THE PHYSICAL GEOGRAPHY OF NEW YORK STATE.

PART II.*

BY

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THE MOUNTAINS OF THE STATE.

Use of the Term Mountain.—There are few geographical terms used more confusedly than that of mountain. In common usage is meant any unusual elevation rising above the surface of the surrounding country. Hence in Texas, a hill reaching an elevation of one or two hundred feet above the monotonous plain is called a mountain, while in New England, elevations of even one or two thousand feet are called hills.

In reality more than one geographic feature is comprised in the single term. If we look at the typical mountains of the world, we find the main fundamental features to be folds in the rocks. A part of the crust has been bent or broken, with the result of an unusual elevation. Such mountains occur in ranges, the axes of the folds being longer than the cross section. However, the mountain folds of the land are no sooner begun than they are modified by denudation. The various forms of rock texture are etched, so that very soon the fold is no longer the prominent feature, but instead, peaks or ridges, which have been brought out into relief. In the course of time denudation may so plane down the mountains, that like the eastern part of the States of Pennsylvania and New York, although the rock structure is that of the mountain, the topography is that of a series of low hills, or in some cases even of a plain.

In a structural sense, and hence in geographic usage, these planed-down mountain ranges must be called mountains still, although they no longer possess the features which we commonly associate with these geographic forms. In their origin, the topographic mountains are elevated structures of folded or faulted strata, but they are greatly modified by denudation. They are carved into peaks and ridges which are made of harder rocks, and these may either be horizontal or tilted sedimentary strata, or even perfectly massive igneous rocks.

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* Continued from Vol. XXVIII, No. 2, 1896, p. 129.

In the peaks the fundamentally important feature is no longer folding, but rock texture as carved by denudation. So the peak and mountain range are not the same, either in origin or structure. The peak is really a hill, and it may be of great or slight elevation. There can be no real line of distinction drawn between the low Pilot Knob of Missouri, which rises to only a slight elevation above the plain, and the great Pike's Peak; both are elevated peaks of igneous rock. Nor is there any essential difference between the low, flat-topped hills of the plains and plateaus, rising above the general level because of the hard upper strata, and the peak carved out of the equally horizontal and variable rock strata, existing in the centre of the syncline or anticline. So I hold, that in geographic nomenclature we must distinguish between the *mountain peak*, an erosional form, and the *mountain range*, a structural type, modified more or less extensively by denudation, and perhaps even cut into peaks, though more commonly into ridges. The mountain range corresponds more closely with the *geographic* use of the term mountain, while the peak is more in harmony with the *common* usage. A geographic mountain need not have an unusual elevation, but *must* have complexity of rock structure; the peak, on the other hand, *must* have elevation, but not of necessity complex internal structure.

Where exactly to draw the line between the geographic mountain and the plateau, and where between the hill and the peak, is difficult to define. Concerning the latter, however, there is little real difficulty, for the peak and hill are of the same geographic type; but the mountain and plateau are quite different topographic forms. We are constantly confronted by the difficulty of deciding which is the true mountain, and which so-called mountain is only an elevated and dissected plateau. In fact, the Catskill Mountains of New York furnish a typical example of this difficulty. These are not true mountains in the geographic sense, but are dissected plateaus simulating mountains; they belong to the type which brings confusion to the geographic nomenclature, for nearly every one recognizes them as mountains. They are more than mere peaks, being in reality a group of peaks. The Catskill type of greatly carved horizontal rocks may be called *pseudo-mountains*.

Mountain Groups in New York.—There are five mountainous areas in the State of New York. These are the Adirondacks, the Taconic series, extending from Vermont across New York into New Jersey, the Kittatinny Mountains, entering the State from

New Jersey, the Palisade range, also entering from New Jersey, and the Catskill Mountains. Of these, three are merely minor portions of mountain masses belonging really to other States. The Adirondacks and Catskills reach the greatest elevation, and from that standpoint are the most representative mountains in New York; and they also are entirely included within its boundaries. Since the Catskills consist of nearly horizontal strata, while the

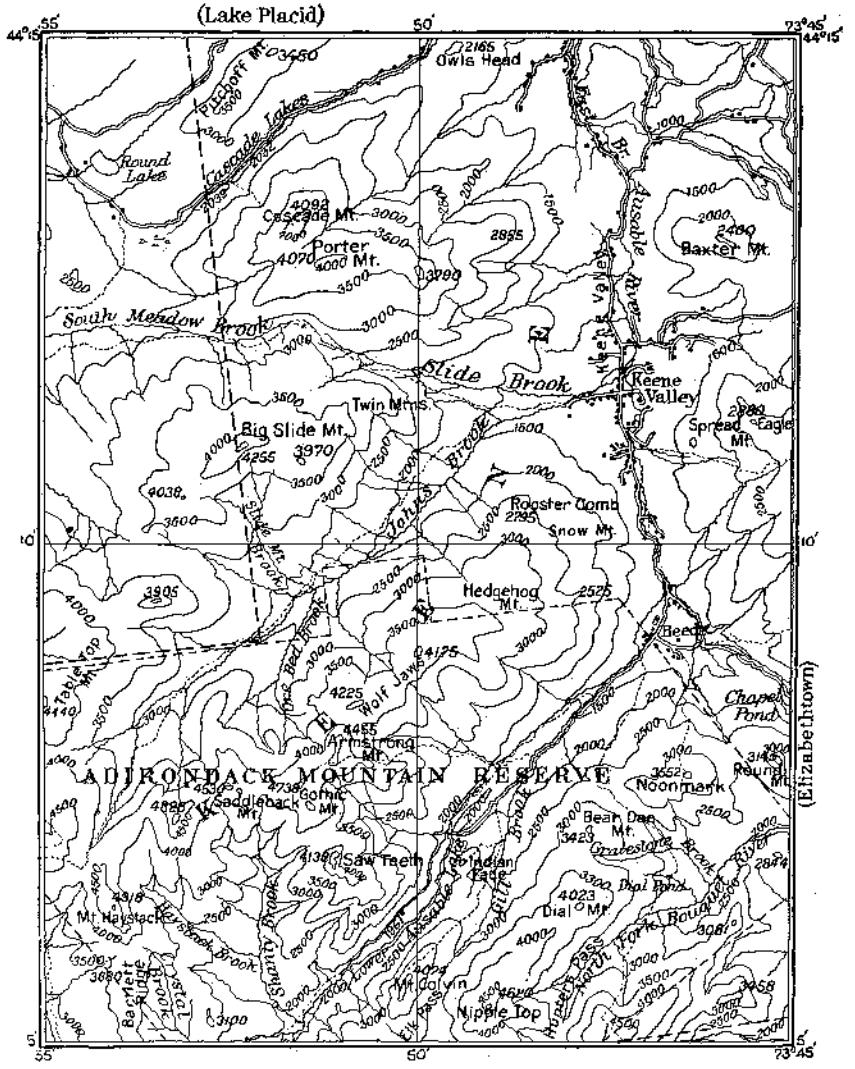

FIG. 1.—MAP OF A PART OF THE ADIRONDACKS, CONTOURS EVERY 500 FEET (BASED ON U. S. GEOL. SURVEY TOPOGRAPHIC MAP).

other systems are made of rocks usually complexly folded, the Catskills are really the least representative mountains in the State; in fact, as has been said before, they are not properly mountains, but imitation mountains.

