DESCRIPTION OF THE LASSEN PEAK SHEET.

GEOGRAPHY.

GENERAL RELATIONS.

The Lassen Peak district is situated in northern California, between the Sacramento Valley and the Great Basin, and adjoins the northern end of the Sierra Nevada. It is bounded by the 121st and 122d meridians and the 40th and 41st parallels. The district is 68.99 miles long; its mean width is 52.68 miles; its area, 3,634.4 square miles.

Along the Pacific Coast of the United States there are three mountain ranges, the Coast Range, the Cascade Range, and the Sierra Nevada. The Great Valley of California separates the Coast Range from the Sierra Nevada in the south, and the valley of the Willamette separates the Coast and Cascade ranges in the north. In the intermediate district of northwestern California and southwestern Oregon the adjoining portions of these ranges appear to be united into one group—the Klamath Mountains. The Klamath Mountains really belong to the Coast Range. The name is here used in a general sense to include all those ridges and peaks which are locally known as Yallo Bally, Bully Choop, Pit River, Grizzly, Trinity, South Fork, Salmon, Marble, Scott, Siskiyou, and Rogue River mountains.

Lassen Peak marks the southern terminus of the Cascade Range and fills a great depression in the auriferous slates between the Klamath Mountains and the northern end of the Sierra Nevada. It is wholly of volcanic origin, and thus, from a geologic point of view, it is like the summits in the long line of extinct volcanoes extending from Mount Shasta to Mount Rainier.

The geographic features enumerated above are not all of the same geologic age. Some were dry land while others were beneath the sea, and still others were built up in later ages by accumulating lavas. The geographic history of the region must be read in the geologic records—the rocks of which the mountains are composed.

TOPOGRAPHY.

Within the district there are three distinct types of physiographic features. Beginning at the west, it includes (1) a small portion of the eastern border of the Sacramento Valley, ranging in altitude, with gentle slope, from 800 to 4,000 feet; (2) the Lassen Peak volcanic ridge, whose highest summit (Lassen Peak) is 10,437 feet above the sea; and (3), upon the east, a portion of the Great Basin platform, with an average elevation of about 5,600 feet.

The included border of the Sacramento Valley consists chiefly of a dry, stony plain, across which the streams from the Lassen Peak volcanic ridge cut deep canyons on their way to the Sacramento. The plain is widest and the canyons are deepest south, southwest, and west of Belle Mill. The lower border of the plain is marked by a well-defined bluff a few miles east of the river. At this bluff the canyons end abruptly and the streams emerge from them upon the alluvial plains of the Sacramento. Northward the stony plain continues to near Pit River, but it is not so well defined, for the valleys of the mountain streams are broader and contain more arable land.

The Lassen Peak volcanic ridge is formed by a belt of volcanic cones about 25 miles in width and 50 miles in length, and extends northwest and southeast directly across the middle of the district from the North Fork of Feather River to the Great Bend of Pit River. Its great peaks, such as Butt Mountain, Lassen Peak, Crater Peak, Burney Butte, and those at the head of Burney Creek, as well as a host of smaller conical hills, are all ancient volcanoes. The lava which issued from the earth's interior through many volcanic chimneys within the district has formed a conical mountain or hill about each orifice. One of the most characteristic views of the ridge is seen from near Hat Creek, on the old emigrant road, looking northward towards Crater Mountain.

The Great Basin platform, which is the general level of the plains in the adjoining portions of California and Nevada, occupies the northeastern part of the district. Although mountainous, its differences of elevation are much less and the slopes are gentler than those in the Lassen Peak volcanic ridge. It extends from Susan River to Pit River, and its western border north of Lassen Peak is marked by Hat Creek Hill. The northern portion of this area is drained by Pit River, but the southeastern portion belongs to the Great Basin and drains into Honey Lake.

DESCRIPTIVE GEOLOGY.

Twenty-two geologic formations are shown upon the map. Thirteen of these were deposited as sedimentary rocks; the remaining nine are of igneous origin and were erupted in a molten condition. Some of the sedimentary rocks, especially the younger ones, including the first six of the legend, have not been materially changed in texture and composition since they were deposited and consolidated; but others, such as the auriferous slates, have been greatly altered or metamorphosed by crystallization and the development of schistosity. They contain veins of quartz and metalliferous deposits.

ALTERED SEDIMENTARY ROCKS (AURIFEROUS SLATES).

SILURIAN PERIOD.

Grizzly formation.—Within the area represented on the map the Grizzly formation is composed chiefly of slates, but in Mount Grizzly, near Taylorville, where the formation has its greatest development, there are besides slates both quartzite and limestone. The last is of special interest, as, being of Silurian age, it is the oldest fossiliferous rock yet discovered in northern California.

DEVONIAN PERIOD.

Arlington formation.—The Arlington formation is composed of the gray sandstone slates and conglomerates which extend into the district and form Arlington Heights and Hough's Peak. Fossils have not been found in this formation, but from the general relation of these rocks to the Carboniferous on the west and to the Silurian on the east, they are supposed to be of Devonian age.

CARBONIFEROUS PERIOD.

Calaveras formation.—The Calaveras formation is so named from its development in Calaveras County. In the Lassen Peak district it consists of comparatively small lenticular masses of quartzites, slates, and limestones, with occasional auriferous-quartz veins and considerable areas of gabbro and other intrusive rocks whose distribution has not been separately delineated. The limestone of this formation on the divide between Yellow and Mosquito creeks and just below Rich Bar on Indian Creek contains Lithostrotion, Fusulina, and other characteristic fossils of Carboniferous age. Other limestones are so fully crystalline that in most cases all traces of fossils have been obliterated. It is possible that some of the beds are older, and others may be younger, than the Carboniferous, and further study will probably lead to the subdivision of this broad belt. The rocks of this system are more widely distributed than any other yet recognized among the auriferous slates in northern California.

Robinson formation.—This formation can be traced with interruptions from Robinson's in Genesee Valley to Keddie Lake on the Keddie-Dyer Ridge, where it forms a long, narrow belt between masses of porphyrite. Like the same formation at Genesee, it is composed of siliceous beds with conglomerate, a purplish sandstone of volcanic material, and tuff containing round crinoid stems, Bryozoa, and other Carboniferous fossils.

JURATRIAS PERIOD.

