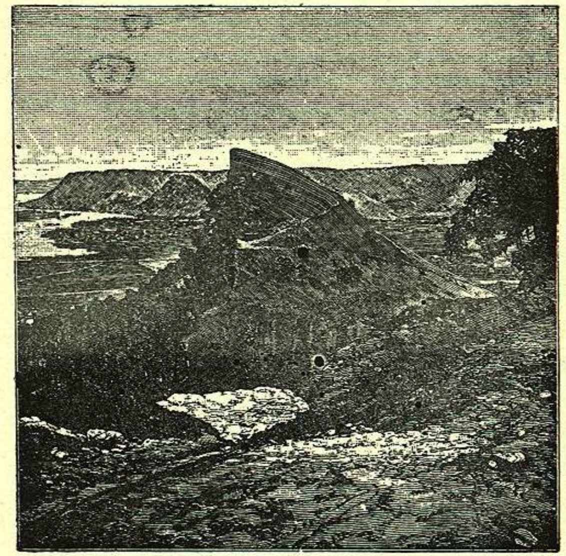
ly glaciated slope, and the southern or lee side a short, abrupt, and craggy or relatively unglaciated slope. By attention to these details, it is often possible to determine, even in the case of detached specimens, in which way along a series of striae the ice moved. When developed on a larger scale, these protruding masses or ledges with an unsymmetrical north-south profile are known as *roche moutonées*, of which there are many fine examples among the ledges of the Boston Basin (**47**). The stones dragged along by the moving ice not only wear away and striate the solid ledges, but they are themselves similarly smoothed and scratched on their working faces (**42–43**) ; and the glaciated or ice-worn stones are easily distinguished from the water-worn stones or pebbles (**23**) by the parallel striae, and by the fact that they are not usually glaciated on all sides. If a stone is turned in the ice, so as to be worn on several sides, it is not rounded ; for glaciation develops a flat surface or facet, and such stones may be described as facetted (**46**). The large mass of slate from East Boston on the right side of the stairway, in the Vestibule, is a larger but very typical example of a glaciated bowlder ; and similar masses, five to ten feet in diameter, are common in excavations about Boston.

The pictures of the glacial pot-holes in Cohasset (**41**) might be duplicated at several other points in the Boston Basin. They are similar in their characteristics to ordinary river pot-holes, except that they usually occur in positions remote from streams, and where it is impossible that they should have been formed by ordinary brooks or rivers. They are, in fact, the product of glacial mills (moulins); that is, they are formed where a stream flowing over the surface of a glacier plunges through a crevasse upon the solid ledges below.

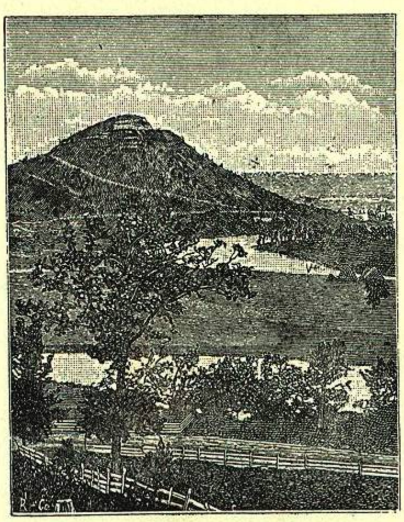
The striated slab of sandstone and the bowlder of gneiss from the Catskill Mountains (**82–83**, section 16) are of interest especially because they were found near the upper limit of glaciation in that region, about 3,000 feet above the sea, and the bowlder has very clearly been brought by the ice from the Adirondacks, nearly one hundred miles to the north. The bowlder from the summit of Mt. Washington (**84**) is wholly unlike the rock in place on this mountain (**85**), and thus proves that the great ice-sheet covered the highest summit of New England.

Aerial Erosion.—The wind has considerable power to wear away and transport unconsolidated sands; and when thus armed with moving sand it is also able, as in the case of the artificial sand-blast, to wear away the hardest and most resistant rocks. The results of the natural sand-blast, as seen in the polished and striated specimens of a hard quartzose rock from Nevada (**26**), may simulate glaciation very closely. The smooth but angular pebbles from Colorado (**28**) and Nantucket (**24–25**) are believed to have been fashioned by blown sands, although it is not improbable that the solvent action of water has played some part here. The angular sculpturing is, as a rule, limited to the upper sides of the pebbles.