*The Adirondacks.**—These mountains furnish one of the most typical illustrations of a class; they are true mountains in form and structure, long subjected to denudation, and reduced to a fraction of their former elevation. Their life history has been long and complex. Commencing at some period of Archean time, long before the beginning of the geological record, which properly commences with the Paleozoic, they have maintained a land condition almost, if not quite continuously down to the present time. Their origin and history have been similar to that of the New England and Canadian mountainous provinces.

First elevated during that earliest geological period, the Archean, the Adirondacks rose as an insular land area in the earliest Paleozoic sea. Then, as now, they were a land of complex structure, composed of hard and durable norites, gabbros, and gneisses. Among these were beds of iron and other minerals and rocks characteristic of the crystalline series. These rose into the air and decayed as rocks do now. Then, as now, rivers flowed down the mountain sides and entered the Paleozoic sea, part of which occupied the site of the present State of New York, and into this sea the rivers carried sediment derived from the mountains. This the waves and currents worked over, building the rocks that now underlie the soil of the State.

This history of mountain destruction and sediment accumulation is told us by the beds of Paleozoic strata which encircle the mountains. There are Cambrian beaches built by the waves of this ancient period, and in these the pebbles are of the same rock that now constitutes the Adirondacks. Hence when these beaches were accumulated, the kind of rock that made the land was the same as at present. In some places beneath these beaches has been found a soil that was formed before the beach gravels were accumu-

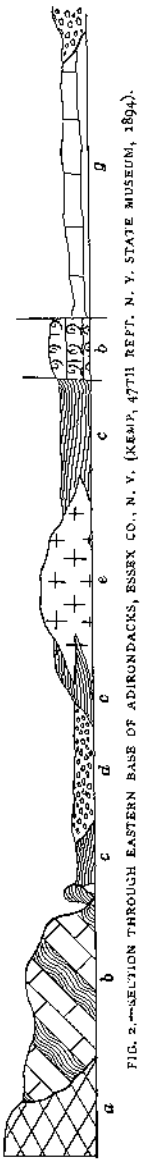

FIG. 2.—SECTION THROUGH EASTERN BASE OF ADIRONDACKS, ESSEX CO., N. Y. (KEMP, 47TH REPT. N. Y. STATE MUSEUM, 1894).

* See references, Bull. Am. Geog. Soc. XXVIII, 1896, 109.

lated, and hence representing disintegration of the rocks at some period before the Cambrian sea encroached upon the land. The surrounding rocks tell us of another stage in the development of this ancient mountainous area. The Cambrian and Lower Silurian (or Ordovician) strata which surround the mountains are folded and sometimes metamorphosed into schists and other kinds of metamorphic rock. Hence, after these were deposited in the Paleozoic sea, in a nearly horizontal position, they were uplifted and folded, and with them of course the Adirondacks of which in some places they now constitute a part (see Fig. 2).

There is negative evidence, and hence evidence of less value, that this was the last time during which the Adirondacks were extensively folded. South of the mountains stretches an extensive area of Silurian and Devonian strata, in a nearly horizontal position. Therefore, since the beginning of the Silurian these rocks have not been folded, and since this is true, it seems probable that the neighboring Adirondacks have likewise been free from extensive post-Ordovician folding. On the other hand, however, there is evidence that, though no folding has taken place, they have been subjected to uplift; for the beds that were accumulated beneath the surface of the Paleozoic ocean are now raised well above the sea-level. Such an uplift, so near them, must also have caused an additional elevation of the Adirondack Mountains, although, as has been said, there is no evidence that this elevation was accompanied by folding.

While these changes of elevation have been in progress, there have doubtless also been times when the level of the land has been lowered. In fact this must have been so, for the thickness of the strata between Lower Cambrian and Upper Devonian, in the region south of the Adirondacks, is several thousand feet. These beds, one deposited upon another, were accumulated in a shallow sea. The evidence of this is, that the strata are varied in texture from pebbles to clay, and are mainly made of fragments of rock that have been derived from the land. Such coarse materials could not have been carried far from shore. Moreover, the presence of ripple marks in many of the beds proves shallowness, and beaches that occur among these ancient sediments point to the same conclusion. To form such a thickness of rock in a shallow sea, the bed of the ocean must have been sinking, and if this were true of the sea bottom, a part, if not all, of the Adirondacks must also have been settling. In later times, when the Tertiary sea entered the Lake Champlain valley, there was another period of depression.*

* Marine beaches north of the Adirondacks furnish evidence of lowering and elevation just preceding the present era.

During these elevations, foldings and depressions, the Adirondack land mass has been subjected to denudation, for it has stood above the sea-level throughout the greater part of the time that has elapsed since the Archean. Naturally, in so vast a period of time the mountains have been deeply breached, and had it not been for new elevations, we may be certain that, by this time, the area would have been levelled to the condition of a plain, standing near the level of the sea. It is impossible to say how much has been removed from the Adirondacks by this action, but certainly many thousands of feet of strata have been cut off and carried away. Could we know in detail what the Archean history of the mountains has been, we might be able to state how much elevation they have lost by denudation; but while figures cannot be assigned, there is on every hand evidence of immense loss by denudation.

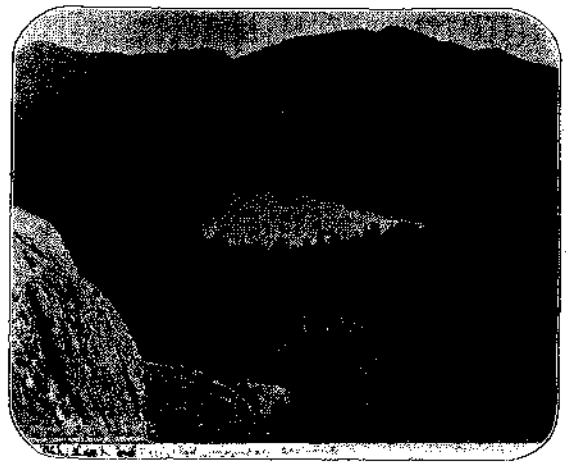

FIG. 3.—THE ROUNDED, MATURE PEAKS OF THE ADIRONDACKS (PHOTOGRAPH COPYRIGHTED, 1888, BY S. R. STODDARD, GLEN'S FALLS, N. Y.).

Examining the surface features of the Adirondacks, we find them to be mountains of considerable elevation, somewhat rugged in outline. Still, when we compare them with the Andes, Alps, or Rockies, we find them to be much less elevated and rugged. There are no lofty, inaccessible cliffs, but instead, rounded, easily scaled hills, and mountain peaks, reaching only very rarely to a height greater than one mile above sea-level. Roads may be constructed upon most of the mountain sides, and railways enter the very heart of the system of peaks, while paths are present nearly everywhere, so that practically no portion is inaccessible. This is very distinctly in contrast with the conditions of the Alps, many portions of which are reached only by the most arduous climbing, while some parts are practically inaccessible.