Cedar formation.—The auriferous slates are all more or less metamorphosed rocks, chiefly of sedimentary origin, in which veins of auriferous quartz have been found. Within the district mapped upon the Lassen Peak sheet there are two areas of these slates: one at the northwest corner, along Pit River, and the other at the southeast corner, about the North Fork of Feather River. The Cedar formation occurs in both these areas. It is best exposed on Cedar Creek along the toll road between Redding and Round Mountain, where it is overlain by the Bend formation. Although there are slates and sandstones, with occasional traces of conglomerate, the principal stratum is limestone, which forms conspicuous ledges on the road a few miles west of Buzzard's Roost. This limestone is rich in fossils. Like the Hosselkus limestone of Genesee Valley, in Plumas County, it contains numerous pentagonal crinoid stems and small coiled shells like Arcestes, besides other fossils.

The Cedar formation has been recognized in the southeastern portion of the district, where it has been traced from Indian Creek across Rush Creek and the North Fork of Feather River and Mosquito Creek to the Humbug Valley region. Here, as on Cedar Creek, limestone forms an important stratum, and the Triassic fossils it contains show clearly that it is in the same horizon as the Hosselkus limestone and associated Triassic rocks of Genesee Valley.

Bend formation.—The Bend formation contains some limestone, but is composed chiefly of slates, sandstones, and conglomerates, and crops out along the western arm of the Great Bend of Pit River. Isolated areas of the limestone are exposed near the stage road, 1 mile west of Montgomery Creek, and the slates and sandstones form the upper part of the north slope of Cedar Creek 4 miles west of Round Mountain.

Belemnites, ammonites, and other fossils have been found at a number of places on both sides of Pit River and on the north side of Cedar Creek, and they are closely related to those found in the rocks of Mount Jura near Taylorville.

UNALTERED SEDIMENTARY ROCKS.

The unaltered sedimentary rocks rest upon the auriferous slates with conspicuous unconformity.

CRETACEOUS PERIOD.

Chico formation.—The rocks of this formation are chiefly soft, yellowish sandstones, but there is some conglomerate and shale. They have been seen on Chico, Deer, Mill, Bear, Cow, and Little Cow creeks, as well as at Tuscan Springs, and they extend beneath the Sacramento Valley.

Marine shells of many types have been found within all the areas of Chico rocks marked upon the map.

NEOCENE PERIOD.

Ione formation.—Near the western border of the Lassen Peak district and extending beneath the Sacramento Valley there is a series of feebly indurated conglomerates, sandstones, and shales which occasionally contain small deposits of coal. These beds appear to be continuous to the southward with the Ione formation. On Little Cow Creek the strata have yielded a Unio and a few plant fossils, of the age of the Auriferous gravels.

Auriferous gravels of ancient streams.—The deposits in the region of Lot's diggings and Dutch Hill are the principal occurrences of auriferous gravels in this area. They have all been mined, and the latter is said to have been rich. The gravel at Dutch Hill is about 1,000 feet above the North Fork of Feather River. At Lot's diggings, near the latitude of the 40th parallel, on the top of a high platform northwest of Spanish Peak, the gravel lies nearly 4,000 feet above the level of the river where it cuts across the range. It is evident that there has been a great change in the drainage of the country since these gravels were deposited.

Tuscan formation.—The Tuscan formation is composed wholly of fragmental material derived from the numerous volcanoes of the Lassen Peak district. Much of it is fine, clearly stratified, and properly called tuff, but a large part is an agglomerate of coarse and fine material intermingled. Most of the fragments are angular, but some beds are made up of pebbles well rounded by water action. It is best exposed in the canyons of Mill, Deer, and other creeks on their way from the mountains to the Sacramento Valley. At a number of points in the tuff there are sheets of lava.

PLEISTOCENE PERIOD.

Alluvium, infusorial earth, sand, and clay.—Along the courses of a number of streams in the Lassen Peak district there are places where the water was once slow-moving or stagnant and spread out in shallow lakes. Such areas are well illustrated by Dixie, Humbug, and Goose valleys, and also by Big Meadows. In these ancient lakes or swamps the gravel, sand, mud, infusorial earth, and vegetable matter accumulated upon the bottom and gradually raised it above the water level. In this way the excellent grass land of these areas was developed. Some of the areas are yet swamps—for example, the eastern arm of Big Meadows—but these are gradually filling up, and in the course of centuries, if nothing happens to change the present current of events, they will be converted into valuable grass lands.

Auriferous gravels of modern streams.—In the present bed of the North Fork of Feather River, Indian Creek, and Rush Creek there are deposits of gravel which are auriferous. This gravel was once rich in gold and has been extensively mined. At some localities it has been worked over a number of times and mining still continues. The gold of this gravel has been derived immediately from the auriferous slates or from the ancient gravel of the same region, and is still in process of slow accumulation.

IGNEOUS ROCKS.

By far the most abundant rocks of the Lassen Peak district are those of igneous origin. They are both intrusive and extrusive. The numerous volcanoes of the district have furnished a great variety of such rocks, which are distinguished chiefly by their structure, the proportion of silica they contain, and the minerals of which they are composed. The extrusive rocks range from basalts, having as low as 48 per cent of silica, through andesites and dacites to rhyolites, some of which contain over 74 per cent of silica. Among the intrusive rocks—diorite, peridotite, diabase, and porphyrite—the range in composition and structure is not as great, but their alteration is much greater.

Diorite.—The diorite of the region usually contains, besides the essential minerals plagioclase and hornblende, a variable but generally large amount of black mica and quartz, so that the rock belongs to the quartz-mica-diorite series. In places orthoclase and pyroxene become important constituents, relating the diorite on the one hand to granite and on the other to gabbro. On the southwest slope of Chip Creek the sedimentary rocks in contact with the diorite were greatly altered at the time of its eruption, showing that the diorite is younger than the associated Calaveras formation.

Peridotite.—Peridotite is an eruptive rock originally composed chiefly of olivine, but in many places it contains pyroxene, which may greatly increase in quantity, when the rock becomes pyroxenite. Since its eruption the olivine and some of the associated minerals have in many cases been changed to serpentine. All of the larger masses of serpentine so far studied in northern California have originated in this way. The surface of the peridotite often weathers reddish, so that the hills formed of it are frequently called "red hills." The one at the junction of Indian Creek and the North Fork of Feather River is a good example. Near the contact of this eruptive and the adjacent country rock considerable quantities of gold have been already taken out, and prospects are promising.

