CHAPTER IV.

RIVERS AND RIVER VALLEYS.

30. Supply of Water. — Part of the rain water returns to the air by evaporation, part sinks into the ground, and part runs off. That portion which passes back to the air need not be considered here. Most of that which sinks into the ground (p. 39), eventually returns to the surface by slow seepage and from springs. It may continue for months on its slow underground journey before finding conditions that favor its return to the surface. Were it not for this steady source of supply, after each rain rivers would quickly dry up. Then river navigation would be stopped, river water power would frequently fail, and the water supply of many cities would be cut off for a large part of the time.

From a third to a fourth of the rain water runs off at the surface. Therefore every rain swells the volume of the streams, adding greatly to the steady supply from underground. When the snow melts or the rains are heavy, the rivers may be quickly transformed to raging torrents (Figs. 60, 61).

The presence of the forest tends to reduce floods. Its dense undergrowth, the mat of decaying vegetation, and the tangle of roots seriously interfere with the run off of the water. There is a greater run off (1) during heavy rains than during long, slow drizzles; (2) on clay soils than on sandy soils; (3) on frozen soils than on those with no frost.

Some rivers have their water supply regulated. This is true of those whose supply comes chiefly from large and copious springs (p. 59). Lakes act as regulating reservoirs, out of which streams flow with little change in volume; thus the volume of Niagara is almost always the same. Swamps also help to regulate the water

FIG. 60. — A waterfall in a dry summer, when even the underground supply was limited (a part of the water has been led off for use in a mill).

FIG. 61. — The same as Fig. 60 after a heavy rain.

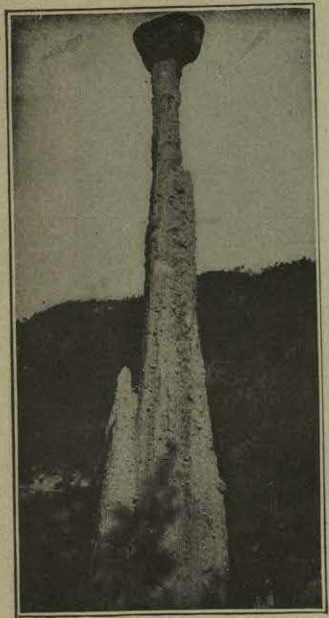

FIG. 62. — A rain-sculptured earth column in the Tyrol of Austria. The bowlder which caps it helps to protect the clay beneath.

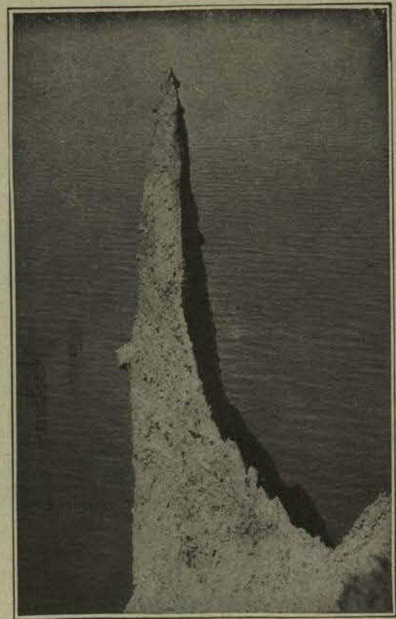

FIG. 63. — A rain-sculptured column in a clay cliff on the shore of Lake Ontario, in New York.

FIG. 64. — A view in the Bad Lands of South Dakota, where, as far as one can see, the surface is rain-sculptured.

supply. Glaciers regulate the flow of many mountain streams; but the melting in summer greatly increases their volume.

Summary. — *Underground water gives to streams a steady supply; the rains and melting snows increase their volume. The forest, nature of the rain, soils, and frost influence the run off. Springs, lakes, swamps, and glaciers tend to regulate the volume of rivers.*

31. Rain Sculpturing. — The surface of a road or a plowed field is often gullied by the washing action of rains and rain-born rills. The material removed is carried on toward the larger streams. In moist countries (Figs. 62, 63) this rain sculpturing is not usually so noticeable as in arid regions where there is little vegetation to protect the soil. Loose clayey soils are deeply gullied by the occasional heavy rains of arid regions; but there is so little weathering that the steep slopes are not greatly rounded. Such rain-sculptured lands are known as *Bad Lands*, one of the largest sections being in South Dakota (Fig. 64). They are unfit for agriculture, and even for cattle raising. Where the forest has been cleared for centuries, as in parts of Greece and Italy, rain sculpturing has destroyed much farm land.