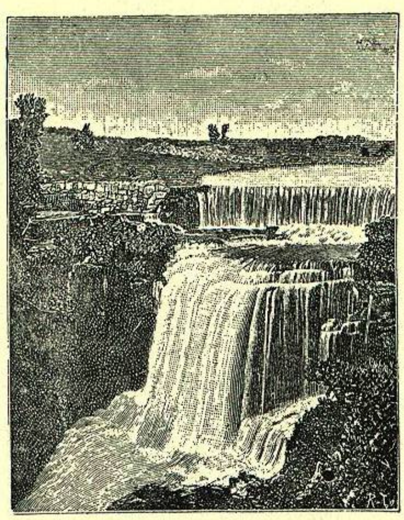
Organic Erosion.—The only clear illustrations to be noted here are the rock-borings of certain bivalve shells (**29–31**) and the spiny echinoderm or echinus (**27**).



Combined ancient and modern erosion contours. Sugar Loaf, near Winona, Minn.



Topographic old age (driftless area).



Topographic youth (drift area).

Major Erosion Features.

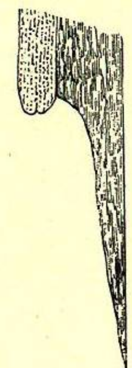
Turning now to erosion-forms in their larger or topographic aspect, the photographs in this section may be referred to as a mere suggestion of what might be done, if space permitted, with this class of illustrations. But even these show some of the more distinctive features of marine (**1**), fluvial (**2**), sub-aerial (**21-23**), and glacial (**42**), erosion, as explained on the labels. The relief map of the Mt. Blanc range (**61**) may be most conveniently noticed in this connection. In spite of its mantle of ice and snow, its contours show the normal results of subaerial erosion at a great elevation on massive rocks. In addition, it is an admirable and comprehensive illustration of local, as contrasted with general, glaciation.

Horizontal or very slightly undulating strata, especially if the upper beds are harder than those below, give rise by erosion to flat-topped ridges or table mountains. But if the strata be softer and of more uniform texture, erosion yields rounded hills, often very steep, and sometimes passing into pinnacles, as in the Bad Lands of the West. Broad, open folds, give, normally, synclinal hills and anticlinal valleys, when the erosion is well advanced. But in more strongly, closely folded rocks the ridges and valleys are determined chiefly by the outcrops of harder and softer strata, the symmetry of the reliefs often depending upon the dip of the strata. This principle of unequal hardness or durability also determines most of the topographic features in regions of metamorphic and crystalline rocks, in which the stratification is obscure or wanting.

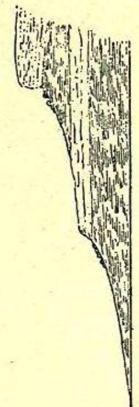
The boldness of the topography, and the relation of depth to width in valleys, depends largely upon the altitude above the sea; but partly, also, upon the distribution of rain-fall, the drainage channels or valleys being narrowest and most sharply defined in arid regions traversed by rivers deriving their waters from distant mountains. That these are the conditions most favorable for the formation of cañons is proved by the fact that they are fully realized in the great plateau country traversed by the Colorado and its tributaries, a district which leads the world in the magnitude and grandeur of its cañons. See the large relief map in the window space. But deep gorges and cañons will be formed wherever a considerable altitude, by increasing the erosive power of the streams, enables them to deepen their channels much more rapidly than the general face of the country is lowered by rain and frost. This is the secret of such cañons as the gorge of the Columbia River, and probably of the fiords which fret the northwest coasts of this continent and Europe.

The smaller plaster model (**22**) with the accompanying section directs attention to the fact that erosion is not limited to the surface of the earth, but, in the case of limestones especially, is very largely subterranean. The solvent action of underground waters, as explained on the label, leads to the formation of caverns, natural bridges, sink-holes and eventually to the lowering of the surface over extensive areas.

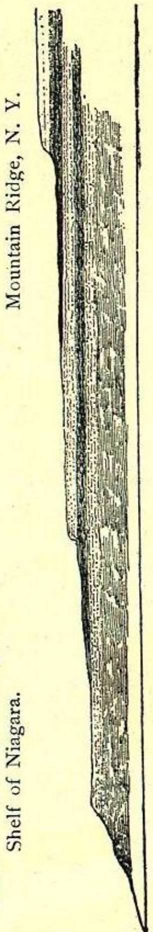
The two wooden models (**41**, **43**) which are the exact complements of each other, one representing a ridge and the other a valley cut out of horizontal strata, are intended especially to illustrate certain relations of strata to the



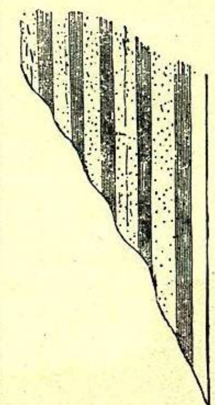
Plateau with simple escarpment.
Shelf of Niagara.



