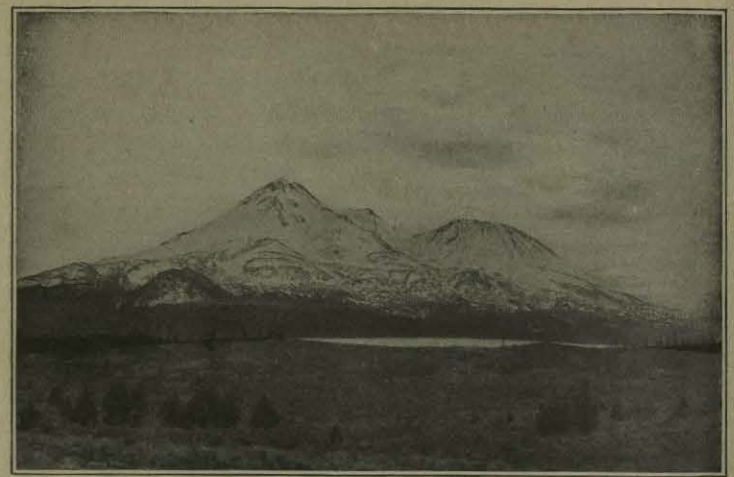

FIG. 214. — Mt. Shasta, California. On the right is Shastina, a newer cone on the flanks of the main volcano. Both these cones are extinct; but Shastina still has a crater, while the crater of Shasta has been destroyed by denudation.

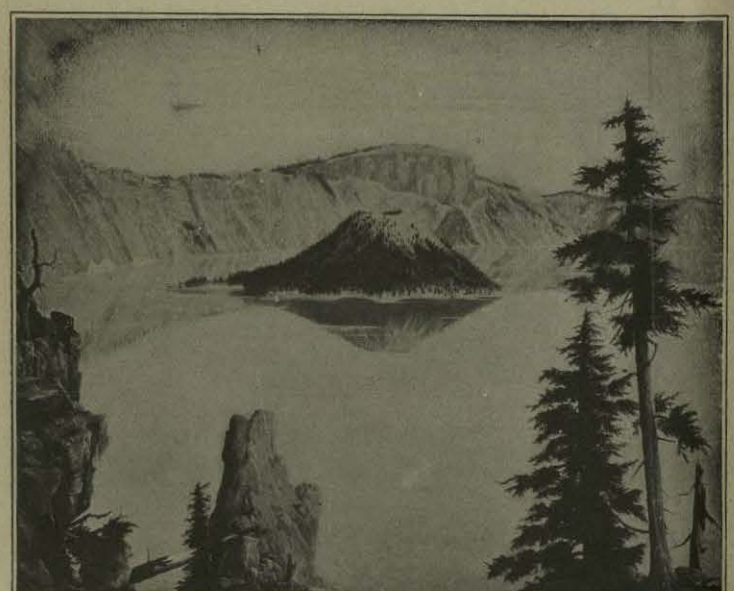

FIG. 215. — Crater Lake, Oregon, the deepest lake in North America. The little island, called Wizard Island, is a cone built up from the bottom of the crater since it collapsed.