Summary. — *In arid lands, and where the forest has been removed, the land is sometimes so gullied by rain sculpturing as to unfit it for agriculture. In the West such regions are known as Bad Lands.*

32. The Rock Load of Rivers. — To the mineral load which is brought in solution by underground water (p. 39) is added some which the river water dissolves from its bed. This dissolved load is sometimes very noticeable, as when river water is "hard," or, as in southwestern United States, even salt or alkaline.

Fragments of rock, loosened by weathering (Figs. 57, 66), or washed in by the rain, are also carried by rivers. Water buoys up these suspended rock fragments so that they lose about one third of their weight. A current moving at the rate of one and a half or two miles an hour, that is about half as fast as a man walks, will transport small pebbles; one moving a quarter of a mile an hour carries only clay. In

Fig. 65. — Four diagrams to illustrate valley broadening by lateral swinging.

mountain torrents bowlders weighing hundreds of pounds are swept along; but only sand and clay can be moved over level lowlands.

These rock fragments are used as tools of erosion. The grinding of pebbles together rounds them and gradually wears them down to sand and clay; and the river bed is also worn away, or eroded, by the grinding of these fragments against it.

The load which rivers bear may be judged from the following. The Mississippi River annually carries to the sea 7,500,000,000 cubic feet of sediment. This would make a prism one mile square at the base and 268 feet high. It also carries 2,850,000,000 cubic feet of mineral matter in solution. Other rivers are bearing similar loads. From this it is evident that rivers are performing a great task in removing rock waste from the lands.

Summary. — *Rivers bear great loads of minerals in solution; also rock fragments, whose size varies with the velocity of the currents. These are used as tools of erosion.*

33. Erosive Work of Rivers. — Rivers aid in lowering the land by removing the materials supplied by weathering and by rain wash. At some time in their history most of them are also at work in a vigorous attack on their channels. This work is both chemical (corrosive) and mechanical (corrasive), and it results in the formation of river valleys.

Streams cut their banks (Figs. 69, 70) as well as their beds. This lateral cutting causes the valley to be broader than the river itself (Figs. 65, 67). This is especially true where

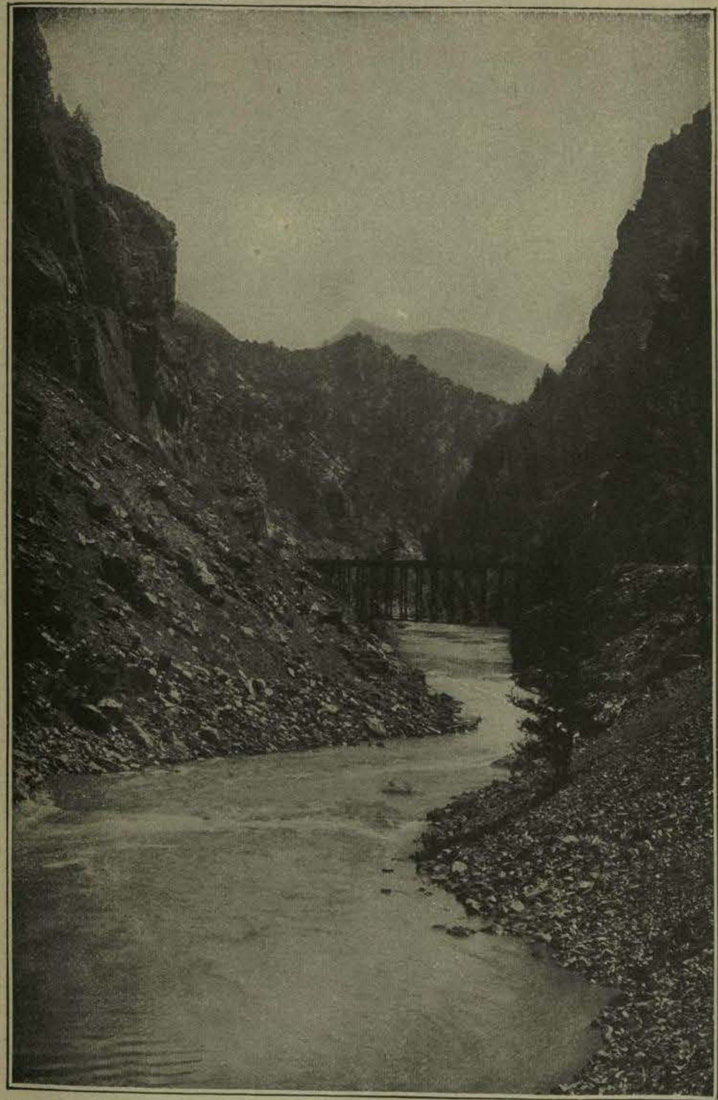

Fig. 66. — The Gunnison River, Colorado. Rock fragments from the cliffs have made a talus, which, sliding into the river, supplies it with tools for work (see also Fig. 57). A railway follows this narrow valley, one of its bridges being seen in the distance. To pass along this gorge it has to wind about, crossing the stream by bridges and tunneling the rocks.