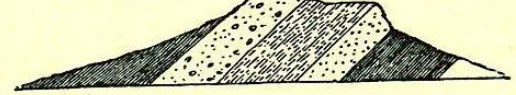
Plateau with complex escarpment.
Mountain Ridge, N. Y.



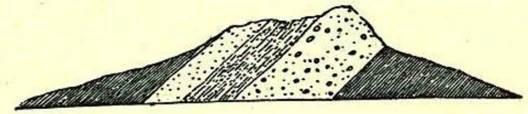
Terraced plains, due to the lateral erosion of horizontal strata.



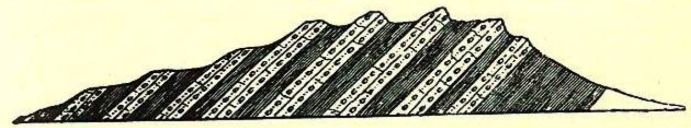
Plateau with terraced escarpment. Pocono Mountain, Pa.



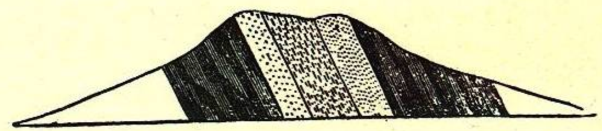
Double monoclinal ridge, with terrace on the back.



Double monoclinal ridge, with terrace on the front.



Complex monoclinal ridge.



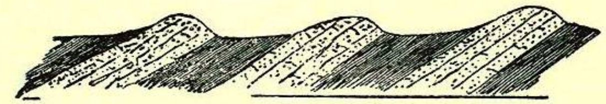
Monoclinal ridge. A profile of the Kittatinny Mountain.

topography to which attention must be given in the construction of geologic maps. These are: First, that the breadth of the outcrops of strata are inversely proportional to the inclination of the surface, the outcrop being narrowest where the slope is steepest, and *vice versa*. This is the rule for horizontal strata; with highly inclined or vertical strata it is reversed. Second, that the outcrops of horizontal strata, being essentially like contour- or shore-lines, are deflected, in crossing the topographic forms, up the valleys and toward the lower ends of ridges.

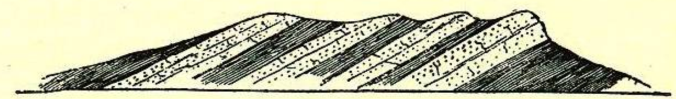
From these general and somewhat isolated illustrations of topographic geology, we pass to the excellent series of topographic models or relief maps which are placed in the upper parts of the cases and on the walls of the window-spaces of this room. These were designed by Prof. W. M. Davis, and their special merit and interest is found in the fact that, occurring in series, they illustrate the development or life-history of topographic features, which is otherwise virtually impossible. They begin with section 1, and since there is but one model in each section, they may be conveniently referred to by the section numbers.

The first series, including the first five models (**1–5**), starts with a region newly elevated above the sea and devoid of relief features, and traces the normal development and succession of the topographic forms in the absence of pronounced contrasts in the geological structure. In the first model the main drainage channel of the distri , and a few tributary channels, are distinctly outlined, but the interstream surfaces are still broad and level. This is evidently a very youthful topography. In the second model (**2**) the development is much more advanced. The drainage lines of the first model are all easily recognized; but the tributaries, cutting steadily backward into the primitive plain, have been greatly extended and ramified; the valleys have been deepened, and broadened by the reduction of their lateral slopes; and the original interstream surfaces are reduced to isolated remnants or completely effaced. This evidently represents a period of topographic maturity, of maximum complexity and relief. This is followed, in the next model (**3**), by a subsidence of the land. The main valley and the lower portions of the tributary valleys are invaded by the sea and become an area of deposition; and while this arm of the sea is being silted up, marine, fluvial, and subaerial erosion are steadily wearing down the surrounding land. Thus by a two-fold process—filling up the valleys and degrading the hills—the topography is flattened and its features slowly effaced. The fourth model (**4**), represents a second elevation of the land; the sea has retired, and the streams have begun to re-excavate their well-nigh obliterated channels. This means, virtually, a renewal of the youthful conditions, the beginning of a new cycle of development, which proceeds (**5**) without interruption by a movement of subsidence until all the lower parts of the district are worn down nearly to the baselevel, and the general surface reduced to a peneplain (nearly a plain), the true topographic old age.