The Alps are *young mountains*, and denudation has progressed

only far enough to sculpture into very rugged relief the strata of varying hardness. In the Alps the granite masses rise into a Jungfrau or Matterhorn (Fig. 4), peaks of marvellous ruggedness; but in the Adirondacks the long-continued action of denudation has carried the development of the topography from this youthful stage to that of *maturity* or early old age. Here the granitic crystallines stand above the general level as a Mt. Marcy, while the softer beds are the sites of valleys. But these granite peaks have a gentler and more flowing outline (Fig. 3), because denudation has passed the stage of greatest activity. The height of the mountains has been so reduced, that the action of flowing water cannot be compared with the intensity that is possible in more lofty ranges, like those of the Alps.

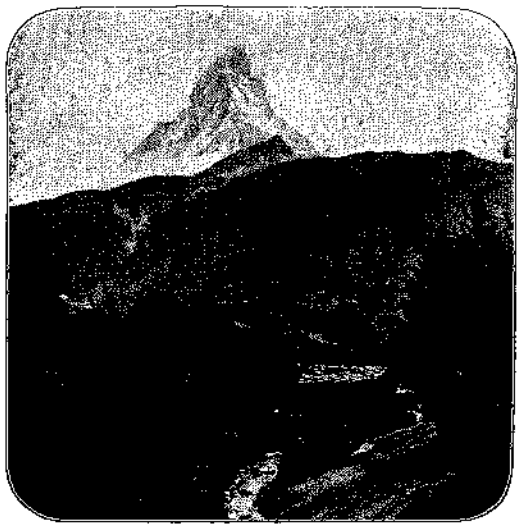

FIG. 4.—THE MATTERHORN, SWITZERLAND, A YOUNG MOUNTAIN PEAK.

This rounded form of the Adirondacks has, perhaps, been increased somewhat by the scouring action of the ice of the Glacial period, which overrode the highest peaks of these mountains. Too little study has been given to this region for us to state much about the action of the ice there. Some material was, no doubt, taken from the mountain sides and valley bottoms, and some was deposited; and as a result of this modification, the surface was left a little smoother than before the ice came. But we may be certain that this was in the manner of finishing touches, not of primary carving and sculpturing.

In New England, New Jersey, and elsewhere in the East, there is evidence (see p. 30) that denudation succeeded in reducing the mountainous land to even less rugged outline than is now present, and many believe that this reduction amounted even to planation, so that the surface became nearly level, or was reduced to the

peneplain. The evidence of this reduction to such moderate outline that mountains lost their truly mountainous form, is very strong indeed, and the levelling seems to have been widespread. This being so, it must have reached the neighboring Adirondacks. So the Adirondacks are mountains of a new cycle, and after a complex history, some of which has been stated, they were nearly levelled, or at least reduced to less relief than now. This was in the Tertiary period. Then they, together with the surrounding country, were uplifted again, and once more brought under the influence of mountain denudation. At present they are well along in development in this new cycle, having again reached the outline of maturity. Perhaps such changes have been passed through again and again during the history of these mountains.

The Adirondacks have been contrasted with the Alps; they may also be brought into contrast with the Appalachians. These likewise are not strictly comparable with the Alps or Rockies, but they have some of the features of the Adirondacks. It is not difficult to ascend to the top of practically all the ridges of the Appalachians; but if we examine these two sets of rounded and easily traversed mountains, we see some fundamental differences. The Appalachians are made up typically of *ridges* (page 31), while the Adirondacks are typically isolated peaks or groups of peaks. These differences are directly traceable to the rock structure. Denudation is a delicate tool in the sculpturing of the earth, and in the course of its work it detects differences in rock hardness with wonderful precision. The soft or weak layers have suffered greatly, while the hard or durable rocks have better withstood the action of the tools. Consequently hard strata are etched out in relief, soft ones cut more deeply.

The Appalachian rocks are sheets of sediment, variable in hardness and folded into waves, as we might fold the pages of this book. Hence, in etching such layers, denudation carves ridges. This can be understood by bending a series of sheets of cardboard, then cutting them horizontally and imagining some to be softer than others. The soft layers, attacked by denudation, are lower in position than the harder ones, and these differences in texture are expressed in ridges and valleys. The hard strata of the Appalachians have resisted denudation and are now elevated. Their sharp edges extend for great distances with relatively narrow width, and the resulting typical form is therefore the ridge (Figs. 5, 6, 7, 12 and 14).

Among the Adirondacks, on the other hand, the rocks have no such sedimentary structure, but are masses of crystalline rock,

intimately and complexly associated. Hence the harder portions that are etched into relief have no such linear arrangement, but are in the form of peaks or groups of hills (Figs. 1 and 3). The Appa-

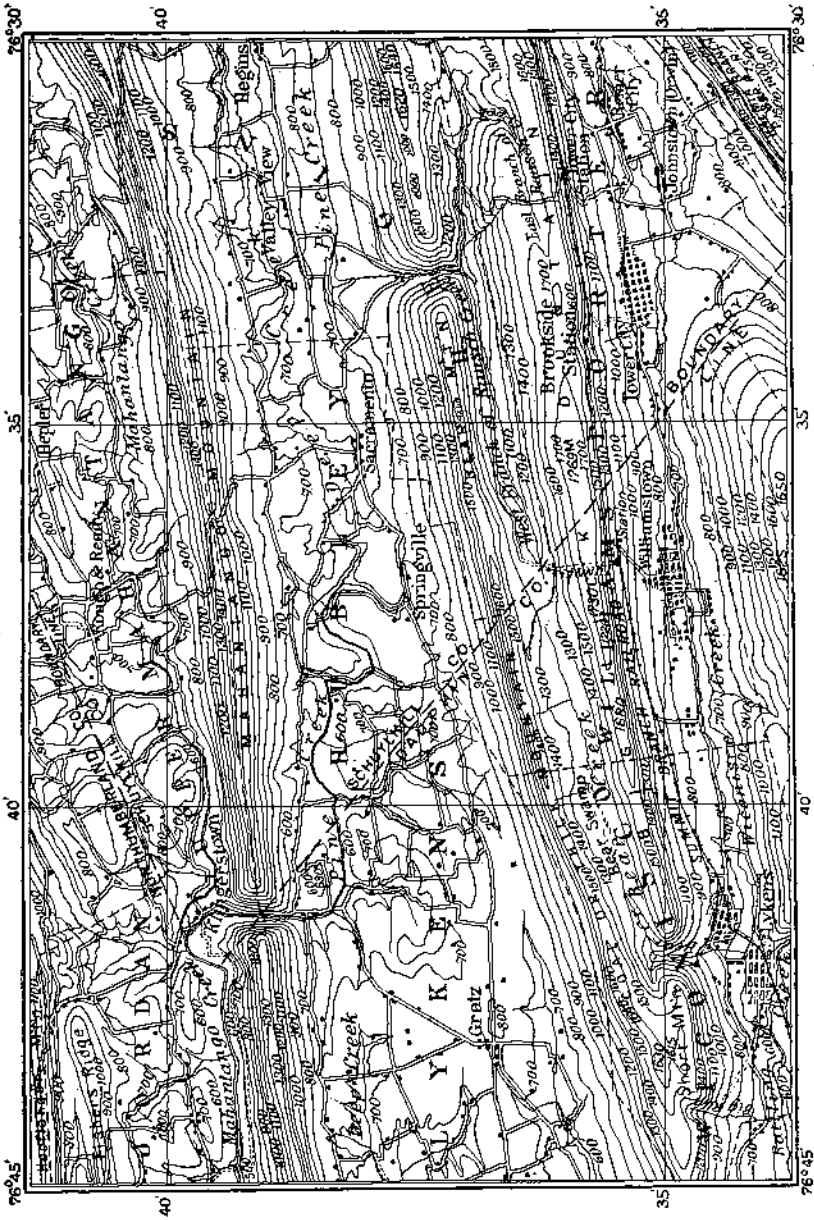

FIG. 5.—MAP OF A PART OF APPALACHIAN MOUNTAINS, PENN. CONTOURS EVERY 100 FEET (BASED ON U. S. GEOL. SURVEY TOPOGRAPHIC MAP).