FIG. 67.—A narrow gorge (Enfield) in central New York. One wall of a pot hole is seen in the foreground on the left. The stream course is here guided by two joint planes which cause the smooth, straight walls between which the water is flowing.

FIG. 68.—Ice in the same fall as Figs. 60 and 61.

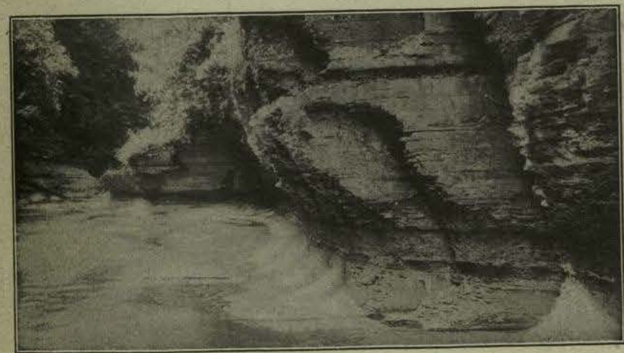

FIG. 69.—A stream swinging against and undercutting a shale cliff, showing lateral erosion in a gorge where the stream is also rapidly deepening its bed.

FIG. 70.—Lateral swinging of a stream against a clay bank, which is caused to slide into the stream. In this way the valley is being broadened.

FIG. 71. — Watkins Glen in central New York. A small stream is cutting this gorge deeper. It is a succession of rapids and cascades, at the base of which pot holes are being cut in the shale. One fairly large pot hole appears in the near foreground; others are seen farther upstream.

the river swings against loose material which slides into the stream (Fig. 70).

The rate of valley deepening varies greatly according to the rock, the slope, and the volume. A stream naturally cuts faster in soft than in hard rock; on steep slopes than on gentle slopes; with great volume than with small volume. The effect of difference in volume may be seen in many streams, which at ordinary times do little work of erosion, but when in flood become powerful erosive agents (Fig. 61).

Since sediment supplies rivers with cutting tools, this also has an important effect on river erosion. When there is little sediment, erosion is greatly reduced. For example, Niagara River emerges from Lake Erie as clear water, the sediment having been deposited in the lake. Therefore, down to the Falls, the river has been able to do very little toward cutting a valley (Fig. 483). The Colorado River, on the other hand, with a heavy load of sediment, has cut an enormous canyon (Figs. 1, 477), which it is still rapidly deepening.

Other rivers, like the lower Mississippi, have more sediment than they can carry, and must deposit some of it, building up their beds. Rivers that are deepening their valleys are said to be *degrading* (Fig. 71), those that are building up their beds are *aggrading* their valleys (Fig. 112).

Joint planes also influence the rate of erosion, and sometimes direct the course of a stream (Fig. 67). Ice (Fig. 68) is likewise of importance. In winter it diminishes the supply of water; but in spring its melting adds to the floods; and it pries and breaks off fragments of the rock and carries them along.

Summary. — *Rivers cut vertically on their beds, and laterally at their banks, the rate varying with the rock, slope, volume, and sediment supply. Some rivers are aggrading, others degrading, their valleys. Joint planes and ice also influence river work.*

34. Waterfalls. — When a stream is degrading its bed, conditions are often discovered which cause the formation of rapids and falls. Most commonly it is a difference in hardness of the strata. Soft rocks are cut more rapidly than hard, and therefore rapids and falls occur where a degrading stream flows from a hard to a soft layer. Such falls are very common in regions of horizontal strata, where hard layers (Fig. 72) retard erosion while weaker layers beneath are removed. This undermines the hard layer, and when a piece breaks off, the fall retreats upstream (Fig. 75), always being located on the steep edge of the hard stratum (Fig. 74). There are thousands of illustrations of this, of which Niagara, located on a hard layer of limestone (Fig. 482), is the largest and best.

Falls and rapids cause streams to concentrate their energy in spots. This is well illustrated by Niagara, where the falling water has excavated a deep hole at the base of the fall. Similar holes, called *pot holes* (Figs. 67, 71, 73), are common in streams that are degrading their beds. They are enlarged and deepened by the whirl of water, which carries pebbles about with it. Pot-hole work is an important factor in the excavation of valleys.