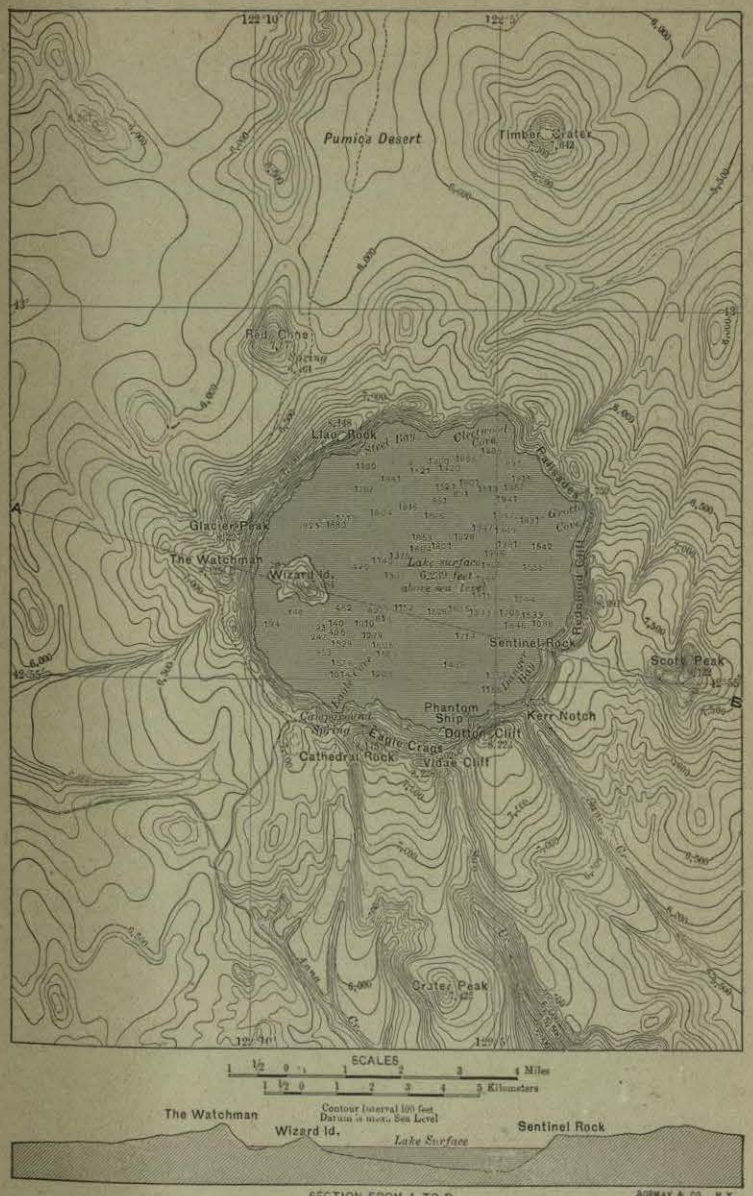

FIG. 216. — Topographic map of Crater Lake. Notice the other smaller craters and cones near by. A section through the mountain, along the line *AB*, is shown at the bottom. (Crater Lake Special Sheet, U. S. Geological Survey Topographic Map.)

FIG. 217. — Flowing lava in Hawaii, 1881.

FIG. 218. — Lava cascade, similar to the above, with the lava cooled.

An earthquake shock accompanies the opening of the fissure, and huge volumes of steam rise from the glowing lava that rushes forth. At first the lava flows rapidly down the mountain side; but it soon cools and solidifies at the surface (Figs. 217, 218). Then the movement becomes much slower. The frozen crust is broken and rolled along by the movement of the lava beneath, and liquid lava may burst through the solid front at any point. The lava front advances for weeks, always more and more slowly, and years may pass before it entirely cools.

Summary. — *Hawaii, the greatest volcanic mountain in the world, has two active volcanoes with huge craters, or calderas. In these are lava lakes which steadily rise, once in about seven years being drained through fissures in the mountain sides. The lava at first flows rapidly; but, as it cools on the surface, its rate of flow is checked.*

87. Mt. Shasta and Lassen Peak. — This extinct volcano (Fig. 214), whose elevation is over 14,000 feet, resembles Etna in form. From its snow-covered top small glaciers descend into the higher valleys, and on its flanks is a later cone.

South of Shasta is the extinct cone of Lassen Peak, and near its base an ash cone about 650 feet high (Fig. 235). The size of trees that have grown in the ash indicates that it was erupted about 200 years ago. A still later lava eruption has dammed a stream, forming Snag Lake, in which are snags of trees killed by the rise of the water. It seems probable that this lava flow is not much over a century old. There are other recent lava flows in various parts of the West.

Summary. — *Shasta is a lofty extinct volcano; but at Lassen Peak, near its base, there have been recent eruptions of ash and lava.*

88. Crater Lake. — Another extinct volcano in western United States is occupied by Crater Lake in Oregon. This lake, which is about 2000 feet deep, lies in a huge crater, or caldera (Fig. 216), between 3000 and 4000 feet in depth, and about 6 miles in diameter. It has been proved that a lofty volcano (Fig. 219) rose where the caldera now stands. The removal of lava from

beneath the cone allowed it to collapse, forming the caldera, in which a later eruption has built a small ash cone (Fig. 215).

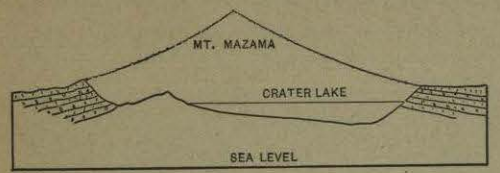

FIG. 219. — Section of Crater Lake, with the old cone, named Mt. Mazama, restored by the dotted line.

