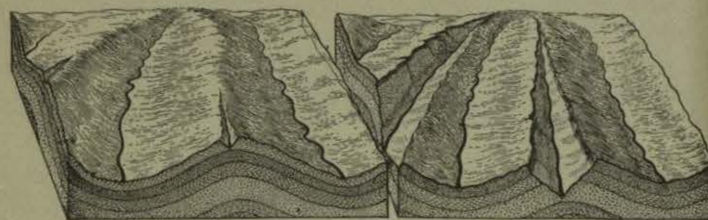

FIG. 174. — The left-hand figure shows two anticlinal ridges each cut into for a short distance by a stream. As the streams cut deeper and grow longer, they reach below a hard layer (the darkest one in the diagram), which, because of its hardness, is left standing as a ridge on each side of the valley (right-hand figure). The law of monoclinal shifting will cause these ridges to retreat away from the stream, thus broadening the valleys in the anticlines, and at the same time narrowing the synclinal valleys. (See also Fig. 179.)

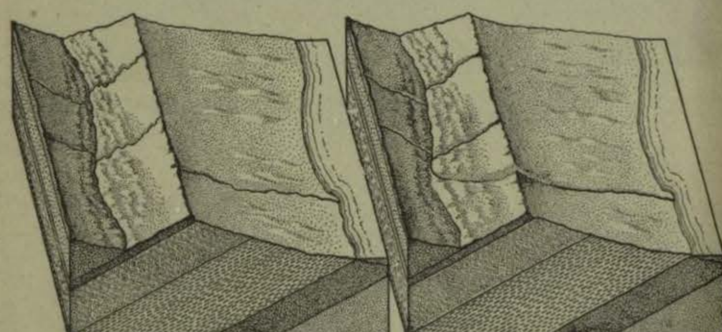

FIG. 175. — In the left-hand figure a stream heads on a divide and flows in a short course toward the right to the sea. This steep slope gives it power to gradually eat backward until it reaches a stream having a long, roundabout course to the sea. It then captures the stream and leads it out to the sea by the shorter course, as shown in the right-hand figure.

Figs. 174, 175, 177, 178, and 179 are introduced for class study, supplementary to the text.

valleys are well settled (Fig. 466), but the ridges are too rough and rocky for farming, and are often timber-covered (Figs. 85, 467). Where streams leave the broad valleys to cross the ridges of hard rock, they flow in narrow gorges, or *water gaps* (Figs. 178, 463, 467), because there has not been time for weathering to broaden valleys in so hard strata.

Summary. — *As mountains rise, the effect of denudation increases, and young mountains are therefore made very rugged. Mature mountains have been lowered and the valleys broadened; and old mountains are still further lowered, and perhaps even reduced to a peneplain. Uplift allows denudation to again etch the hard strata into relief.*

74. The Drainage of Mountains. — In early stages, in consequence of the slopes, numerous short streams flow down the mountain sides in gorges; and longer streams follow the broad valleys between the mountain folds. Here and there the main streams cut deep gorges across low points in the folds (Fig. 168). In such *consequent mountain drainage* there are, at first, numerous lakes held up by the mountain dams. These, however, are soon filled with sediment brought by the mountain torrents. A slight renewal of mountain movement may warp the valleys and form new lake basins (Fig. 296). Some of the Alpine lakes, such as Geneva, are thus explained.

If the elevation of the land ceases, the valleys pass through the stages of youth, maturity, and old age. But the great elevation, and the hard and complex nature of the mountain rocks, make the life history of a river valley in mountains longer than in plains and in most plateaus.

The wearing away of the weak rocks leaves the hard strata standing as divides (Figs. 38, 154, 169). As the surface slowly wears down, the divides still remain on the more durable strata. These mountain strata usually incline, or dip; and, as they are slowly worn away, their crests, that is the divides, not only become lower, but shift to one side

(Fig. 176). This, called *the law of monoclinal shifting*, may be stated as follows: *As denudation lowers a region of inclined strata, the divide migrates in the direction of the dip.*

Mountain divides may migrate for other reasons (Figs. 175, 177, 178). Thus, two streams heading on the same divide are constantly battling for drainage area, and the stronger one pushes the divide back into the territory of its opponent. If it succeeds in robbing its opponent of its headwaters, it is called a *river pirate*. There are various reasons why one stream may have more power than another: one may have more rainfall; or it may have a shorter and steeper slope; or it may have only weak strata to remove while its opponent struggles with hard strata.