Waterfalls and rapids are of great importance in supplying power, the water being led through canals or pipes and allowed to fall upon a wheel which turns machinery. Now that electricity is used for power, falls are of value even in sparsely settled regions. Niagara Falls power, transmitted by wire, lights and runs the cars of Buffalo; falls in the Alps and Sierra Nevada supply electric power for places miles away.

Summary. — *Falls and rapids, of use for water power, are common where a degrading stream flows from a hard to a soft stratum, as at Niagara. Pot holes are excavated by the falling water.*

LIFE HISTORY OF A RIVER VALLEY

A river valley, like an animal or plant, changes as it grows older. To understand these changes, or the life history of a river, it seems best to start with simple conditions — a plain of moderate elevation, with nearly horizontal strata,

FIG. 72. — A hard layer of rock in a stream bed. When the water is higher there is a fall here, and the falling water removes the softer layer from beneath, undermining the hard stratum.

FIG. 73. — The man is standing in a pot hole. In the bottom there are small round stones which the water whirls about, grinding out the rock and thus deepening and enlarging the hole.

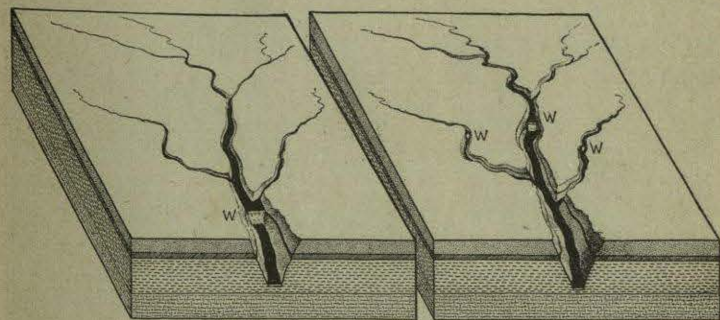

FIG. 74. — Two diagrams to illustrate the history of a waterfall. In the left hand figure a hard stratum (the darkest) has a waterfall (W) over its edge. As the falling water undermines this hard stratum the fall retreats upstream, always being located on the hard layer. At a later stage, therefore (right hand figure), the fall is farther upstream; and falls are also present on the same layer in two tributaries. The stream erosion has formed a deep gorge below the fall, as in the case of Niagara.

FIG. 75. — Taughannock Falls near Ithaca, New York, 220 feet high. The angles and smooth rock faces near the upper part, and the angle in the crest of the fall, are caused by joint planes. A few years ago a huge block fell from the crest of the fall, giving its present shape; before that, the crest of the fall projected downstream.

and a moist climate. Later study will show that many rivers depart from such an ideally simple condition; but these variations will be better understood if we first study a simple case. Such a study will reveal some important laws of valley formation.

35. Young Stream Valleys. — On such a plain as that just described the drainage is at first somewhat indefinite. Water fills the depressions in the plain, forming shallow lakes; and large expanses of the level plain form flat-topped divides, often swampy, because there has not been time enough for many tributaries to develop. Wherever water runs off, it flows in consequence of the original slope, or has a *consequent course*. Florida (Figs. 78, 79) has such a condition of drainage.

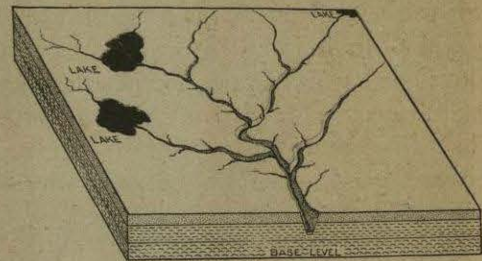

FIG. 76. — A young stream valley on a plain. It is still well above base level; the divides are flat-topped; there are few tributaries; and lakes still exist.

The consequent streams quickly cut into the plain, forming narrow, steep-sided valleys (Fig. 76). As they degrade along their beds they discover differences in hardness of the strata, and therefore develop falls (Fig. 74) and rapids. At the same time weathering and meandering slightly widen the valley.

There is a limit below which no part of a stream may deepen its bed, and this is called its *base level* (Fig. 81). The sea is the permanent base level, and the down-cutting of every stream that enters the sea is arrested by it. Lakes act as temporary base levels; but their effect does not last long, because the sediment that the streams bring, quickly fills and destroys them (p. 164).