Summary. — *Crater Lake occupies a huge crater, or caldera, formed by the draining off of lava from beneath, causing the cone to collapse.*

89. Materials Erupted. — Every volcanic eruption is accompanied by vast quantities of steam, and smaller amounts of sulphurous and other gases. These gases are commonly called "smoke," and the glow of light reflected from the melted lava is popularly termed "flame."

If the eruption is moderate, melted rock usually flows out, and, in cooling, forms *lava flows* (Figs. 217, 218). Expansion of steam in the pasty lava makes many small rounded cavities, especially near the top; and the surface is broken by the movement of the lava after a crust has been formed. In violent eruptions the expansion of the steam blows the lava to pieces, forming *scoria*, *pumice*, and *ash*. These are so light and porous that they float in water, and the fine ash even remains suspended in the air.

Lumps of lava thrown into the air, cooling in oval, twisted masses, are known as *volcanic bombs* (Fig. 236). They vary from a few inches to many feet in diameter. During eruptions the condensation of the steam causes heavy rains, accompanied by vivid lightning. The rain often washes down much loose ash, forming *mud flows*.

Summary. — *Steam and other gases accompany all volcanic eruptions. Lava comes from moderate eruptions; ash, pumice, and scoria from violent ones. Volcanic bombs are also thrown out; and rains wash down the ash, forming mud flows.*

90. The Forms of Volcanic Cones. — A volcano is a conical peak with a crater at the top. If the eruptions are of ash the cone is steep, because the fragments that fall back near the vent have a slope as steep as loose ash will stand (Fig. 221). On the other hand, cones made of flowing lava are broad and have a low slope (Fig. 221). (Compare Figs. 223 and 224.)

One reason for these differences is that lava flows away as a liquid; another, that some of it starts, not from the top, but from fissures on the slopes of the cone (Figs. 210, 211); and a third that it all remains on the cone, while in ash volcanoes a large part is drifted away by the winds. When the material is now ash, now lava, as in Vesuvius, the cone has a slope intermediate between that of lava and ash.

The crater of a volcano may be so large, perhaps from one to five miles in diameter, as to deserve the name *caldera*. In addition to the calderas of the Hawaiian Islands (p. 120) and Crater Lake (p. 121), there are calderas in Italy, the Eifel district of Germany (Fig. 225), and other places. The craters on the moon (Fig. 14) are enormous calderas. Calderas may be caused either by collapse of the cone, or by violent explosions which blow the top of the cone away. In some cases, as in Krakatoa (Fig. 220), explosions wreck the cone and make it irregular.

Summary. — *Ash cones have a steep slope, while lava cones are broader and more gentle in slope. Cones consisting of both ash and lava have a slope between the two. Calderas are huge craters caused either by the collapse or by the blowing away of the tops of cones.*

91. Distribution of Volcanoes. — There are thousands of volcanic cones, only about 300 of which are known to be active. The great majority of these cones are in or near the sea, far the greatest number being in the mountains and islands which partly encircle the Pacific Ocean (Fig. 222).

The many lofty cones in the Andes, Central America, and southern Mexico are in this belt. Associated with it is the volcanic belt of the Lesser Antilles, 500 miles long, in which Mont

Pelé and La Soufrière are situated. Most of the islands of the Lesser Antilles are volcanic. From Mexico northward, through western United States, are hundreds of volcanic cones, all either dormant or extinct. Among the best known of these are Mt. Ranier, Mt. Shasta, Mt. St. Helens, and Mt. Hood.

The Aleutian Islands, which inclose Bering Sea, form a volcanic chain 1600 miles long, including 57 volcanoes, some of which are very vigorous. From Kamchatka southward, along the Kurile, Japanese, and Philippine islands, there is another great chain of volcanoes. The East Indies have numerous active cones, and this chain swings down to New Zealand.

Practically all the small islands of the open Pacific and Indian oceans are volcanoes. Even the coral atolls are volcanic cones with a veneer of coral.

There are volcanic areas in the continents of Europe, Asia, and Africa, including a line extending from central Africa to Asia Minor; also Mt. Ararat; volcanoes in the Caucasus Mountains; and a number in the Mediterranean near Greece, and in and near Italy.