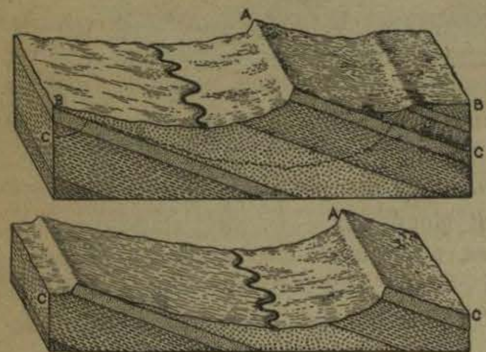

FIG. 176. — To illustrate the migration of divides. A hard layer *A* forms a divide ridge. When the surface has been worn down to the line *CC* (upper figure) the ridge *A* will have migrated to the right, as shown in the lower figure. See also Figs. 174, 179.

There are numerous illustrations of such migration of divides. In the Catskills, for example, the streams descending the steep eastern slope to the Hudson have pushed the divide backward and captured the headwaters of streams that have a long, gentle slope (Fig. 177). The Appalachian rivers, — the Potomac, Susquehanna, Delaware, etc., — which cross ridge after ridge (Figs. 172, 192), are believed to have slowly eaten their way across the mountains by headwater erosion and river capture. *Wind gaps* of the Appalachians are also caused by river capture (Fig. 178).

Summary. — *Consequent mountain streams flow down the mountain sides, along the valleys of folding and across the ridges. They*

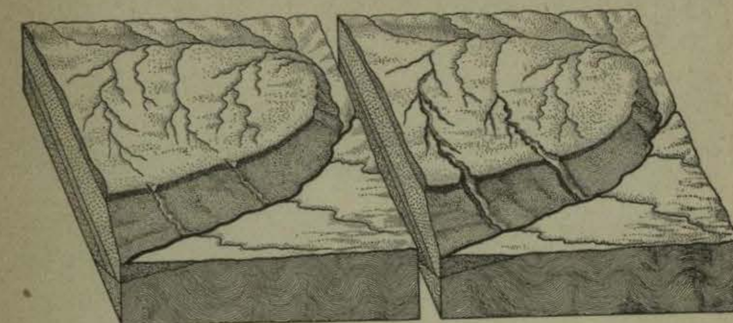

FIG. 177. — The headwaters of a tributary (left-hand figure) rise on a highland and flow a long distance, in a roundabout course, to reach the main stream. Two short streams head in the same region, but flow in steep courses to the main stream. This gives them power to eat back at the divide and rob the long tributary of some of its headwaters (right-hand figure). This condition is somewhat like that in the Catskills. Note that the tributaries of the captured streams join in barb fashion.

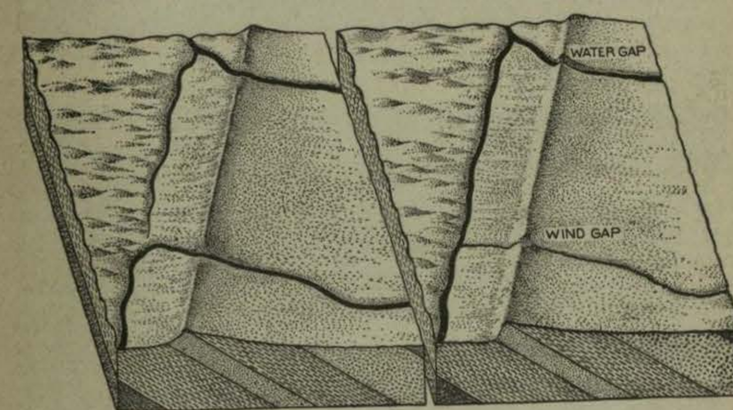

FIG. 178. — In the left-hand figure two streams cross a mountain ridge of hard rock. A tributary of the upper one heads back nearly to the point where the lower one turns to cross the ridge. For some reason (perhaps greater volume) the upper stream has more power to cut into the ridge, thus deepening its valley. This gives to its tributary a slope which permits it to gradually eat backward until it taps the lower stream, drawing it off through the upper water gap. This leaves a *wind gap* where the lower stream formerly crossed the ridge (right-hand figure).