While the lakes are being filled and the valleys deepened, tributaries are developing. Little by little the tributary streams gnaw their way back from the main stream, narrowing the flat-topped divides and in time draining the level, swampy areas.

A stream with these characteristics — steep-sided valleys, waterfalls, lakes, illy defined divides, and tributaries only partly developed — is a *young stream.* It has not had long to work, and consequently its valley is not thoroughly developed; it is still growing. A young stream is better developed in its lower portion than above, as a young tree has a thick, strong trunk and delicate, growing branches. The Niagara Gorge (Fig. 483) and Colorado Canyon (Fig. 1) are good examples of young stream valleys (see also Figs. 77, 80); but no lakes remain in the course of the Colorado.

Although such valleys are young, the time required to perform even this much work is long, measured in years. A river may have been working for 5000 or even 50,000 years, and yet have a valley with the characteristics of youth. As in the case of plants, some of which grow old in a few days while others require weeks or even years, so in river valleys there is a great difference, under different circumstances, in the time required to pass the stage of youth. Yet in all cases the features of youth are so distinct that a young valley is hardly more difficult to distinguish than a young plant.

Summary. — *A young river is one that has not had a long time for development. It, therefore, has a steep-sided valley, few tributaries, indefinite divides, and, if conditions favor, waterfalls and lakes. The term "youth" does not refer to years, but, as in plants, to form.*

36. The Grade of a Stream. — The lowest grade to which a stream can cut its channel is one down which it is just able to carry its sediment load. The grade line is a curve, reaching base level at the river mouth and rising rapidly near the divide (Fig. 81). All streams that have not reached grade are working toward it, and young streams, which have a

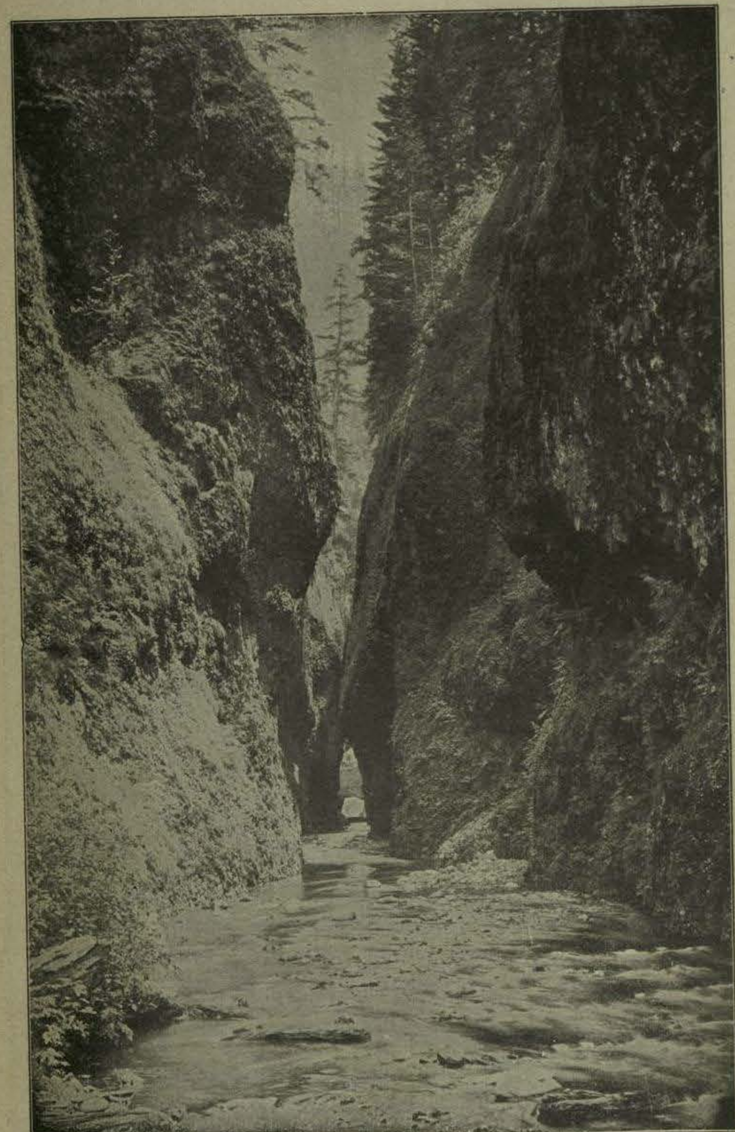

Fig. 77. — Narrow gorge of a young stream cut in hard rock. Even here the valley has been widened somewhat by meandering and by weathering. The latter cause accounts for the breadth of the gorge at the top.