Diabase and porphyrite.—The diabase and porphyrite, which are among the ancient eruptive rocks of the region, at the time of their eruption usually reached the surface and flowed out as lavas similar to the andesites and other closely related volcanic rocks of the Lassen Peak district. Since then they have been subjected to great pressure, accompanied by an alteration of their mineral constituents. They form a large portion of the Keddie-Dyer Ridge as well as of that extending into the district from the deep canyons of Indian Creek between Arlington bridge and Shoo Fly.

Hornblende-andesite.—Hornblende-andesite containing rather prominent crystals of hornblende and usually a little pyroxene is the oldest lava exposed in the district. Its largest area is in the mountains about the head of Burney Creek, but several small peaks are nearly buried beneath the Tuscan formation.

Pyroxene-andesite.—In this group are included andesites which are characterized by the predominence of pyroxene. In some places the hypersthene and augite are present in nearly equal amounts, but more frequently the hypersthene predominates and the rock is hypersthene-andesite. In a similar manner some of the lavas are augite-andesites. Traces of hornblende and olivine are occasionally found and relate these rocks to the hornblende-andesites and basalts. The scale of the map is too small to allow these various forms of lava to be clearly outlined in all cases. Generally, if not everywhere within the district, the lavas of this group are older than the rhyolites, dacites, and basalts.

Rhyolite.—Although the andesites of this region are generally porphyritic, with white phenocrysts of feldspar or dark ones of pyroxene or hornblende, the rhyolites are not so. They are light-colored, usually lithoidal, but occasionally, as near Deer Creek Meadows, they are composed of perlitic glass. At Bear Creek Falls the rhyolite contains streaks of black glass. Canyons have been cut in the rhyolite by Deer Creek and its branches. Streams of basalt have flowed down these canyons and show very clearly that the basalt of that region is younger than the rhyolite.

Dacite.—Lassen Peak is composed chiefly of dacite, which, although it contains much glass, has occasionally a superficial resemblance to gray granite. Near the northern base of the peak is an extremely rough, treeless tract, which has been called "Chaos." At that place the youngest dacite of the region is well exposed.

Basalt.—Basalt is the most common and widely distributed lava of the district, and has escaped from many volcanic vents. One of its best preserved and most accessible craters is on the south slope of Inskip Hill. Most of the basalt is younger than any of the lavas already mentioned. It has flowed down the canyons, cut in the older volcanic rocks, and, occasionally forming dams, has given rise to many fertile meadows.

Quartz-basalt.—Quartz-basalt occurs at three localities within the Lassen Peak district: at the Cinder Cone, at Silver Lake, and on the northern slope of Lassen Peak. The Cinder Cone and the lava-field 10 miles northeast of Lassen Peak are the result of one of the latest volcanic eruptions in this country south of Alaska. It is illustrated upon the accompanying sheet. The lava is a basalt, which is peculiar in containing numerous grains of white quartz.

STRUCTURE.

The beds of unaltered stratified rocks, none of which are older than the Cretaceous, still lie as they formed, in a nearly horizontal attitude. Although uplifted they have not been compressed enough to produce folds. On the other hand, the auriferous slates have been thrown into a series of arches (anticlines) and troughs (synclines) and so greatly compressed as not only to close the folds, leaving the strata approximately vertical, but also to break and displace them along a series of thrust faults. These changes occurred during the earth movements by which the mountains were produced.

The auriferous slates crop out in the northwestern and southeastern corners of the Lassen Peak district. Between these points there is a great depression in these ancient rocks, marking the limit between the Sierra Nevada and the Klamath Mountains of the Coast Range. The depression is filled below by the Chico and other unaltered sedimentary formations, and these are overlain by a great thickness of lavas, which have been erupted from the volcanoes of the Lassen Peak region. Although the older igneous rocks, such as diabase, porphyrite, peridotite, and diorite, have been subjected to the same sort of extensive displacement as the auriferous slates, the newest lavas have not been folded to an appreciable extent. They have, however, been faulted on a small scale. Several fault cliffs may be seen about the head of Butte Creek and on the road between Big and Mountain meadows. The most important one in the region, however, is that which forms Hat Creek Hill, east of Hat Creek. At that point the lavas have been broken along a fissure for at least 25 miles, and those on the east side of the fissure have been lifted so as to form a prominent cliff.

The bluff which marks the western limit of the dry, stony plain 4 miles east of Red Bluff is due to an abrupt downward bend of the Tuscan tuff to plunge beneath the Sacramento Valley. This monoclinal flexure in its effect resembles a fault.

GEOLOGIC HISTORY.

To get a clear view of the geologic history of the Lassen Peak district it is necessary to outline the principal events in the development of northern California and southern Oregon.

The oldest rocks yet positively identified in the geologic series of California and Oregon are those of the Grizzly formation. They are known to be Silurian by fossils found in them near Taylorville. These fossils are of marine animals, showing that the slates, quartzites, and limestone of Mount Grizzly were formed beneath the sea.

The source of these early sediments has not yet been definitely determined, but it is probable that they were derived, at least in part, from a land mass of pre-Silurian rocks which occupied during Paleozoic time the western part of Nevada and may have extended a short distance into California. Part of the sediments may have been derived from islands which skirted this ancient coast, a source from which later formations have evidently derived much of their material.

The relations of land and sea continued, in northern California and Oregon, to be essentially the same throughout the Silurian, Devonian, Carboniferous, and Juratrias periods, although frequent oscillations of the land with reference to the sea-level are recorded in the changes of sediments in that region. Including the Grizzly beds at the base, there is a mass of marine sediments, over $4\frac{1}{2}$ miles in thickness, which accumulated on the sea bottom throughout northern California between the early part of the Silurian and the close of the Juratrias period. These strata, although originally horizontal, have since been closely folded, faulted, and metamorphosed, and the fractures have been filled by auriferous quartz veins.

The deformation of the strata did not all occur at the same time. The Silurian and Carboniferous systems received their first tilting before the oldest Triassic formation was deposited on their upturned edges. So also during the Juratrias the rocks were again folded, and it is probable that upheaval accompanied the folding and that the land areas were thereby enlarged, but how much is not yet known. It was not until the close of the Juratrias that the great deformation occurred which raised the whole of northern California above the sea. At that time, so far as is yet definitely known, the first dry land appeared in that region, but it is probable that islands existed there as early as the Archean. Immediately after the post-Juratrias uplift the land extended northwest from the Sierra Nevada and Klamath Mountains into the Pacific west of Cape Blanco. How far westward and northwestward beyond the present coast-line the land may at that time have encroached upon the sea is not known, but its extent was probably not very great, for the sea soon came to occupy the Sacramento Valley and a large part of Oregon.