lachian type of mountain might be called the *sedimentary type*, the Adirondacks the *crystalline type.** We will speak of those mountains having the ridge form as the *Appalachian type*, because so typically

FIG. 6.—THE APPALACHIAN RIDGES (A PART OF HARDEN'S MODEL OF THE ANTHRACITE COAL REGION, PENN.).

represented in these mountains; and the crystalline type of peaks may be called the *Adirondack type.*

Having *contrasted* the Adirondacks with other well-known systems of mountains, it remains to compare them with their analogues. Their type structure is that of crystalline mountains of rounded, mature form, with peaks caused by the etching out of harder areas of crystalline rocks. The White Mountains of New Hampshire are of the same type exactly; so also are many of the mountains of the Labrador peninsula, and the Canadian Highlands; and the same type is found in the Scottish Highlands and the Scandinavian peninsula. In New England there are many other than the White Mountains which belong to the Adirondack type. Mount Katahdin,

* Some mountains of crystalline rocks, such as those of New England, have the linear or ridge form of typical topography, and some massive sedimentary rocks have been carved into peaks resembling the crystalline type.

in Maine, the Blue Hills near Boston, and many other peaks and groups of peaks in this part of the country are of this type.

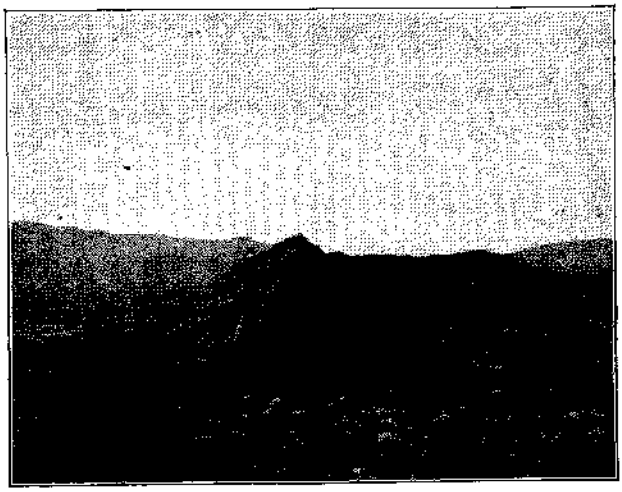

FIG. 7.—A MOUNTAIN RIDGE OF APPALACHIAN TYPE IN COLORADO (U. S. GEOL. SURVEY PHOTOGRAPH).

But we cannot properly compare the Adirondacks with *all* the New England mountains, for in many parts of these States, as well as in New Jersey, eastern Pennsylvania, and the more southern States of the coast, east of the Appalachian ranges, there are mountains of mature form, composed of crystalline rocks, which differ from the Adirondacks, first in being generally less elevated and less diversified, and secondly in frequently assuming the form of ridges. These ridges are less distinct than those in the Appalachians, which are made of sedimentary strata, and they are often so dissected that they approach the Adirondack type. In reality they belong to an intermediate group of mountain form, in which the characteristic feature is that of elongated peaks or shortened ridges (Figs. 8 and 10). The mountains of this type may be called the *Berkshire type*, because they are well illustrated in the mountains which were formed during the growth of the Taconic and other ranges in eastern New York and western New England. They are most perfectly illustrated in the Berkshire Hills; hence the proposed name.

*The Taconic Mountains.** — Before the dawn of the Paleozoic time mountains existed in New England and New Jersey, as well

* See references, Bull. Am. Geog. Soc. XXVIII, 1896, 102, 103, 104.

as in the States south of here. The sea which bathed the Adiron dacks also beat against the foot of these more eastern mountains. This shore line passed somewhere near the New York State border.

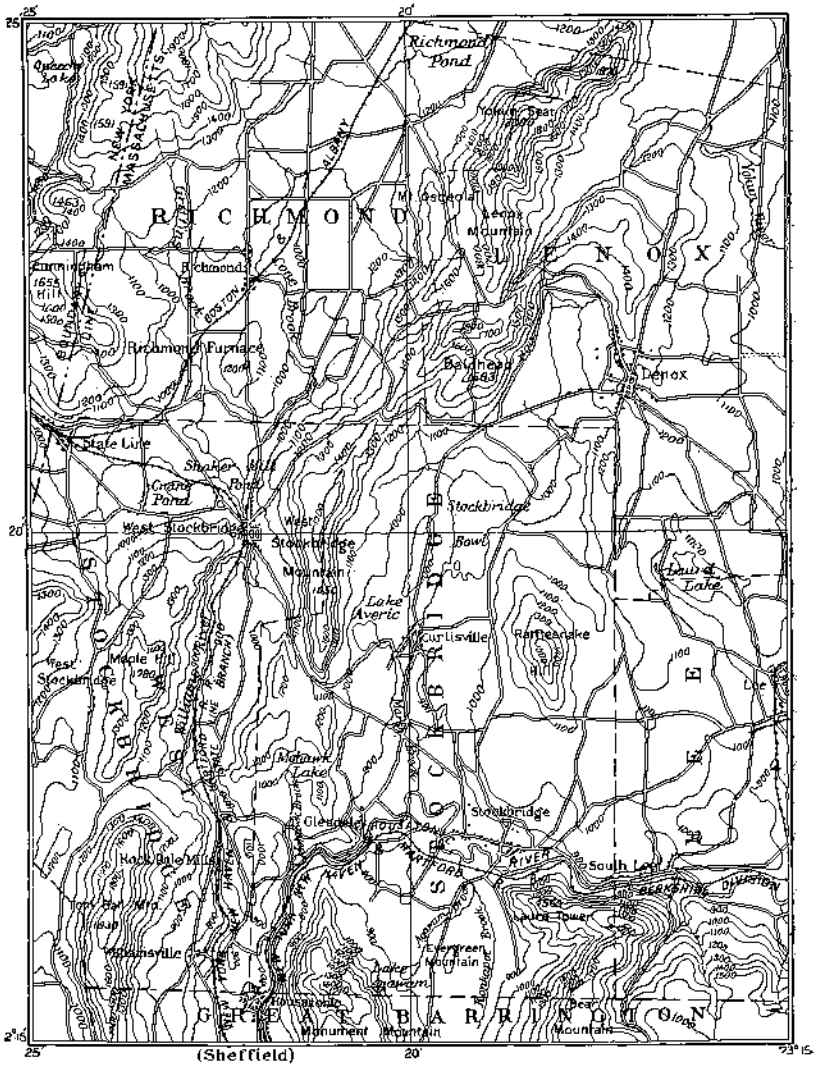

FIG. 8.—MAP OF PART OF BERKSHIRE HILLS, WESTERN MASSACHUSETTS. CONTOURS EVERY 100 FEET (BASED ON U. S. GEOL. SURVEY TOPOGRAPHIC MAP).

