late frosts as it is in more distant regions where this development has proceeded farther. In the fall the warm body of water, with its temperature raised through the summer, does not cool so quickly as the land; and hence by its presence the water prevents frosts near the lake shore and lengthens the growing season. Also, during both summer and winter the presence of the water serves to moderate the climate. Upon the shores of the lakes there are real lake and land breezes, just as there are sea and land breezes along the ocean shore.

The effect of the water of the Great Lakes is felt very nearly all over the State, for many of the winds must blow over their surface before reaching other parts of the State; but the really noticeable influence is confined to a distance of but a few miles from the shore. This influence becomes particularly noticeable where the lake shore plains are backed by an escarpment, which serves to keep the lake influence partly confined within a narrow space. This is shown very well indeed near Lewiston at the base of the Niagara escarpment, and also along the Erie shore in Chautauqua County.* In both of these places the climates are so favorable that they are the sites

* See Tarr, Bulletin 109, Cornell University Agricultural Experiment Station, "Geological History of Chautauqua County," Ithaca, N. Y., Jan., 1896. Also for other parts of the Lake shores, Winchell, Proc. Am. Assoc. Adv. Sci. XIX, 1870, 106–117; Kirtland, Am. Journ. Sci. XIII, 1852, 215–219; Hazen, Bull. 10, U. S. Weather Bureau, 1893. The last three are not for New York, but illustrate lake effects in other States.

of extensive fruit raising. To a less extent this is true of the whole lake shore.

In the Chautauqua region the difference is most remarkable. Upon ascending the escarpment the temperature becomes noticeably lower in a distance of a few miles. Very often rain falls upon the lake shore plains while snow is being precipitated on the hills; and frequently during the winter there is sleighing on the hilltops, while no snow exists upon the lower plains upon which one looks down. With this difference in elevation there is also a difference in the *amount* of precipitation, and the rainfall upon the hills is perceptibly greater than that on the plains. This is frequently well illustrated during the summer when thunder showers are seen hanging over the crest of the escarpment, while no rain falls in the grape belt of the lake shore plain.

There is also a perceptible effect upon the climate in the neighborhood of the smaller lakes. This is illustrated in the valleys of the several larger Finger Lakes which occupy deep trenches in the plateau. In these the winds are deflected somewhat, so that nearly north or south directions of wind are the common ones. Also the valley sides are warmer than the enclosing highland, partly because they are enclosed, but partly because of the influence of the water. Even the small body of water in the lakes serves to modify the neighboring climate very perceptibly. Near the lake shores, both the nights and the days of summer are cooler than they are upon the neighboring hills, and the winter climate is perceptibly less severe. Here also there are important fruit districts because of this marked modification of the climate, which locally is rendered less extreme.

In the Mohawk and Hudson River valleys there is the same kind of influence upon the climate, and we find that the isotherms extend well up into these valleys. Here also the winds are deflected, in the Mohawk to a general east and west direction, and in the Hudson to north and south directions. So the relation between the physiographic features of the State and the details of climate and weather is very intimate. In this place, however, no more can be done than to point out the bare fact.

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