The islands of the open Atlantic are volcanic, and some of them are active. Iceland has a number of volcanoes, some of which have had terrific eruptions. The Faroe Islands are ancient volcanoes, and there were formerly volcanoes in the British Isles. In the Azores Islands, which are all volcanic, there are hundreds of cones (Fig. 226), some of which were in eruption during the last century. The Bermuda islands are a coral group on a volcanic cone. The Cape Verde, Canary, and other islands farther south, including St. Helena, the prison home of Napoleon, are all volcanoes.

In spite of the great numbers of cones, they are really exceptional land forms. By far the greater part of the earth's surface is now free from volcanic action; and large areas have never been disturbed by eruptions. In other places, as in eastern United States, central France (Fig. 227), and the British Isles, volcanic action long ago died out. Both at the present time and in the past, volcanic activity has been associated with mountain growth.

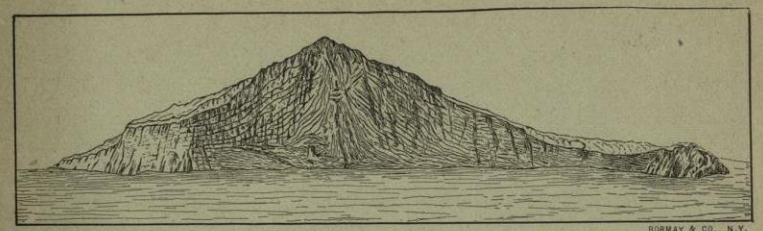

FIG. 220. — The half of Krakatoa left after the eruption.

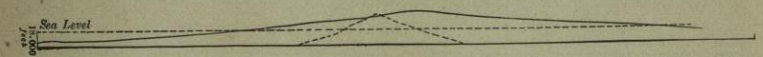

FIG. 221. — The slopes of two volcanoes, one ash (dotted), the other lava. The latter, represented by the continuous line, may be considered to be Mauna Loa. Not only is the ash cone steeper, but it contains much less material, because so much has been drifted away by winds and ocean currents. See also Figs. 223, 224.

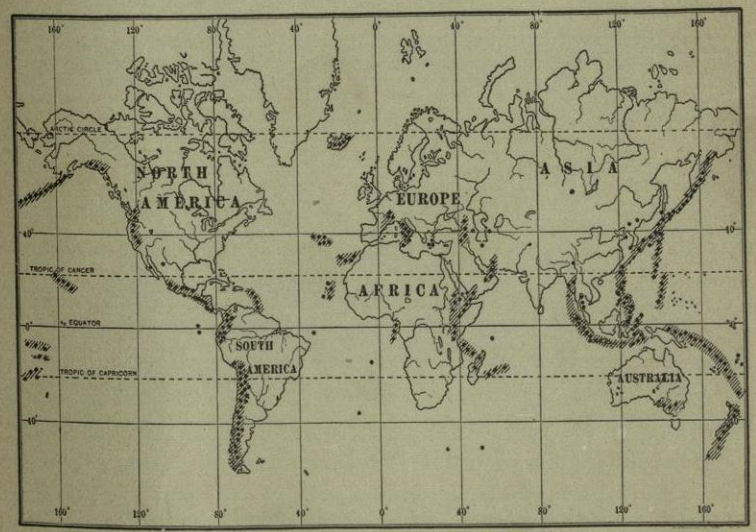

FIG. 222. — The distribution of volcanoes. The shaded sections show the main areas, and the dots locate some of the active or recently extinct volcanoes.

FIG. 223. — Chimborazo, Ecuador, 20,500 feet high; so high that, though under the equator, it is snow-covered.

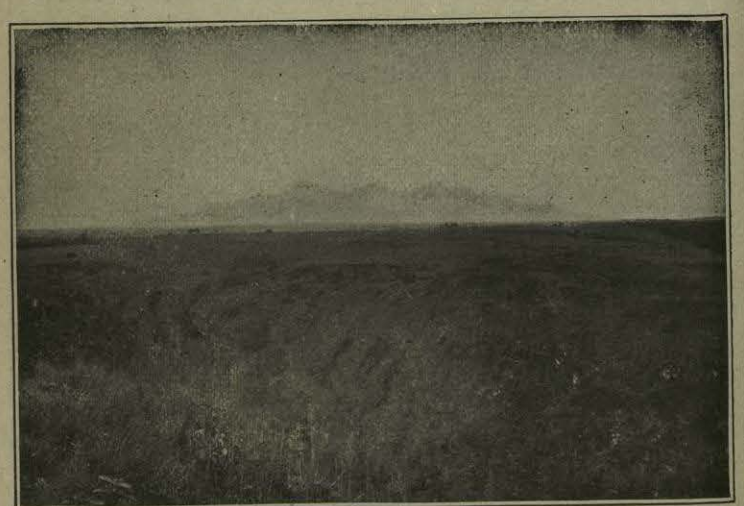

FIG. 224. — A volcanic lava cone in the Hawaiian Islands. Compare its low slope with that of Chimborazo. See also Fig. 221.