Remains of these mountains are still left in various parts of New England, where they form mountains of true Adirondack type. By their long-continued denudation, sedimentary deposits were fur-

nished to the interior sea, and during the Cambrian and Lower Silurian periods the waste of this mountainous land, and of the Adirondacks, was strewn over the sea bottom, partly within the boundaries of the State of New York. Similar mountains also occupied the site of the greater part of New Jersey, and the old Archean land probably extended to the eastward of the present shore.

The close of the Lower Silurian was marked by a regrowth of these eastern mountains; but the new rock-folding involved a part of the old sea bed, and as has been stated, at the same time caused a new development of mighty mountain ranges in western New England (and probably also in the eastern part of these States) and eastern New York. Folds of great complexity (Fig. 9), and faults of marked extent, raised the ocean sediment into lofty mountains, while denudation in time breached these into rugged peaks and ridges. Accompanying this, in many parts of the East, volcanic energy broke forth, and great sheets of lava flowed out over the surface, while beds of volcanic ash were strewn over land and sea.

As in the case of the Adirondacks, the later history of these mountains has been mainly one of destruction in the air. There has been later folding and elevation, as well as depression; but the great post-Ordovician work has been reduction of the mountain height; denudation has breached the ridges so that now their very roots are revealed, and their internal anatomy exposed to view.

By the study of the basal parts of these mountains, it is seen that the mountain growth was more extensive in the northern than in the southern part of New England, and that it also increased in intensity from west to east. This is proved by the fact that the rocks of the Green Mountains of Vermont have been much more metamorphosed than those in the same line of folding in New Jersey, and that the strata in the Berkshires of Massachusetts have been more highly altered than those of the Taconic Mountains just west of the Berkshires. In some places this metamorphism has proceeded so far that gneisses have been made out of conglomerates and other sedimentary beds; and nearly everywhere in the New York-New England area the sedimentary strata have been transformed to schists, or the sandstone to quartzite, the limestone to marble and the shales to slates.

Denudation has etched these complexly altered and folded strata, and since they were originally deposited as *sheets* of sediment, though now greatly changed, the folding has placed them in such a position that, like the Appalachians, they have been carved into ridges. But the *complexity* of the rock structure and position

is greater than in the Appalachians, and hence the ridges are not long and continuous, but short and choppy, with many intermediate peaks (Figs. 8 and 10). This is the typical Berkshire type. There

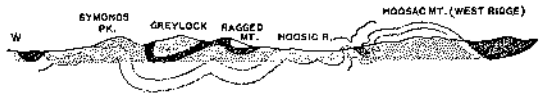

FIG. 9.—CROSS SECTION OF PART OF BERKSHIRE HILLS IN WESTERN MASSACHUSETTS (PUMPELLY, ETC., MONOGRAPH XXIII, U. S. GEOL. SURVEY).

is a mixture of the sedimentary and crystalline habit; hence, in general, the mountains extend in ridges that run parallel to the lines of folding (generally about north and south in New England and New Jersey); but we cannot follow the ridges for any considerable distance. The difference between Appalachian and Berkshire types of mountains is quite like the difference between the well-developed ocean swell and the deep, wind-broken waves of the billowy sea.

The Taconic series includes mountains of varying height, some nearly as lofty and rugged as the Adirondacks. These are well illustrated in the Hoosac Mountains of western Massachusetts and the Green Mountains of Vermont. In other parts the ridges are low hills, like those in the southern part of Connecticut and in the neighborhood of New York City. These latter, though in the form of low, well-rounded hills, are as typical mountains, in a geographic sense, as are the peaks and ridges of the Green Mountains. The difference is merely that, in the vicissitudes of destruction, the former have been lowered nearly to a lowland condition. They are mountains reduced in elevation nearly to sea-level. If the rocks that once covered the site of the City of New York could be restored, they would rise into peaks rivalling the highest mountains of the world.

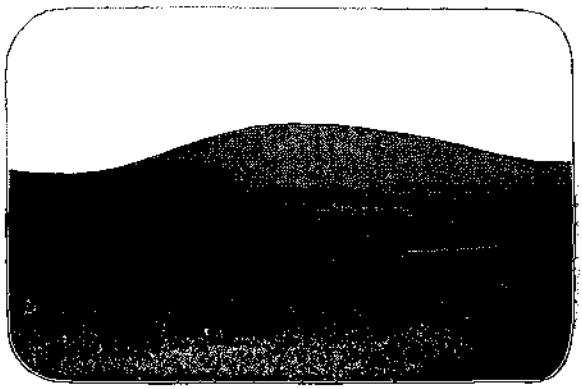

FIG. 10.—A SHORT RIDGE SHOWING BERKSHIRE TYPE, WESTERN MASSACHUSETTS.

Standing upon the crests of the hills in the Highland Mountains

of New Jersey, or the hilly land of Connecticut or central Massachusetts, we see that the peaks and ridges rise to a moderately uniform elevation (Fig. 11). Descending into the valleys, the mount-

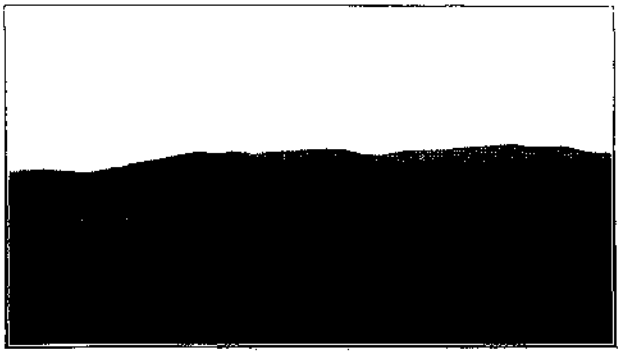

FIG. 11.—THE ANCIENT MOUNTAINS OF NEW ENGLAND, SHOWING PENEPLAIN SURFACE.

ains are seen to rise hundreds, and in some cases a thousand or more feet above the valley bottoms. The appearance made by the regular crests, viewed from the hill tops, is that of an undulating plateau, while from the valley bottom one appears to be in a mountainous region of geographically mature form. This evenness of elevation is all the more remarkable because of the irregularity of the rock structure and position; it looks as if the crests were merely remnants of a former lowland, now elevated and dissected. This supposed lowland has been called a *peneplain*,* and the most forceful proof of this former nearly level condition is found in the fact that in a country of moderate ruggedness, and of complex rock structure, the peaks should rise to a nearly uniform level.