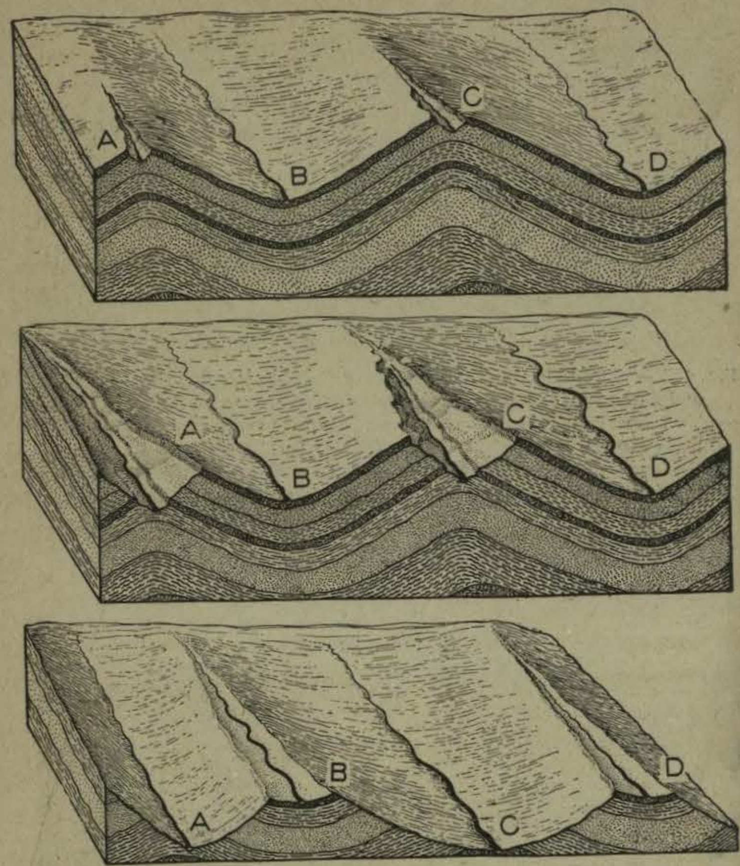

FIG. 179. — The process of monoclinal shifting, illustrated in Figs. 174 and 176, is carried farther in this diagram. In the upper diagram there are four streams, *A*, *B*, *C*, and *D*; *A* and *C* in small valleys in the anticlines, *B* and *D* in broad synclinal valleys caused by down folding. They are consequent on the mountain form. In the middle figure there is little change, excepting that the anticlinal valleys have been lengthened and deepened, this being possible because they are so high that the streams have much power, while the synclinal streams are held back in their work by lakes (not shown here) and hard strata. The lower figure represents a much later stage, in which the surface has been greatly worn down. Monoclinal shifting has pushed the divides away from the anticlinal streams (Fig. 174), therefore broadening their valleys and narrowing the synclinal valleys. This has robbed the synclinal streams of water, and consequently weakened them, while it has increased the power of the anticlinal streams. As a result, the conditions have been reversed from the first stage, and the anticlinal streams, *A* and *C*, flow in broad, deep valleys, while the synclinal streams are in high, narrow valleys, on the tops of synclinal mountains. Instances of this change are found in the Appalachians.

FIG. 180. — The lower slopes of the Alps along the deep valley occupied by Lake Como. These slopes are cultivated, growing olives and grapes, and towns cling to the mountain base wherever there is enough level land, especially on the stream deltas (Figs. 107, 297).

FIG. 181. — The high, snow-covered slopes of the Jungfrau in the Alps, showing summer pasturage above the timber line, and up to the very edge of a glacier.

FIG. 182.—An Alpine valley and village, from which rise the barren, rocky mountain slopes, down which rock waste is streaming, forming alluvial fans.

FIG. 183.—The bare, rocky slopes of the high Alps, among which men do not live. The houses are hotels, open only for two or three months in summer.

are likely to be interrupted by lakes. Slowly they pass through youth, maturity, and old age, unless interrupted by renewed mountain growth. The divides change position by the law of monoclinal shifting, and by headwater erosion. In the latter case the more favorably situated streams capture the headwaters of opponent streams.

75. Settlement of Mountains. — The soil and climate of mountains are usually unfavorable to agriculture, and, in many cases, absolutely forbid it. Large areas are even unfit for the growth of forests. For these reasons mountains are usually sparsely settled (Figs. 157, 158, 183, 185).

The relation of mountains to settlement is well illustrated by the Alps, which rise in the midst of a densely populated land, — Italy on the one hand, France and Germany on the other. If we were to cross the Alps from the Italian side, this is what we should see: first a level plain, the Po valley, dotted with farms and villages, and densely settled. As the land becomes irregular in the foothills, there are fewer people; and, when the mountains are reached, large areas are found with a surface too rocky for cultivation (Figs. 107, 180). Wherever there is soil enough, however, vineyards and groves of olive and mulberry trees are seen on the valley sides.

Higher up, where the climate is cooler, the olive, mulberry, and grapes no longer grow (Figs. 153, 182). There small grain-fields and pasture lands are interspersed with rocky cliffs and forested areas, in which the chestnut is a common tree. Still higher, where the climate is that of the cold temperate zone (Fig. 109), evergreen trees prevail, and only the hardiest grains can be raised. Most of the land that has soil enough is used as pasture, and cows and goats are raised in large numbers. Between the timber line and the snow line there is an area on which no crops can be raised, but where the pastures support herds of cows and goats for a month or two in summer (Fig. 181). Above this is a wild, dreary mass of snow, rock, and ice, where no one can find sustenance (Figs. 157, 182, 183).