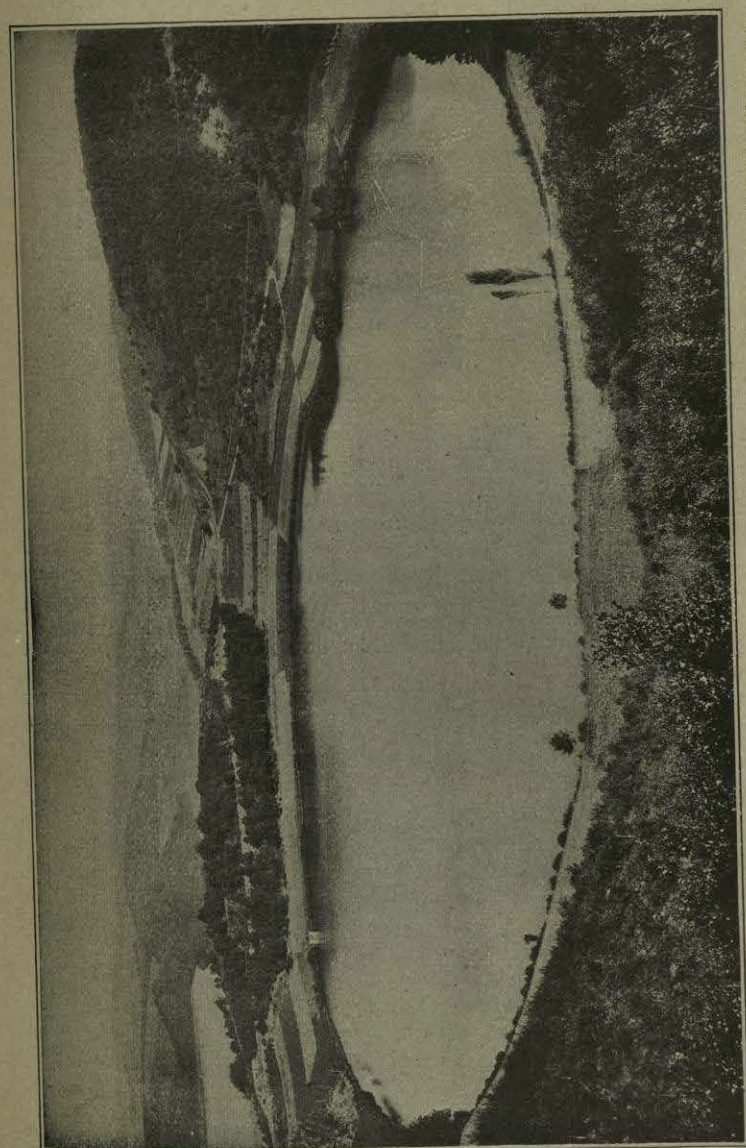

FIG. 225. — Caldera in the Eifel region of Germany. This is a region of extinct volcanoes; but they have become so recently extinct that lakes still occupy their craters.

FIG. 226. — A volcanic cone in the Azores. It is so recent that it has a perfect crater. The stone walls by the roadside are made of lava blocks.

FIG. 227. — Volcanic peaks in the Auvergne region, a volcanic region in central France. The peaks on which the buildings are situated are remnants, or necks, of volcanoes partly destroyed by denudation.

Summary. — *The majority of volcanoes are in or near the sea, the greatest belt being in the chain of mountains and islands which partly encircle the Pacific. There are many volcanic islands in the open Pacific, Indian, and Atlantic oceans, and in the Mediterranean. Volcanoes are exceptional land forms. They have never been present in some places and have become extinct in others.*

92. Cause of Volcanoes. — The immediate cause for a volcanic eruption is undoubtedly the explosive force of pent-up steam. It is believed that this steam is caused by water that percolates down to the melted rock. As it slowly accumulates, it finally gains force enough to push its way to the surface and carry some of the melted rock with it.