If the evidence of the level crests is to be believed, then the mountains of the East were once reduced to the much lower and more uniform condition of old age, or certainly of great maturity. The surface of all the land south of New England and New York was then a lowland. Elevation then lifted the bevelled mountains and permitted denudation to begin upon a new cycle of work. It has now produced the present low, rounded form, indicating maturity of development in a new cycle. Upon this explanation of the mountain features, it is necessary to suppose that the ancient

* Davis, Am. Journ. Sci., 1889, Ser. III, XXXVII, 430; Proc. Bost. Soc. Nat. Hist., 1889, XXIV, 373; Nat. Geog. Mag., 1895, II, 81; National Geographic Monographs, I, 269; Bull. Geol. Soc. Am., 1896, VII, 377.

peneplain has been lifted higher in northern and western New England than nearer the sea coast. Hence in the more northern region the high mountains are now carved into more rugged appearance.*

Other mountainous areas which are believed to have once reached the old age condition of the peneplain, and have later been lifted, are described from various parts of the earth. The most typical cases in the United States are those of New England, particularly of Connecticut and eastern and central Massachusetts. The same feature is seen in New Jersey and the crystalline region east of the Appalachians, as far south as Alabama. In Europe, cases are reported from the valley of the Rhine, the Scandinavian peninsula, and the Highlands of Scotland. From the numerous instances, it would seem that in the Tertiary period there was a widespread levelling of the land, which indicates that in places there was a general freedom from extensive elevation. Also it would seem that this period of land quiet and land lowering was succeeded by a time of general uplift and deep dissection.

The Berkshire type of mountain, especially well illustrated in western Massachusetts and eastern New York, is also found all the way along the eastern base of the Appalachians, as far as Alabama. Undoubtedly its counterpart will be found in portions of all the great areas of low mountains composed of crystalline rock in various parts of the earth. The type may be looked for in New England, Labrador, Greenland, Scandinavia and Scotland; and in many places it may grade into, or be intimately associated with, the Adirondack type of mountain structure.

The Kittatinny Mountains.†—The folds of the Appalachians involved a small part of southeastern New York. The great plateau of the State was raised and the rocks composing it slightly folded; but in one part, in Orange, Sullivan and Ulster counties, ridges of distinct kind enter the State from New Jersey. These, given various names, are the continuation of the Kittatinny range of New Jersey.

* It should be stated that I am not convinced of the full truth of this explanation, but believe that it should be modified. My reasons for this will shortly appear in an article in the *American Geologist;* but since the peneplain explanation has been so fully stated, so ably supported by numerous facts, and is widely accepted, and since it is impossible in this place to present my arguments in detail, I have felt called upon to present as plainly as possible the generally accepted explanation.

† 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.

After the Taconic Mountains and the ranges of New England were elevated, near the close of the Ordovician time, the sea occupied the greater part of New York State, and continued to do so until the beginning or middle of the Carboniferous period. The Taconic Mountains, and those of the New Jersey Highlands, formed the eastern boundary of this sea, and at that time the site of the Appalachians was sea-bottom near this shore line. Then came an uplift, involving the New England region, and extending at least as far south as Alabama. Sedimentary strata were folded into ridges, sometimes with rock folds and faults of great complexity, but generally in simple or slightly overturned anticlines and synclines. In the greater part of the area outside of New England, the folding was not sufficiently intense to greatly metamorphose the strata, and hence they still exist as sedimentary layers of conglomerate, sandstone, shale, limestone, etc. (Figs. 12, 13, 18 and 19).

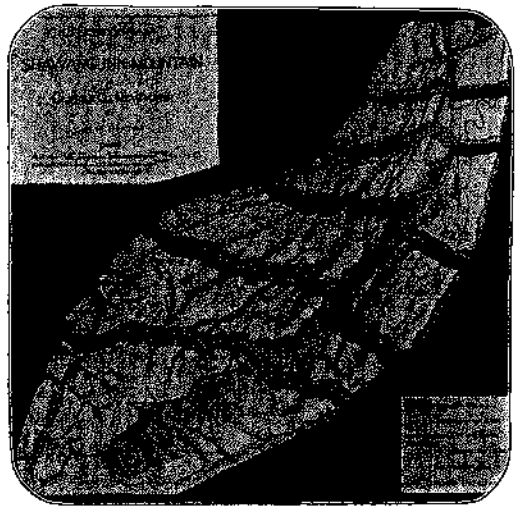

FIG. 12.

These Appalachian foldings probably affected the entire southeastern part of the State of New York; but the influence upon the ancient mountains, which were uplifted in Ordovician times, is so masked that it is difficult to detect. In Pennsylvania the ridges are typically developed (Figs. 5 and 6), and some of these enter New Jersey and cross the State into New York. Of these the most notable are the Kittatinny Mountains, which, at the New Jersey-Pennsylvania line, are traversed by the Delaware River, where it passes through its famous "Gap." Folded rocks here stand tilted at a high angle and extending along the strike in a northeast direction. These mountain ridges are capped by a hard layer of conglomerate, and rise to a wonderfully uniform level.

This range grades westward into less and less folded strata, and

finally the folds give place to nearly undisturbed horizontal rocks (Fig. 17), just as they do in Pennsylvania west of the Appalachian chain. In New York the folds also die out in the northern portion. Hence, pronounced in New Jersey, the ridges become less notable in New York, and finally practically disappear in Ulster County. Here they merge into and give place to an escarpment of Helderberg limestone, forming the so-called Helderberg Mountains of Albany County.

These foldings tilted the horizontal rocks and elevated them into mountains; denudation sculptured and lowered them, and it is believed even reduced the mountains to a lowland of moderate level, like the peneplain of New England. When, in late Tertiary times, New England and the neighboring regions were elevated, the Appalachians were again raised, not perhaps by folding, but by a slow uplift, which, giving new life to the streams, and new power to the agencies of the weather, permitted the sculpturing of the rocks anew. The softer layers were removed and the harder ones left standing in relatively prominent position. Since they were tilted layers or sheets, this sculpturing commonly caused ridges where harder strata occurred, and valleys where softer beds existed between them. This is the characteristic Appalachian type of mountains, and it is seen in the Kittatinny Mountains of New Jersey and the Shawangunk Mountains of New York (Fig. 12). Sometimes the durable rock at the crest of the ridge is conglomerate, at other times sandstone, and still again, as in the Shawangunk, a limestone of dense and resistant nature. Upon these ridges one may travel for miles at a nearly uniform level.

So the mountain ridges of the Appalachian type in New York, represent mountains of mature form, without great relief and with moderate, easily scaled slopes, quite in contrast with Alpine or Andean ruggedness. They have passed the stage of rugged youth, but their maturity of form is that of a new cycle. Formerly they were more reduced, and now have been advanced as far as maturity in a new life history, made possible by elevation.

This stage of mature development is found in many of

FIG. 13.—A SECTION SHOWING APPALACHIAN FOLDS AND ETCHED MOUNTAIN RIDGES (U. S. GEOL. SURVEY, RINGGOLD; FOLIO 2, HAYES).

the mountains of the world. (See page 31.) It is especially well shown in the entire Appalachian chain. The type of mountain form called the Appalachian, whose characteristic feature is the ridge of sedimentary rock, made into a ridge because of the resistant nature of some of the beds, is seen all through the Appalachians (Figs. 5 and 6). The ridges are etched into moderate relief by denudation, and the slope is steeper on the side away from the direction of dip of the strata than in the direction from which the rocks dip (Fig. 14). In the Sierra, the Coast Ranges, Basin Ranges, and Rocky Mountains of the West (Figs. 7 and 14) it is a common type, as it is in the Andes, the Himalayas, the Alps, Jura and a multitude of other mountains of the world. There is much difference, however, in the details of form. The typical Appalachians are mature in geographic age. But among many of the younger mountains mentioned above (the Andes, etc.), the time for the action of denudation has not been sufficient to carry the topographic outline far enough for the typical development of the type features. In origin and rock structure they are the same as the Appalachians; but they are not sufficiently mature for the full development of all their latent possibilities. Given time, they will become so, for they are of the same geographic family.