During the Cretaceous period the land gradually subsided, so that the sea again swept over and covered a part of the area that had lately been raised above sea-level. During the latter part of this period the Klamath Mountains and other portions of the Coast Range were almost, if not altogether, beneath the ocean, but the Sierra Nevada has remained above the sea ever since its development at the close of the Juratrias. When the Chico formation was deposited the seashore lay along the western base of the Sierra Nevada and extended around its northern end. The Pacific occupied nearly the whole of the Lassen Peak district and spread far into Oregon.

At the close of the Chico epoch the Klamath Mountains were again raised above the sea, and the Cretaceous strata over portions of these mountains were much folded and broken. A large part of the Chico beds thus exposed to erosion were washed off the land before the sea again partially invaded the same region and deposited the Tejon formation, which, although well represented in middle California and part of Oregon, has not yet been certainly recognized in California north of the 40th parallel.

The Ione formation of the Neocene system appears in some places to lie upon the upturned edges of the Chico and contains fresh-water mussels. It must have originated in a body of essentially fresh water which extended from the northern end of the Sacramento Valley through the Lassen Peak region into northeastern California and separated the Klamath Mountains from the Sierra Nevada. It was an estuary or lake at or near the sea-level, for the water was salt at Marysville Buttes, and the leaves found buried in the formation are of the kind of vegetation prevailing at low altitudes.

After the uplifting at the close of the Chico the land of northern California was long subjected to continuous erosion, and finally, during the early part of the Neocene, had been worn down to almost a plain—a peneplain. The streams, having nearly reached their baselevel of erosion, were unable to remove the insoluble residual material resulting from the disintegration of the rocks. As a result the land became coated with a sheet of such material, containing quartz, gold, and other insoluble detritus.

In the early Neocene there was such a change of level of the land that the grades of the streams were increased and the residual material was swept down. Most of the fine and light material was carried into the Sacramento Valley, but the coarse and heavy material (quartz gravel and gold) accumulated in the old channels which furnish the principal placer mines of to-day.

The ancient auriferous gravels of the northern end of the Sierra Nevada were deposited by streams tributary to the body of water in which the Ione formation was laid down. This water body surrounded the northern end of the Sierra Nevada and received one of the ancient Auriferous gravel streams at the southern end of the Mountain Meadows.

Some of these gravels which were once but little above sea-level are now on the summits of the Sierra Nevada, at altitudes ranging from 5,000 to 7,000 feet above the sea. They contain leaves of maple, fig, walnut, magnolia, and oak, besides those of other trees which are common at low altitudes, but, so far as yet known, only few if any leaves of pine or other conifers which now grow so abuntantly at the present altitude of these gravels. This indicates clearly that since these early gravels were deposited the northern end of the Sierra Nevada has been upheaved more than 4,000 feet.

By the upheaval of the range the drainage was considerably changed and the erosive power of the streams increased. Since then all the streams flowing down the western slope of the northern portion of the range have cut deep canyons. The canyon of the North Fork of Feather River is nearly 4,000 feet deep, opposite a mass of ancient gravel at Lot's diggings, showing the large amount of cutting done by the modern streams since the ancient gravels were deposited.

In this brief sketch of the geologic history of northern California the mention of volcanic phenomena has thus far been avoided, so as to render as distinct as possible the sequence of great events which can be made out from the sedimentary rocks alone. The Lassen Peak district abounds in volcanoes, both ancient and modern, and lava-capped terraces suggest that volcanic energy may have had something to do with the uplifting of the land in that region.

In the Taylorville region there were active volcanoes during the Carboniferous and Juratrias periods. The large mass of diorite, which forms an important part of the northern end of the Sierra Nevada, is an eruptive rock, and originated either immediately after the deposition of the early portion of the Juratrias formation or at the close of that period. Many of these older eruptives have been folded and displaced with the sedimentary rocks.

The volcanic action which has built up Lassen Peak with its many associated cones is comparatively recent. It began at the close of the Ione epoch and occurred most violently at the time the Sierra Nevada was upheaved, but it has continued spasmodically to the present time. The earliest eruptions were of hornblende-andesite, which were here succeeded by those of pyroxene-andesite. In general the rhyolites are older than the dacites. Although some of the basalts are old, yet, taken as a whole, they are the youngest lavas of the region. Many of them were erupted after the canyons had been deeply cut in the older lavas and slates. This is especially noticeable along the North Fork of Feather River, where the basalt has flowed down the canyon for about 20 miles. The river has worn through this lava-flow and cut its canyon several hundred feet deeper, leaving bits of basalt to form terraces along the sides of the canyon. At a number of points the gravel of the old river channel is visible beneath the lava of the terraces.

To the younger flows of basalt the Lassen Peak district is indebted for the development of its most valuable agricultural and grazing lands. At the entrance of every canyon into which basalt flowed the lava accumulated so as to form a dam for the streams of water. In this way lakes or swamps were produced, and from these, by the gradual accumulation of gravel, sand, mud, infusorial earth, and vegetable matter, the beautiful meadows of Prattville, Coppervale, Butt Creek, Battle Creek, and Dixie were produced.

The latest volcanic eruption in the Lassen Peak district, and possibly the latest in the United States south of Alaska, occurred at the Cinder Cone about 200 years ago. Some of the trees killed at the time are still standing. The lava, although very viscous, spread more than a mile from the vent and formed a huge tabular pile which extends across a little valley. The lava dam thus formed developed Snag Lake, which contains stumps of some of the trees drowned at the time the lake originated.

That volcanic activity is not yet extinct in the Lassen Peak district is shown by the presence of numerous solfataras and hot springs. At Bumpass's Hell, near the southern base of the peak, there are boiling mud pools and vigorous solfataric action. Near by, at the head of Mill Creek, the sulphur deposited by such action is so abundant that attempts have been made to mine it. Similar phenomena occur in Hot Spring Valley and at Lake Tartarus and the Geyser, near Willow Lake. The geyser is much less vigorous than formerly, and now the column of water rises scarcely a foot above its pool.