It is probable that the folding of the mountain rocks squeezes the lava upward until it reaches places so near the surface that water is able to enter it and force it the rest of the way. Faults formed during mountain growth furnish pathways for the rise of this lava.

When mountains stop growing, volcanic activity dies out. For this reason western United States, which in the last geological period was a region of intense volcanic activity, is now almost, if not quite, free from active volcanoes. There may yet be eruptions in the West; but unless there is a renewal of mountain growth, these eruptions will probably not be numerous.

Summary. — *Water, descending from the surface, comes in contact with melted rock, probably squeezed upward during mountain folding. This forms steam and forces the lava to the surface, often along faults. When mountain growth ceases, volcanic activity dies out.*

93. Lava Floods. — In western United States, in addition to volcanoes, there were great lava floods which escaped from fissures and deluged the surrounding country. They were perhaps squeezed out as a result of mountain growth, somewhat as water rises through a crack in the ice of a frozen pond. The greatest of these floods was in the valley of the Snake and Columbia rivers (Fig. 476), mainly in Oregon,

Idaho, and Washington, where an area of fully 200,000 square miles is covered with lava. By these lava floods, which extended up valleys and surrounded mountains, as lake water does, an irregular land surface was changed to a great lava plateau. Deep canyons show a depth of 3000 to 4000 feet of lava, layer on layer. In some places, as in the Cascade Ranges, blocks of this lava have been broken and tilted to form mountains.

Throughout the Far West there are other instances of lava floods, for example, in the Yellowstone Park. Similar floods have been formed in other parts of the world, as the plateau of the Deccan in India, which in extent rivals the Columbia lava plateau.

At present such lava floods are nowhere issuing from the earth. The nearest approach is in Iceland, where lava, welling from fissures, has built a broad plateau. When such a fissure is partly closed, leaving only one or two places for the lava to escape, volcanic cones are built along it. This accounts for some of the chains of volcanic cones.

Summary. — *Great lava floods, rising through fissures, and perhaps squeezed out by mountain growth, have deluged large areas of country in western United States and other regions. Iceland has the nearest approach to this condition at present. The closing of most of a fissure allows the formation of a line of volcanic cones.*

94. Lava Intrusions. — Not all the lava that starts toward the surface reaches it. For example, when eruptions cease, the vent of a volcano becomes filled with solid lava. This is called the *volcanic neck* or *plug* (Figs. 34, 227, 231). The long, narrow sheets filling the fissures, through which lava escapes on the flanks of a volcano, are called *dikes* (Fig. 34). In the neighborhood of volcanoes, similar dikes are intruded into the rocks (Fig. 232) deep in the earth. These and other forms of intruded rocks are brought to light by denudation.

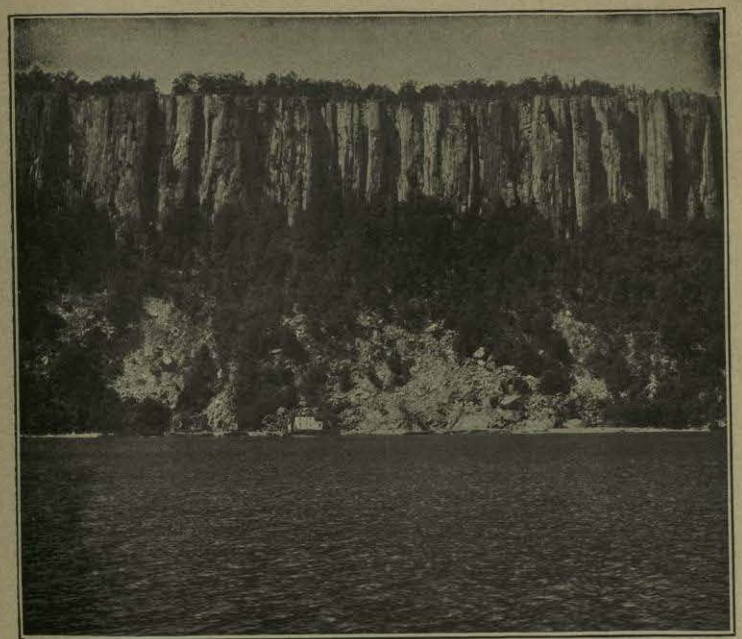

FIG. 228. — Intruded lava sheet forming the Palisades of the Hudson. Notice the columnar appearance due to jointing. (See Fig. 230.)