FIG. 14.—A MOUNTAIN RIDGE ON CANADIAN PACIFIC (NOTMAN, PHOTOGRAPHER).

*The Palisade Ranges.**—When a much more durable rock occurs among softer ones, in the course of denudation it will remain well above the general level of the others. It is upon this principle that the ruggedness and many of the characteristic features of mountains depend. In New Jersey there is a series of such dense beds of

* See references, Bull. Am. Geog. Soc., XXVIII, 1896, 103.

unusual kind, and one of these enters the State of New York along the western bank of the Hudson, from Upper Bay to Haverstraw. These are beds of trap rock, a black, dense diabase, which is decidedly more durable than the enclosing sandstone strata. In New York the diabase forms the Palisades, in New Jersey several ranges of hills or low mountains, notably those along the Hudson, near Hoboken, and also those near Paterson, Orange and other parts of northeastern New Jersey.

FIG. 15.—TRAP RIDGES (BLACK) IN CONNECTICUT VALLEY. (DANA'S TEXT BOOK OF GEOLOGY, AFTER J. G. PERCIVAL.)

During the Triassic period, eastern New Jersey was beneath the sea. An arm of the ocean also extended up the Connecticut, at least as far as the Vermont boundary; and at the same time various other parts of the Eastern States were submerged. Beds of sandstone and shale were deposited in nearly horizontal position in these ocean bays. At the same time, in the Connecticut valley, and perhaps also in New Jersey, volcanoes erupted flows of basaltic or diabasic lava, which entered the seas and covered the sands and clay, very much in the same way as the basalt of the Hawaiian volcanoes is doing at present. These lava sheets were then buried beneath other sandstone beds deposited in the sea.

Approximately at the same geological time, or possibly a little later, lava rising toward the surface was *forced into* the sandstone, between the layers of which it spread out in extensive sheets. In this way the trap of the Palisades was introduced into the rocks. After this the Triassic beds of sandstone and included lava were elevated above the sea, broken by faults and tilted from the horizontal position, so that there were produced alternate beds of lava and sandstone, inclined at various angles. The forces of denudation have removed much material from this series of rocks, and have etched the harder lavas into relief, so that they now stand up distinctly above the surrounding country.* In topographic form they simulate the Appalachian type in the fact that they are usually

* Like the other mountains of the East, the crests of these rise to a nearly uniform sky-line, which, as in the other cases, is interpreted to represent the remnants of the ancient base-levelled land, or peneplain.

ridges, though the ridges are less continuous, and also more curving, generally with a diminution in elevation at one end (Fig. 15).

This may be called the *Palisade type* of mountain, because typically illustrated there. Aside from the instances mentioned in New Jersey, this type finds illustration also in the East and West Rocks near New Haven, Connecticut, the Hanging Hills near Meriden, Connecticut, Mounts Tom and Holyoke in Massachusetts and Cape Blomidon, Nova Scotia. The typical feature is that of a ridge, or a series of ridges, of tilted trap rock, either lava flows or intrusions, etched into relief as are the ridges of harder rocks in other mountains. They differ from the true Appalachian type in the fact that they are monoclinal, and that the ridges are not associated with anticlinal and synclinal folds. Frequently, if not always, the uplift is due to faulting. This is noticeably the case in the Connecticut valley, as has been so clearly shown by Professor Davis.* In passing over this interesting phase in the geographic history of the State, it should be stated that the old volcanic centres from which the lavas came, including the cones, have long since been lowered by denudation. That the volcanic energy was widespread in its effects, is shown by the fact that, from Nova Scotia to Carolina, dikes of this black trap rock cut the strata. The volcanic activity was not manifest far west of the present coast line, but seems to have been most intense approximately along that line. Dikes, apparently of the same age, are found cutting the Devonian shale near Ithaca, N. Y. They abound in the Highlands of New Jersey and of New England.

The Catskill Mountains.†—As was stated in the first part of the article (p. 17), these are not true mountain ranges but rather pseudo-mountains. During the Devonian period, just before the uplift of the great interior Paleozoic sea, which accompanied the development of the Appalachians, the site of the Catskills was the shore line of a sea-bottom that was slowly sinking. The land side of the shore was occupied by the Taconic Mountains, from which sediment entered the sea, where it was strewn over the bottom in the region where the Catskill Mountains now rise. Here, near the coast,

* Davis, Seventh Annual Report U. S. Geol. Survey, 1885–6, 455; Davis and Whittle, Bull. Mus. Comp. Zool. XVI, 1889, 99; Davis and Loper, Bull. Geol. Soc. Am. II, 1891, 415; Davis and Griswold, Bull. Geol. Soc. Am., V, 1894, 515; Davis Am. Journ. Sci., Ser. IV, 1, p. 1; Davis, Pop. Sci. Monthly, 1891, 221. See also Percival, Geology of Connecticut, 1842, p. 299; Dana, Manual of Geology, 4th Ed., 1895, 800; Emerson, Bull. Geol. Soc. Am., II, 1892, 451.

† See references, Bull. Am. Geog. Soc., XXVIII, 1896, 105.

coarse beds of sandstone and conglomerate were accumulated, while further west, shales and sandy shales were being deposited. The sinking of the sea-bottom permitted these beds to gather to