Summary. — *Mountains are sparsely settled. Agriculture may flourish at the base, but the area suitable to cultivation becomes smaller the higher one goes, and the climate more and more unfavorable, until, at the snow line, a barren area of snow and rock is reached in which there are no inhabitants.*

76. Mountains as Barriers. — Mountains are barriers to the passage of animals, plants, and men. On a plain, animals and plants spread freely; but the ruggedness and coldness of mountains check, and in many cases prohibit, the passage of animals and the spread of plants. Even the passes of high mountains, like the Alps, have deep snow until summer.

The low Appalachians served as a barrier to the westward spread of the early colonists (p. 308). The Alps (p. 388) have always been an obstacle to man, being crossed only with difficulty and along the few passes. The Himalayas (p. 388) are an even more effective barrier; and the Pyrenees are so excellent a barrier that they serve as the boundary line between two countries. Name other cases where mountains serve as boundary lines.

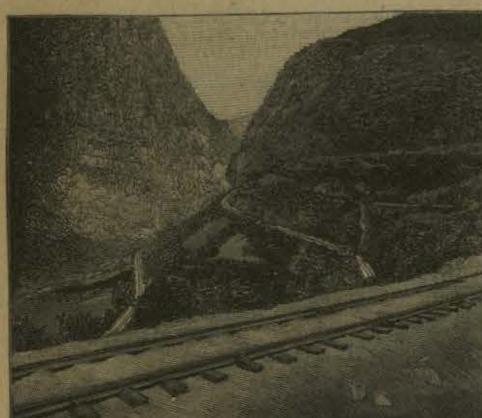

FIG. 184. — A railway crossing the Andes of Peru. There are three levels here, as in the St. Gothard railway (Fig. 186).

In the past century men have found means of reducing the difficulties of crossing mountains. Excellent carriage roads, rising with gentle slope by great sweeping curves, now cross the principal Alpine passes (Fig. 185). In places where snow-slides and avalanches are common, the roads

FIG. 185. — A mountain road rising up the slopes of the Alps to one of the passes. The Rhone glacier is seen in the middle of the picture. Notice the stream that issues from it, and flows with numerous branches, or with a braided course, over the sediment that it brings from the ice.

FIG. 186. — The St. Gothard railway on the Italian side of the Alps. Notice the three levels. At this point the railway passes through two spiral tunnels in order to climb the steep slope of the mountain valley before finally plunging into the main St. Gothard tunnel.

FIG. 187. — A summer hotel on a pass near Grindelwald in the Alps. The mountain in the distance, on the right, is the Wetterhorn.

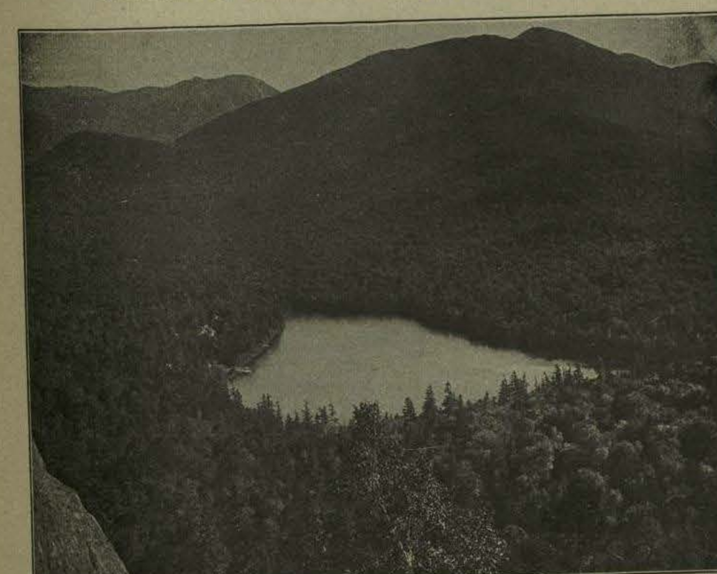

FIG. 188. — The forest-covered slopes of the Adirondacks, with a beautiful lake nestled in a valley in the midst of the forest. Copyright, 1888, by S. R. Stoddard, Glens Falls, N.Y.)

FIG. 189. — The forest-covered slopes of the White Mountains of New Hampshire, a famous summer resort.