In the next series, including three models (**6-8**), the topography is, obviously, controlled in a much larger degree by the geologic structure. The region repre-

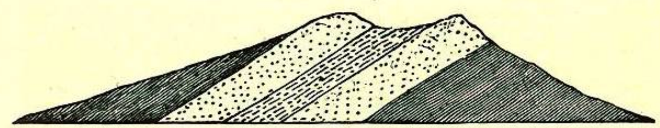


Ridged or undulated plain or wide valley.

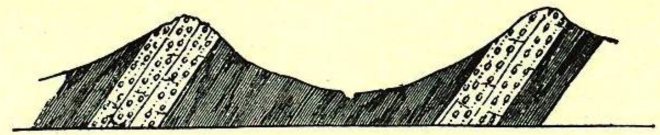


Ridged or undulated table land.

Single-crested monoclinal ridge.



Double-crested monoclinal ridge.



Simple monoclinal valley.

Double monoclinal valley.

Complex monoclinal valley.

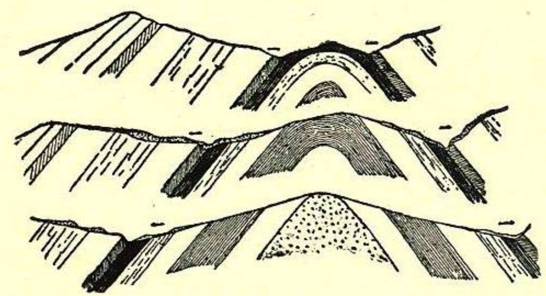
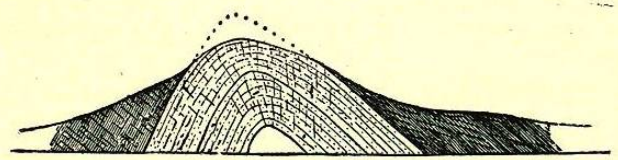


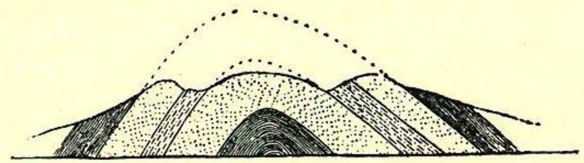
Diagram illustrating the gradual separation of two streams by the wearing down of an anticline.

sented is one traversed by approximately parallel ranges of mountains, which have, like the parallel ranges of the Great Basin, been produced in the first instance by faulting, by the tilting of long and narrow blocks of the earth's crust, the precipitous faces of the ranges being the somewhat eroded fault scarps. In this case the valleys and all the main topographic features, are clearly antecedent, and not the product of erosion. The first model represents the valleys as partially filled with water, resembling the extensive Quaternary lakes of the Great Basin. In these lakes silt washed from the mountains is deposited in horizontal layers to a great depth. The climate then becomes more arid, the lakes waste by evaporation and are finally reduced to a series of isolated and shallow pools, as shown in the second model (**7**), in which the buff tint represents the newly-deposited sediments. Most of these pools or playas, being without outlets, are necessarily saline or alkaline. But as the small streams draining into them cut down and cut back their channels, the playas of the same valley are gradually drained, and the whole valley eventually drains directly into one basin or pool. The principal streams tributary to such a basin will naturally rise in the passes or low gaps between the ranges that bound the valley; and the head waters of the streams, cutting steadily backward, will sometimes reduce these barriers sufficiently so that the stream in the higher valley will be gradually reversed and become tributary to the lower valley. Through the continued and repeated operation of this principle, all the valleys represented ultimately become united in one connected but intricate drainage system, as shown in the third model. The principle especially illustrated by this series is, evidently the union of distinct, and even closed, drainage systems or hydrographic basins in one continuous system, through the backward erosion of the streams, the basins having been made distinct in the first place by the deformation of the earth's crust, by causes quite independent of erosion. A river system thus tends to become constantly more extended, through the backward cutting of its headwaters and the development of new tributaries or branches, and also by capturing a part or the whole of adjacent systems and thus enlarging its drainage area. Streams of considerable fall and erosive power possess, evidently, a marked advantage, in these respects, over those of more sluggish habit.