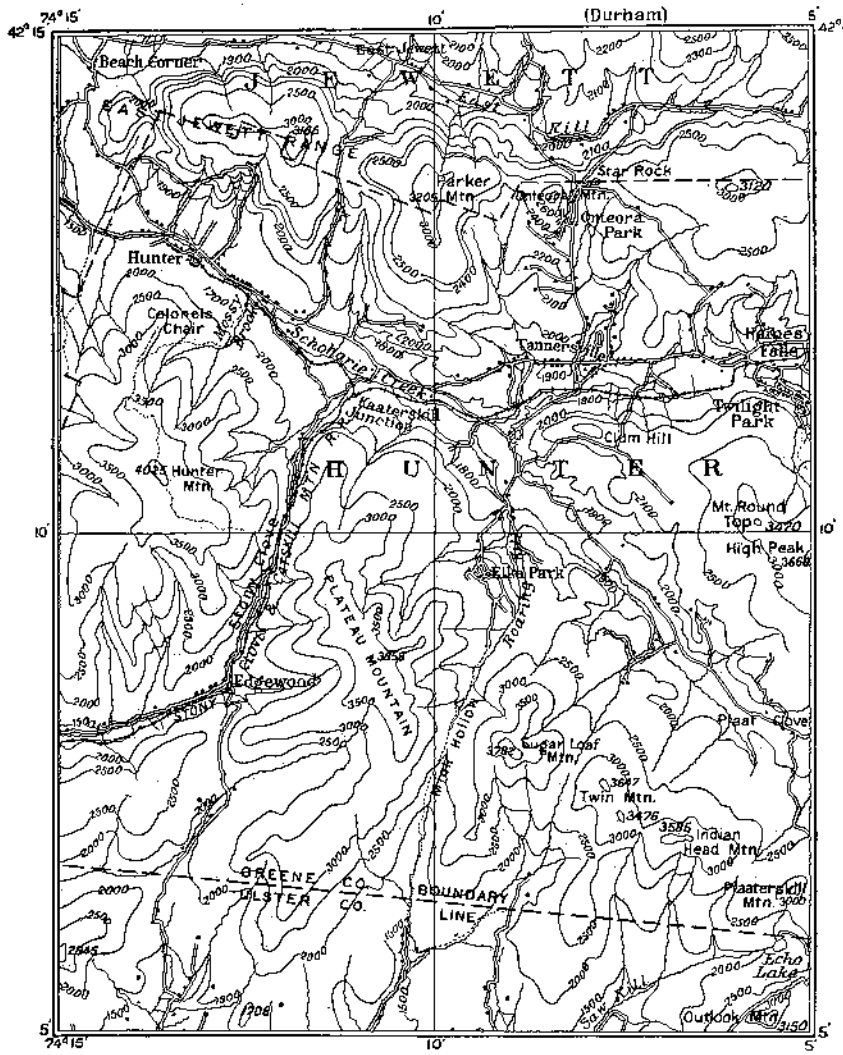

FIG. 16.—MAP OF PART OF CATSKILL MOUNTAINS, CONTOURS EVERY 500 FEET. (MADE FROM U. S. GEOL. SURVEY TOPOGRAPHIC MAP.)

great depth. Then, when the reverse process of elevation had commenced, the sea-bottom was raised to dry land, and eventually uplifted to the condition of a plateau. Possibly the uplift in the

Catskill region was greater than that in central New York, although of this there is no direct proof. But in both places the elevation was accompanied by very little disturbance of the strata, so that in the two parts of the State the upper Paleozoic beds are still nearly horizontal.

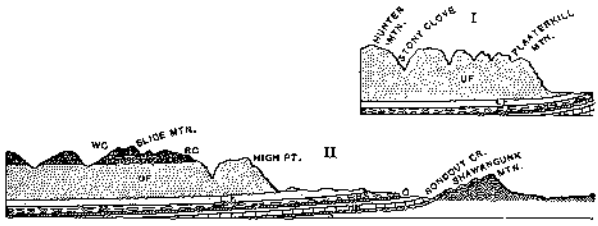

FIG. 17.—CROSS SECTIONS SHOWING CATSKILLS IN ULSTER CO. IN NEW YORK AND THE SHAWANGUNK MTS. ON RIGHT IN LOWER FIGURE. CATSKILLS CAPPED BY HARD SANDSTONE LAYERS (DARTON, 47TH REPT. N. Y. STATE MUSEUM, 1894).

This great New York-Pennsylvania plateau, which borders the western base of the Appalachians, is now considerably dissected. While in most parts it is a fairly level plateau, as viewed from the higher hills, it is, nevertheless, deeply cut by broad valleys. This is true throughout the State, but in the Catskill Mountains the topography is much more rugged and more mountainous than elsewhere. Denudation, operating upon hard rocks of nearly horizontal position, has carved out a complex of peaks (Fig. 16), which, because of the superior hardness of their rocks, rise higher than the rest of the plateau.

As might be expected from the association of the Catskills with the Appalachian uplift, the horizontal rocks of the higher and more typical portion of the Catskill range change gradually (Fig. 17), toward the south and east, into a region of disturbed rocks, thus merging into the true Appalachians. In these sections of the State there is every gradation from the plateau feature to the true folded mountain. The counterpart of the Catskills is found in various parts of the mountainous plateau region on the border between the Appalachians and the real plateau which lies west of their base. This is notably the case in the Cumberland plateau in Tennessee. The same features are present in innumerable places in the great plateau region of the Far West.

This case of the Catskills is an interesting instance of the simulation of features of one geographic type by another of quite a different kind. The life history of the mountain *range* involves folding and uplift of the rocks into complex topographic features. At first denudation increases the complexity, and brings out the variations in rock texture into markedly rugged contrast. The tilted position of the layers, and other complexities of rock position, in-

crease this irregularity. Then as development continues, the ruggedness decreases, and the surface is smoothed over, while the elevation is diminished. This may proceed until old age, when the formerly irregular surface becomes reduced nearly to the condition of a plain.

So also the plateau, with horizontal rocks of varying hardness, etched by the agencies of denudation, commencing as a level surface, becomes more and more rugged and mountainous, until finally it so closely simulates the true mountain that in common usage it takes the name. Then, as denudation proceeds, in this case also there is first produced a less rugged surface, and finally a plain. In the middle and final stages these two diverse forms are as one in surface outline, though so utterly different in internal structure and origin.

The difference between the typical *Catskill type* of mountain and the Alpine ranges of highly folded rock, is striking, when we consider the extremes. But there is no hard and fast line to be drawn between the two. The folds of the mountains die out by degrees, and change from tilted to horizontal strata quite imperceptibly. The folds become less and less intense, and finally entirely disappear (Figs. 17, 18 and 19). Where in this gradational area are we to define the boundary between the mountain and plateau? For instance, in the vicinity of Chattanooga, Tennessee, is the Lookout Mountain, with its nearly horizontal limestone, capped by sandstone, a mountain or a plateau? It is a part of a broad syncline, quite flat-topped and elevated because of the greater resistance of the upper sandstone beds. Calling this a true mountain, as we apparently must, what of Walden's Ridge, to the west of Lookout? This is still gently folded, but is a much broader and more typical plateau. Still to the west of this, and west of the Sequachee valley, is the Cumberland Plateau, where the rocks are nearly horizontal, and practically beyond the

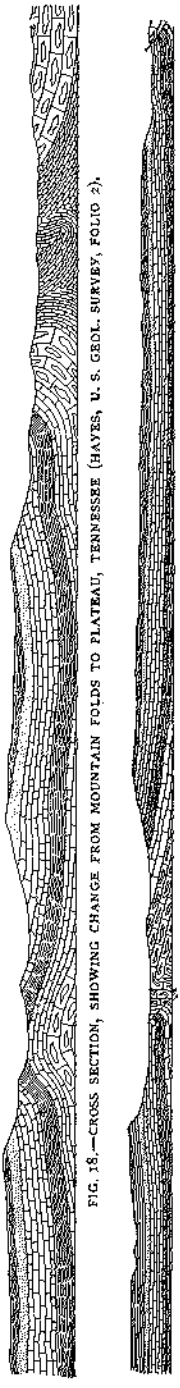

FIG. 18.—CROSS SECTION, SHOWING CHANGE FROM MOUNTAIN FOLDS TO PLATEAU, TENNESSEE (HAYES, U. S. GEOL. SURVEY, FOLIO 2).

FIG. 19.—CROSS SECTION, SHOWING PLATEAU FORM OF MOUNTAIN, WALDEN RIDGE (RIGHT HALF) (HAYES, U. S. GEOL. SURVEY, FOLIO 6).

zone of folding. No doubt this should be called a plateau and Walden's Ridge probably a mountain; but wherein lies the essential difference?

Here, as nearly everywhere, the one who would classify is confronted by the difficulty that we wish to draw distinctions where none really exist. The *typical* species of animals and plants, or of minerals and rocks, or of geographic forms, are easily separated and defined; but when we examine them further, we find them grading one into the other and the definition no longer defines, nor can the distinction longer be followed.

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