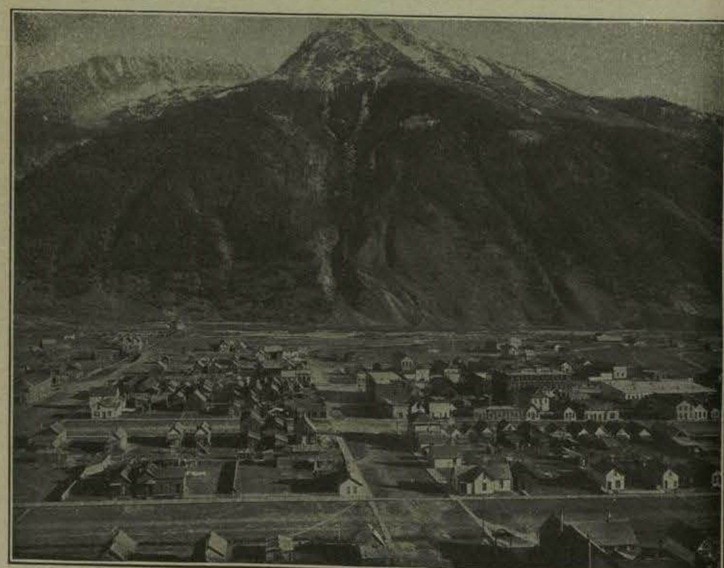

FIG. 190. — Silverton, Col., a mining town in a Rocky Mountain valley. The timber line is seen on the mountain slope.

are covered and protected by avalanche sheds. Railways cross even the lofty Rocky Mountains (Fig. 471), Andes (Fig. 184), and Alps (Fig. 186). They pass up the valleys as far as they can (Figs. 57, 66), curving about, first on one side, then on the other; crossing deep gorges by lofty bridges; tunneling the rock, even by curved tunnels; and finally, when it is no longer possible to climb higher, plunging through a great tunnel into the very heart of the mountain. The St. Gothard tunnel is nine and one fourth miles long; the Simplon tunnel, farther west, is even longer.

Summary. — *The ruggedness and coldness of mountains make them barriers to the spread of plants, animals, and man. Now, owing to the building of roads and railways, mountains are far less important barriers than formerly.*

77. Mountains as Summer Resorts. — The cool summer climate and the wild and beautiful scenery attract many people to mountains. The numerous mountain lakes which offer opportunities for boating and fishing, and the hunting on the forest-covered mountain slopes, are further attractions. The mountains of New England (Fig. 189), the Adirondacks (Fig. 188) and Catskills of New York, and the Appalachians are visited each year by large numbers of people. But in winter they are cold, snow-covered, and nearly deserted.

The Alps, the wildest and most beautiful of European mountains, have come to be the greatest summer resort in the world. In the small country of Switzerland, which is only one third the size of Pennsylvania, there are thousands of summer hotels. At every point where many tourists are likely to go, even on mountain trails far from wagon roads, a hotel is sure to be found (Figs. 169, 183, 187). In the height of the season most of these hotels are full to overflowing with tourists from all parts of Europe, in fact, from all the world. One of the leading industries of Switzerland is the entertainment and care of these visitors.

Summary. — *The climate, scenery, boating, fishing, and hunting attract people to the mountains for a vacation.*

78. Mountains as Timber Reserves. — Mountain slopes are so often unsuited to agriculture that in many places the forest remains (Figs. 85, 188, 189). About one fifth of the surface of Norway is forest-covered, and much of the remainder is either too high or too rocky for trees to grow. The mountains of eastern and western United States still have great timber resources and are the seats of important lumber industries.

Summary. — *Mountains are important timber reserves, because agriculture has not demanded the removal of the forests.*

79. Mineral Wealth of Mountains. — The Alps have little valuable mineral; but the mountains of eastern and western United States, and many other lands, are very rich in mineral. In the West, gold, silver, lead, and copper are most important; but zinc, iron, coal, and building stones are also found. In the mountains of eastern United States, coal, iron, and building stones are the leading mineral products.

The presence of metal has attracted many people to mountain regions, where otherwise there would be only a sparse population of farmers, herders, hunters, and lumbermen. In rugged mountain valleys, and on arid mountain slopes, cities with thousands of inhabitants have quickly grown up around mining centers.

FIG. 191. — To illustrate how folding and denudation bring to light valuable mineral deposits. The black layer may represent a bed of coal. If the strata were horizontal, it might be deeply buried; but folding has raised it, and deep mountain valleys have exposed it to the air.