Having considered the geologic history written in the stratified rocks and the lavas of the district, we come to that recorded in the superficial deposits about the higher parts of the region. There we find striæ and moraines left upon the rocks by glaciers. Patches of perennial snow still cover portions of Lassen Peak, and their condition is almost that of a glacier. Formerly they were much more extensive, real glaciers stretching in all directions from Lassen Peak. The period of glaciation may have been a long one. Its maximum occurred soon after the mountains had reached their greatest altitude, when by far the largest portion of the lavas had been erupted. The canyons were cut in the earlier lavas, and some of the later lavas, as well as the glaciers, flowed down these canyons for long distances.

MINERAL RESOURCES.

Upon the economic map special attention is called to the distribution of the auriferous slates, in which alone there is any probability of discovering valuable deposits of precious metals. These rocks are exposed in the southwestern and northwestern portions of the area mapped, and extend through, under the lavas of the Lassen Peak district, from the Sierra Nevada to the Klamath Mountains. The broad stretch of unaltered lavas about Lassen Peak does not contain an appreciable amount of the precious metals, and may be wholly neglected by the prospector.

Among the auriferous slates seven formations have been distinguished, ranging in age from the Silurian to the Jurassic, inclusive. Of these the Cedar formation, of Juratrias age, and the Calaveras formation, of Carboniferous age, have been the most productive. By their disintegration they have furnished the gold for the placer mines of Indian Creek below Shoo Fly, of Soda Creek, Rush Creek, the North Fork of Feather River, and also the rich deposits about Lot's diggings and Dutch Hill. The mines near the North Fork of Feather River are on this belt, and active prospecting is going on at a number of points. Numerous copper prospects have been discovered in the Pit River region, and at present prospecting is active.

Intermingled with the auriferous slates are eruptive rocks, such as diabase, porphyrite, peridotite, and diorite, which have much to do in determining the distribution of certain classes of ore bodies. The areas of eruptive rocks have been outlined, and it has been found that the most promising prospects of that region are located near the borders of these eruptive masses. The ore deposits may be in the auriferous slates or the eruptive rock, but in either case they are not far from the contact. The eruptive rocks in which the active mines of Crescent and Greenville are located do not extend into this area.

Limestone is abundant in the Cedar formation, and occurs also in the Calaveras formation, as indicated upon the economic sheet. It is most conveniently located by the stage road along Cedar Creek in Shasta County, and has been burned, making good lime, near Prattville.

The coal of the Ione formation has been prospected on Little Cow Creek and elsewhere in the same region. At several places small quantities have been taken out for local use, but nowhere has a sufficient outcrop been seen upon the surface to warrant expensive exploration.

The Tuscan tuff, when fine-grained and sufficiently indurated, stands fire well and may be used to advantage in building chimneys and hearths. On account of its porosity, which allows considerable evaporation, it is used for water coolers. The same sort of material, especially when highly colored, is used quite extensively in the manufacture of cement.

The large deposit of infusorial earth on Pit River below the mouth of Hat Creek is of economic importance. The beds have a thickness of nearly 100 feet. This earth makes an excellent polishing powder, and it is used also in the preparation of cement and explosives, as well as for protecting steam boilers and pipes.

The minerals in the basalt are such that by decomposition and disintegration it furnishes an excellent soil for agricultural purposes, much richer than that derived from the other lavas of the district. As the basalt was more liquid at the time of its eruption than the other lavas of the region, it spread farther and formed comparatively smooth surfaces; this also is in its favor from an agricultural point of view.

ILLUSTRATIONS OF RECENT VOLCANIC ACTIVITY.

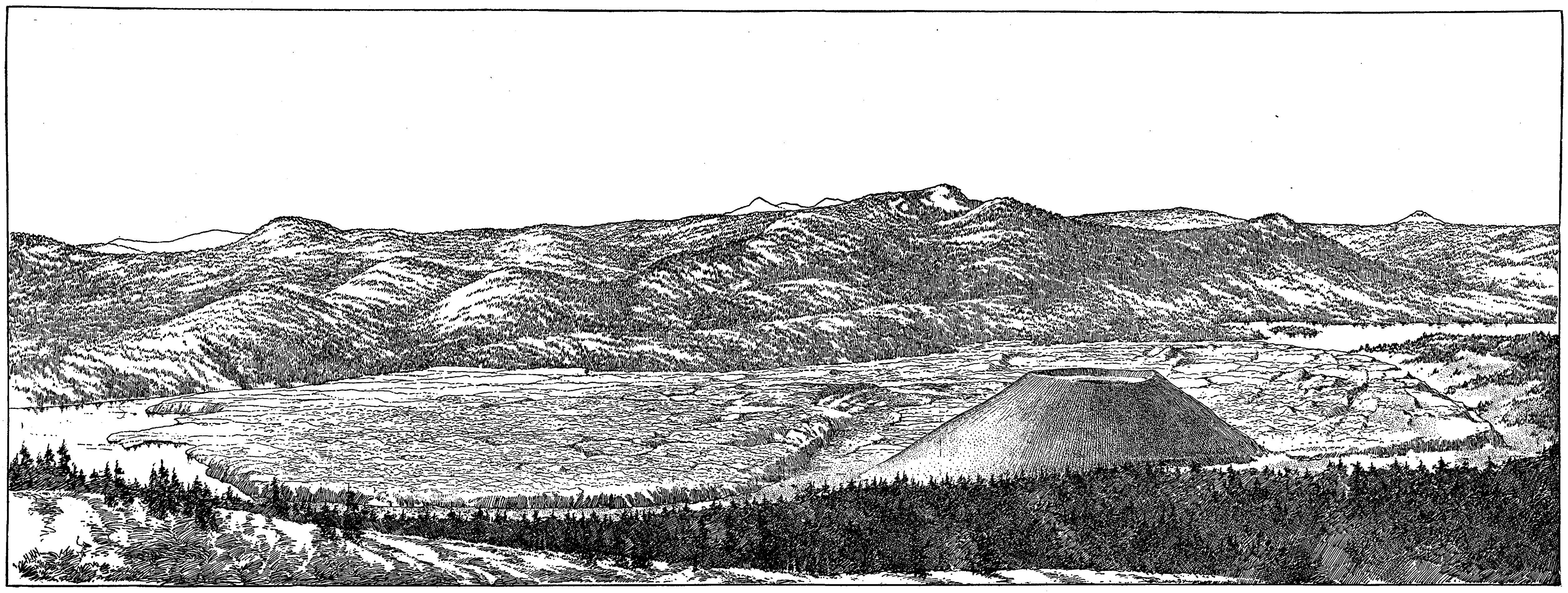

FIG. 1.—THE CINDER CONE AND LAVA FIELD FROM PROSPECT PEAK.