FIG. 229. — Mt. Tom, Massachusetts, a ridge formed by a sheet of lava that was intruded into the sandstone strata several geological ages ago, then tilted and worn into its present mountain form.

FIG. 230. — Columns caused by the jointing of an ancient sheet of lava at Giant's Causeway, Ireland. The columnar jointing is the result of the breaking of the lava as it cooled. (See Fig. 228.)

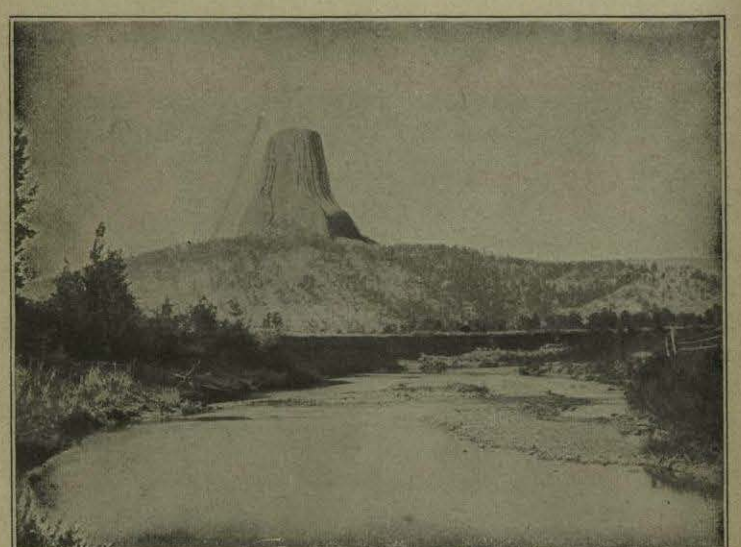

FIG. 231. — Mato Tepee, Wyoming, a volcanic neck or plug. All the other material has been removed by denudation, leaving the hard lava plug standing above the surrounding country. (See also Fig. 227.)

Sheets of lava have been intruded between strata (Fig. 34). Such intruded *sheets* or *sills* frequently have a well-developed jointing, which causes them to break in columns, usually with five or six sides (Fig. 230). The Palisades of the Hudson (Fig. 228), Mts. Tom (Fig. 229) and Holyoke, Massachusetts, East and West Rocks at New Haven, Connecticut, the trap mountains near Orange, New Jersey, and the lava sheets in many other regions have reached their position by intrusion into the strata.

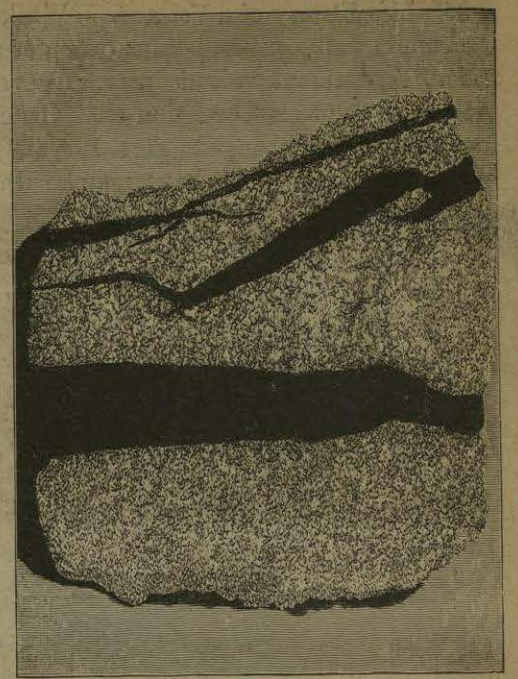

FIG. 232. — Dikes (black) crossing a granite rock.

A large mass of intruded lava which raises the strata to form a dome is called a *laccolith*, or rock lake (Figs. 164, 233). Irregular masses of intruded lava form *bosses* (Fig. 34), often made of granite. These are found in the cores of old, worn-down mountains, as in the Adirondacks, New England, Scotland, and Norway.

FIG. 233. — Ideal section through a laccolith (see also Fig. 164).

Summary. — *Various forms of intruded igneous rocks — necks, dikes, sheets, laccoliths, and bosses — are caused by the rising of lava that does not reach the surface. The wearing down of the surface by denudation brings these intruded lava masses to view.*