Mineral beds and veins are revealed by folding of the strata and erosion of valleys in the mountain rocks (Fig. 191). Sometimes they are preserved from erosion by being folded down in the synclines, as in the case of the anthracite coal of Pennsylvania (Fig. 194). This was formed at the same time as the bituminous coal that is found west of the Appalachians; but, during the folding of these mountains, the pressure

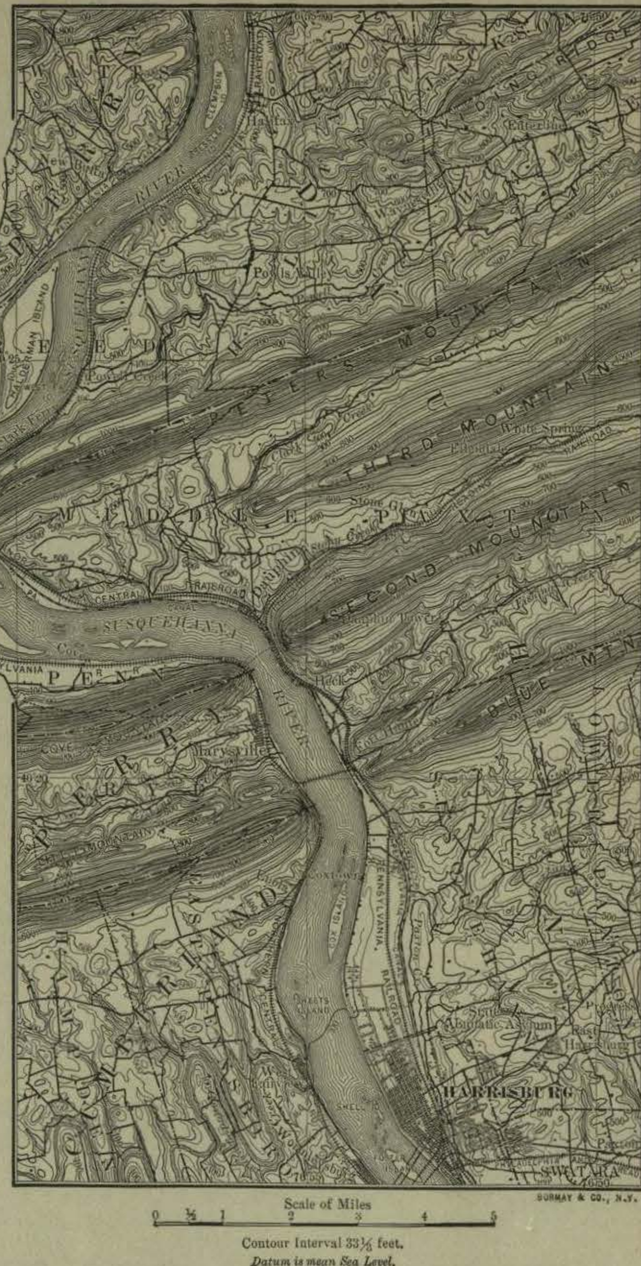

FIG. 192. — Topographic map of Appalachian ridges where crossed by the Susquehanna above Harrisburg, showing the broad valleys and the narrow, steep-sided water gaps. See Figs. 172 and 173. (Harrisburg Sheet, U. S. Geological Survey Topographic Map.)