THE CINDER CONE, CALIFORNIA.

The general view.—Looking southeast from the summit of Prospect Peak, one sees the general view represented in fig. 1. It is the scene of a comparatively recent volcanic eruption at the Cinder Cone, 10 miles northeast of Lassen Peak, California. The dark, desolate, treeless lava field and cinder cone present a strong contrast to the deep-green pine forest by which they are surrounded. From this point, better than anywhere else excepting the summit of the cinder cone itself, is obtained a view of the hopper-shaped depression of its crater. On the right of the lava field is Snag Lake, whose waters escaped through the lava into Lake Bidwell on the left.

When one obtains the first near view of this scene the impression of its newness is vivid, and he looks in the expectation of seeing steam rising from the crater or lava field. The feeling of disappointment is somewhat allayed, however, when he observes charred trunks of trees (fig. 2), apparently long since dead, yet attesting the scorching temperature of that place in recent times.

The cone.—Descending from the summit of Prospect Peak toward the cinder cone, attention is at once arrested by the soft, dull-black volcanic sand which covers the surface and renders walking tiresome. At first it is fine and only a few inches deep, but as we approach the cinder cone the sand becomes coarser and deeper. How thick the layer of sand may be at the base of the cone is unknown, but one-fourth of a mile away in all directions it is about 7 feet in thickness, and it decreases so as entirely to disappear at a distance of 8 miles. Encircling the cinder cone at its base, as shown in figs. 3 and 7, is a collection of volcanic bombs, ranging in size from a few inches to 8 feet in diameter. They are much fissured, and many of them have fallen to pieces, showing an interior of compact lava, while the surface is somewhat scoriaceous and ropy.

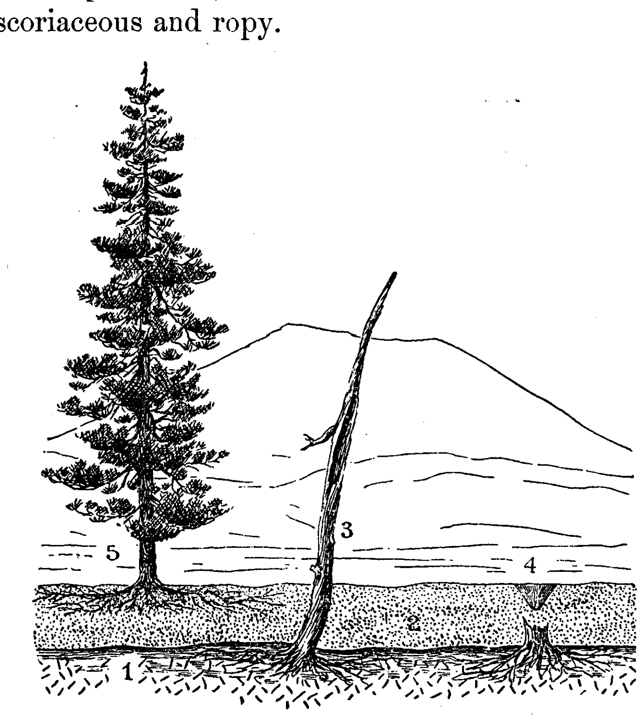

FIG. 2.—SECTION SHOWING RELATIONS OF FORMER AND PRESENT FOREST.

1.—Original soil.
2.—Volcanic ashes and lapilli.
3.—Tree of the former forest, killed by the shower of volcanic ashes.
4.—Pit formed by the decay of an old stump.
5.—Tree of the present forest.

Having arrived at the cinder cone, the first impulse is to climb to its summit. It is then that we become aware of its real composition, for as we struggle up the steep slopes of loose material the scoriæ, lapilli, and sand, improperly called cinders and ashes, give way under our feet, and the climbing is found to be especially fatiguing. The cinder cone is regular in form, with surprisingly smooth, dark surface, showing no traces of waterways or other marks of the ravages of time. It rises to an elevation of 640 feet above the lowest point of its base (6,907 feet above the sea), with an average diameter of 2,000 feet below and 750 feet across the top. Its slopes are as steep as it is possible for such loose volcanic material to maintain, and are marked in many places by slides. The angles of the slope range from 30 to 37 degrees, according to the size of the volcanic fragments. The dull, somber aspect of the smooth, dark slope is greatly relieved by the carmine and orange-colored lapilli on the southeastern side, so that when viewed from near Snag Lake the cone presents the pleasing hues of sunset. The strangeness of the scene is greatly enhanced by the almost complete absence of vegetation; only two small bushes cling on the outer slopes and give life to the barren cone.

On the summit of the cone, we have before us the well-developed crater illustrated in fig. 8. The pit has a depth of 240 feet, with a narrow bottom and partially slaggy slopes, so steep as to be scaled with difficulty. A peculiar feature is the double character of the crater. It has two rims, one within the other, separated by a shallow moat which encircles the great funnel-shaped depression in the center.

The lava field.—From the summit is obtained an excellent view of the lava field. A small portion of it near the cinder cone, being covered with sand, is smooth, as illustrated in fig. 4; but the larger portion, composed of angular blocks of lava loosely piled together, as in fig. 6, is extremely rough. The relation of these two portions to each other and to the volcanic sand of the region is of special importance in tracing the history of the volcanic phenomena of this vicinity, but will not be noticed until after the form of the lava field and the character of the ancient lake bed associated with it are considered.

The general form of the lava field is tabular, and it covers an area of about 1 by $2\frac{1}{4}$ miles in extent. It ends on all sides abruptly, like a terrace, and is in many places over 100 feet in height. Fig. 9 shows this termination at the northwest corner of Snag Lake.