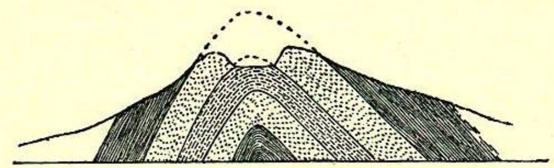
The next series embraces but two models (**9–10**) and these are intended especially to illustrate the topographic contrast between a typical unglaciated area (**9**) and a typical glaciated area (**10**); or, in other words, to show the effect of glaciation upon a topography which has been fully and normally developed by aqueous erosion. In the first model the topographic development has passed the period of maximum ruggedness, the original interstream surfaces having been entirely obliterated; but the drainage over the entire area is perfect, free and unobstructed. The second model represents precisely the same area after long-continued glaciation, during which the hills have lost still more of their rugged character and the valleys have become clogged with irregular deposits of drift, greatly obstructing and even diverting the drainage. The obstruction of the drainage is seen in the numerous lakes and lake-



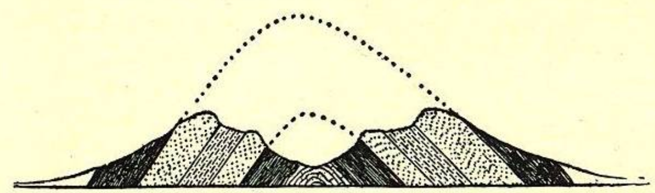
Single-crested anticlinal ridge.



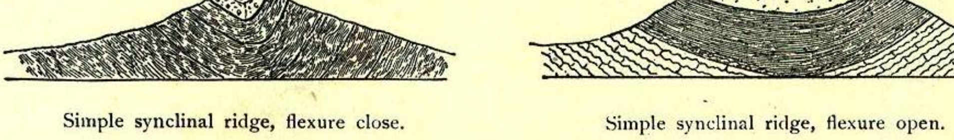
Triple-crested anticlinal ridge.



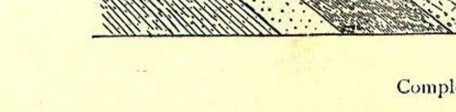
Double-crested anticlinal ridge, or simple valley of elevation.



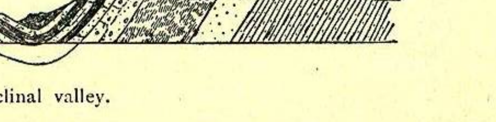
Complex valley of elevation.



Complex valley of elevation, with central anticlinal ridge.

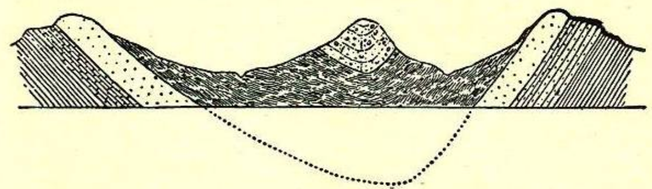


Simple synclinal ridge, flexure close.

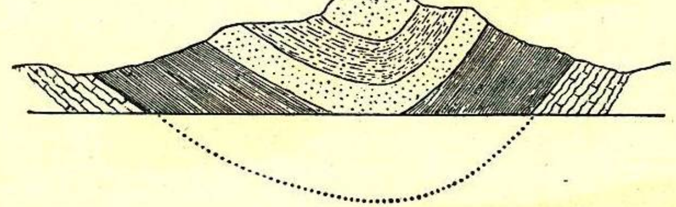


Simple synclinal ridge, flexure open.

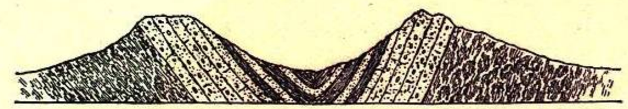
Complex synclinal valley.



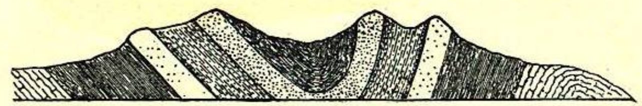
Synclinal ridge in synclinal valley.



Triple synclinal ridge or terrace.



Simple synclinal valley or basin.



Complex synclinal valley.