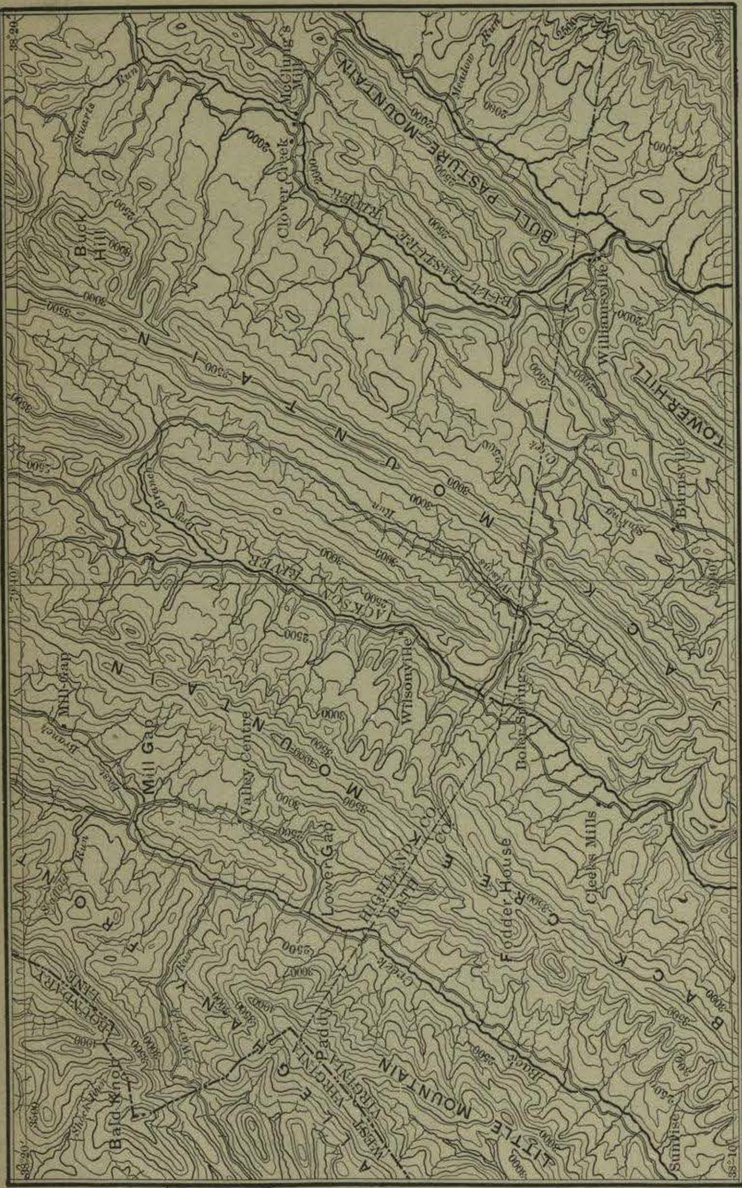

FIG. 193. — The drainage of a mature mountain region in the southern Appalachians. Here the streams are well adjusted to the rock structure, flowing in parallel courses along the lines of weaker strata, receiving short tributaries from the slopes of the ridges, and here and there escaping in gaps across the ridges. Such drainage is characteristic of mature mountain regions, and is said to be *maturely adjusted*. (Part of Monterey, Va.-W. Va. Topographic Sheet, U. S. Geological Survey.)

metamorphosed it to "hard" or anthracite coal. At Scranton, Wilkes Barre, and elsewhere, the anthracite is now being removed from the synclines in which it has been so long preserved.

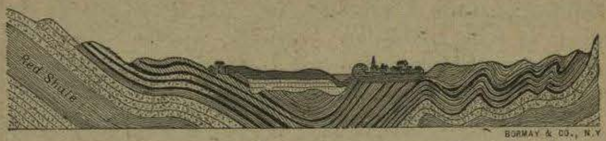

FIG. 194. — A section of the coal beds (dark layers) at Wilkes Barre. They have been folded down in a syncline, and thus preserved from erosion.

Summary. — *Many mountains contain valuable mineral deposits, which attract settlers. Folding and erosion help to reveal these deposits; and sometimes they are preserved in the synclines.*

TOPICAL OUTLINE, QUESTIONS, AND SUGGESTIONS.

TOPICAL OUTLINE. — 64. **Introductory.** — Influence of mountains on settlement; reasons for studying about mountains.

65. **The Mountain Rocks.** — Position of rocks; faulting; folding; complex folding; Appalachians; kinds of rock; effect of complexity.

66. **Names applied to Parts of Mountains.** — System; range; cordillera; ridge; peak; interior basin; smaller basins; park; water gap; pass.

67. **Climate of Mountains.** — (*a*) Temperature: normal change; snow line; timber line; variation. (*b*) Rainfall: rainy slopes; arid slopes.

68. **Denudation of Mountains.** — (*a*) River erosion. (*b*) Weathering: reasons for activity. (*c*) Talus: cause; form produced; change to farm land; débris cones. (*d*) Avalanches: size; effects; Simplon avalanche; cause. (*e*) Effect of denudation on land form.

69. **Resemblance between Mountains and High Plateaus.** — Resemblance in height; in ruggedness; the Catskills; difference from mountains.

70. **Distribution of Mountains.** — In open ocean; fringing continents, — as islands, peninsulas, and continent borders; in interior; direction.

71. **Cause of Mountains.** — Contraction theory; successive uplifts; slow growth; absence of mountains in certain sections.

72. **Types of Mountains.** — Faulted blocks; domes; regular folds; complex folds; cause, characteristics, and examples of each.

73. **Life History of Mountains.** — (*a*) Young mountains: early growth; earthquakes; volcanoes; increasing denudation; valleys; unfitness for occupation; examples. (*b*) Mature mountains: broadening; lowering; examples; fitness for occupation. (*c*) Old mountains: further reduc-

tion; peneplain; settlement; instance; Piedmont belt. (*d*) Renewed elevation: Appalachians; ridges; broad valleys; settlement; water gaps.

74. **The Drainage of Mountains.** — (*a*) Consequent drainage: stream courses; lakes. (*b*) Life history — compare with plains. (*c*) Monoclinal shifting: nature of process; law. (*d*) River pirates: battle at headwaters; favoring conditions; Catskills; Appalachians; wind gaps.