The old lake bed.—Within the lava field and about its end bordering on Lake Bidwell is a lot of soft, white material which, when examined under the microscope, is found to be infusorial earth, mixed with vegetable matter, such as grows on lake bottoms. It is evident that this was once the bed of a lake, and as it connects directly with the present bed of Lake Bidwell, it shows that Lake Bidwell was once larger than it now is, occupying not only its present area but also much of that now covered by the lava field. The thickness of the ancient lacustrine deposits is at least 10 feet, and they are well exposed at several points. Near the western end of Lake Bidwell, where the sheet of volcanic sand which covers the

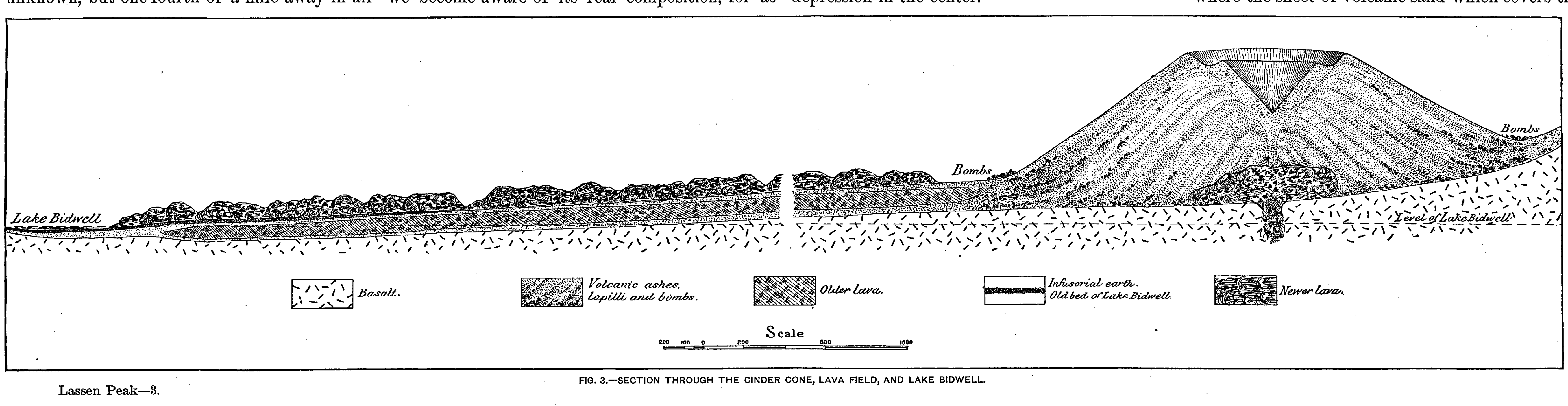

FIG. 3.—SECTION THROUGH THE CINDER CONE, LAVA FIELD, AND LAKE BIDWELL.

country about the cinder cone may be seen adjoining the ancient lake bed and the lava field, a trench was dug to determine their relations, and it was found that the lake bed separated the lava from the volcanic sand. The sheet of volcanic sand formed the foundation on which the ancient lake bed was deposited, but this in turn was covered by the flow of lava, which has no sand on its surface.

Section of the formations.—Beneath the ancient lake beds, and to some extent covered by volcanic sand, is a lava which corresponds to that occurring near the southern base of the cinder cone. The general relations of all these parts are shown in fig. 3, a section of the cinder cone and lava field. The country rock on which the cinder cone and sheet of volcanic sand rest is basalt from the neighboring but older volcano of Prospect Peak. The two sheets of lava in the lava field are separated by the infusorial deposit of the ancient bed of Lake Bidwell, and also by a thin sheet of sand which covers the older lava near the cinder cone. The hopper-shaped crater in the summit of the cone, the collection of volcanic bombs encircling its base, and the volcanic neck within, are all represented in the section.

HISTORY OF THE ERUPTION.

Order of events.—The facts just mentioned show that there were at least two periods of eruption from the cinder cone, and that they were separated by a time interval sufficiently long to allow 10 feet of infusorial earth to accumulate on the ancient bottom of Lake Bidwell. The first period was characterized by a violent explosive eruption, which formed the cinder cone and ash field; the second, by a quiet effusion of a large mass of lava.

The first eruption began with an explosion and the ejection of a great deal of light, scoriaceous, almost pumiceous material, blown chiefly by escaping steam from the upper portion of the molten lava (magma) in the throat of the volcano. Succeeding the explosion and the eruption of the pumiciform material, and continuous with it, came the volcanic sand, lapilli, scoriæ, and bombs. They fell about the hole from which they were blown, and by their accumulation built up the cinder cone, which is composed almost wholly of fragmental material.

After the greater portion of the fragmental material had been ejected the magma rose in the cinder cone, and, bursting it asunder, flowed over the southeastern portion of its base. This effusion was accompanied and succeeded by a shower of sand, which may have given rise to the inner rim of the crater and formed a thin coating over the lava already effused. Whether or not the effusion of the oldest lava and the succeeding shower of ashes belong to the closing stages of the first eruption is not easily determined, but it is certain that both preceded that long interval of quiet during which the old lake beds were deposited. This season of volcanic rest was probably at least a century long, for to accumulate 10 feet of infusorial earth would require considerable time.

The new flow of lava, which developed the tabular lava field, filled the shallow valley, and formed the lava dome, giving birth to Snag Lake, occurred at the close of the lake-bed interval. The remarkable characteristic of this eruption as compared with the former was the entire absence of any explosion from the crater in connection with the effusion of so large an amount of very viscous magma, since the same vent at an earlier period had been the scene of violent ejection.

Everywhere in the lava field one is impressed with the idea that the lava of this final eruption moved slowly and with great difficulty, repeatedly breaking its crust and pushing along as a great stone pile, presenting an abrupt terrace-like front on all sides. It is a typical example of a lava field formed by the effusion of a viscous lava on gentle slopes. Had it been highly liquid, like many of the other basalts in the same great volcanic field, it would have found egress at the outlet of Lake Bidwell and stretched down the little valley for miles to the northward.

Age of the eruption.—The whole aspect of the cinder cone and lava field is so new that one at first feels confident of finding historic evidence of its eruption. To say that it was formed in the geologic yesterday, even, makes it too old, for it appears rather to belong to the early part of to-day. Yet the evidence clearly demonstrates that the earliest eruption occurred before the beginning of the present century.

Its age is best shown by the relation of the old and new forest trees to the volcanic sand of the first eruption. The living trees near the cinder cone, shown in fig. 4, grow upon the top of the sand, but the dead ones in the foreground were standing at the time of the eruption, and, instead of growing upon the sand, grow from the soil which now lies beneath it, as represented in fig. 2. It is evident that the region was forested at the time of the eruption, for about the cinder cone there are many pits in the sand, resulting, as illustrated in fig. 2, from the decay of the earlier generation of trees.