75. **Settlement of Mountains.** — (*a*) Unfavorable conditions. (*b*) The Alps: the base; the slopes; above the timber line; above the snow line.

76. **Mountains as Barriers.** — Reasons; instances; overcoming barriers, — roads, railways, tunnels.

77. **Mountains as Summer Resorts.** — Attraction; mountains visited in eastern United States; the Alps; importance to Switzerland.

78. **Mountains as Timber Reserves.** — Reasons for forests; instances.

79. **Mineral Wealth of Mountains.** — Alps; the West; the East; effect on settlement; effect of folding and erosion; anthracite coal.

QUESTIONS. — 64. Of what importance are mountains to men?

65. What is the position of the mountain rocks? What differences are there in the folds? In the rocks? What effect has this complexity?

66. What are the following, and what causes each: mountain system, range, cordillera, ridge, peak, interior basin, park, water gap, and pass?

67. What is the snow line? The timber line? How do they vary? What effects have mountains on rainfall?

68. Why are rivers and weathering very active in mountains? What becomes of the fragments that fall? What are the nature, effects, and causes of avalanches? What effect has denudation on mountains?

69. Compare and contrast high plateaus and mountains.

70. In what situations are mountains found? Give illustrations. What about the direction of mountain ranges?

71. State the theory of contraction. How do mountains grow?

72. Give four types of mountains. What are the characteristics of each? How do they differ? Are they alike in any respect?

73. What happens when a mountain is rising? What effect has denudation? What are the characteristics of young mountains? Trace the development through maturity to old age. Give illustrations of each. What is a peneplain? What has been the history of the Piedmont Belt? What changes have occurred in the Appalachians?

74. Describe the consequent drainage of mountains. What is the normal life history? What causes lakes? How does the law of monoclinal shifting operate? What are river pirates? Why do they succeed? Give illustrations. Explain wind gaps (Fig. 178).

75. Why are mountains sparsely settled? How does the appearance of the Alps change from base to summit? How do the occupations vary?

76. Why are mountains barriers to the spread of animals and plants? Give illustrations. How are these barriers now overcome by men?

77. What attracts people to mountains? Give instances.

78. Why is there much forest among mountains? Give illustrations.

79. What mineral deposits are found among mountains? What effect have mountains in revealing and protecting mineral deposits?

SUGGESTIONS. — (1) Slowly dry an apple. Notice how the skin wrinkles as the inside grows smaller through the evaporation of the water. Compare this with what is happening in the earth. (2) Find out how the tire of a wagon wheel is put on, and why it fits so tight. (3) Get a metal rod, and have a thick metal ring made just too small to fit over it. Heat the ring red-hot and see if it goes over the rod. Have another ring made to fit the rod exactly. Heat the rod and see if the ring will go over it. What does this show? (4) See suggestion for covering a ball, given on page 99. (5) It is not very difficult to make an apparatus for imitating the folding of rocks. Of one-inch boards make a long, narrow box, say 2 feet long, 5 inches wide, and 8 inches deep, open at one end and the top. Place four or five thin layers of wax, differently colored, on the bottom. At the open end apply slow, steady pressure, best obtained by using a screw, like that which sets a vise, fastened to a board that just fits into the end of the box. Before applying the pressure, place over the wax layers enough of shot to nearly fill the box. After pushing the layers a few inches, remove the shot, unscrew one side, and the layers will show folding. A simpler experiment may be made by taking a series of pieces of thick cloth and felt, cutting them to the same size, and pressing them up with the hand. (6) Is your home among mountains, or have you ever been among mountains? What is the nature and position of the rocks? Do the mountains rise above the timber line? Are they young, mature, or old? Are they well settled? Why? Are there forests? Mineral? Are they resorted to in summer? Why?

Reference Books. — KING, *Mountaineering in the Sierra Nevada*, Scribner's Sons, New York, 1902, $1.50; LUBBOCK, *Scenery of Switzerland*, Macmillan Co., New York, 1896, $1.50; RUSSELL, *Southern Oregon*, 4th Annual U. S. Geological Survey, p. 435; TARR, *Physical Geography of New York State*, Chapter III, Macmillan Co., New York, 1902, $3.50; HAYES, *Physiography of the Chattanooga District*, Part II, 19th Annual U. S. Geological Survey, p. 9; WILLIS, *The Northern Appalachians*, *National Geographic Monographs*, American Book Co., New York, 1895, $2.50; HAYES, *The Southern Appalachians*, same; WILLIS, *Mechanics of Appalachian Structure*, Part II, 13th Annual U. S. Geological Survey, p. 217.