The new forest has attained its maximum growth for that region, and there is no appreciable difference between it and the present forest farther away from the cinder cone. Several of the largest pine trees (*Pinus ponderosa*) in the vicinity of the cinder cone were measured 2 feet above the ground, and found to be 12 feet in circumference, with a diameter, therefore, of 45 inches and a thickness of solid wood of not less than 43 inches. The rings of growth were counted upon numerous stumps of the same pine, and it was estimated that the large trees near the cinder cone must have not less than 200 rings of growth. There is in that mountainous region but one season of growth and one of repose for each year, and there is therefore good reason for supposing that each ring represents a year's growth. If so, the trees by the cone must be about 200 years old. Presumably, as is well known to be true in other cases, the vegetation would take hold upon the volcanic sand very soon after the eruption, so that the age of the oldest trees may be taken as a rough approximation of the age of the first eruption, and we may with some reason conclude that it occurred nearly a century before the American Revolution. The second or effusive eruption occurred at a much later date, but certainly more than 50 years ago, and was of such a character as not to attract attention.

THE GREAT VOLCANIC REGION OF THE NORTHWEST.

The cinder cone and lava field just described are part of the Lassen Peak volcanic ridge, which was built up by the eruptions from over 120 volcanic vents. Some of these eruptions were on a grand scale, and a few of the craters are over a mile in diameter. During the development of the volcanoes some of the vents shifted their position. Lassen Peak is connected by lava with Mount Shasta, and may be considered the southern end of the Cascade Range. From this range the great volcanic field, which is perhaps the largest in the world, extends eastward, covering a large part of northern California, Oregon, Washington, Idaho, and Montana. The lava-covered area is estimated to be 200,000 square miles in extent, or larger than France and Great Britain combined.

In the Lassen Peak region and throughout the Cascade Range the lava was generally rather viscous, and the amount erupted at one time from the same place was not very large. Being too stiff to flow far, the lava accumulated about the vent and formed large cones, of which Lassen Peak, Mount Shasta, Mount Hood, Mount Rainier, and other peaks, ranging from 10,000 to 14,000 feet in height, are conspicuous examples. One of the longest lava-flows in the range came from the southern slope of Mount Shasta and descended the canyon of the Sacramento River for 50 miles. To the eastward, along the Columbia, Deschutes, and Snake rivers, the lavas at the time of their eruption were much less viscous, and sometimes almost as fluent as water, for they spread out into thin sheets, following the sinuosities of the lower slopes of the ridges, and surrounding isolated hills as islands in a lake. The thickness of the great lava field, which has been studied by Le Conte, Geikie, Symons, and Russell, is supposed to average about 2,000 feet. The lava beds are exposed in excellent sections along the Columbia, Snake, and other rivers, where the lava is seen to be arranged in horizontal layers, like undisturbed sedimentary rocks. The separate layers range from one to scores of feet in thickness.

MOUNT VESUVIUS.

Mount Vesuvius is illustrated in fig. 5, and the marked similarity of its cinder cone to that near Lassen Peak is at once apparent. It is composed of a larger proportion of coarse fragments, and the surface of the lava in the foreground is puckered by the flowing of the underlying material, so as to produce what has been called a ropy surface; and, being also very vesicular, it is strongly contrasted with the extremely rough lava field near Lassen Peak. On the slopes of the cone of Vesuvius, as shown in the illustration, is a spiracle, formed of lava that rose out of a little vent at that point and, being stiff, remained close to the orifice, building up a very steep little cone. The ropy lava fields of Vesuvius were formed by slowly moving streams, and the rough cindery ones by streams that moved rapidly and yielded a great quantity of steam, which tore up the surface and left it extremely rough and jagged.

Mount Vesuvius is a much larger and more complex volcano than the Cinder Cone near Snag Lake. It is made up of both cinders and coulées (lava-streams), and illustrates the structure and growth of such large volcanoes as Lassen Peak, Mount Shasta, and many others of the Cascade Range. With a circular base 30 miles in circumference, it rises from a plain that borders the Bay of Naples and reaches an altitude of nearly 4,000 feet. The lower part of the mountain is like the base of a simple cone, but the upper part, above 2,500 feet, is double, being made up of a crescentic ridge, Monte Somma, encircling the base of the top cone, which forms the highest summit of Vesuvius. Although the name Vesuvius is applied to the whole mountain from the sea up, it is sometimes restricted to the small summit cone, a portion of which is illustrated in fig. 5. The basal portion of Vesuvius rises from about 2,500 feet; beyond this extend Monte Somma to 3,730 feet, and the cone to about 4,000 feet, above the sea.

The base of the mountain is encircled by a fertile plain, whose soils are derived from the volcanic material of the mountain slopes. Above this belt, although vineyards extend here and there in fertile spots to an altitude of 2,500 feet, a large portion of the mountain is a barren waste. The fresh lava has not yet been sufficiently decomposed to furnish soil. Many lava-streams which burst from the slopes above have crossed the cultivated belt, which is traversed in its older portions by small ravines or waterways, marking lines of long-continued drainage. Upon the newer slopes such ravines are filled by later streams of lava, and thus what is removed by erosion is restored by volcanic activity. At present the additions by eruptions greatly exceed the loss by erosion, and the mountain is growing. In this respect Vesuvius differs from Lassen Peak and Mount Shasta. As they are extinct volcanoes, they have stopped growing and are now gradually wasting away.

Monte Somma, the semi-circular ridge which forms the northern summit of Vesuvius, has, outward, a gentle slope connecting with the general slope of the cone below. Inward it is very steep, and a crescentic valley, above which it rises—generally about 1,200 feet—separates it from the summit cone. Monte Somma is an older portion of the mountain, a remnant of an ancient crater rim, which indicates that the mountain was once larger than it now is.

The cone which forms the principal summit of Vesuvius is regular in shape and rises to an altitude of about 4,000 feet above the sea, or 1,500 feet above the sterile valley of Aerio del Cavello, which separates it from Monte Somma The steep slopes, composed largely of loose cinders and ashes, have an angle of from 30° to 40°, and the ascent on foot is very laborious. The sand, ashes, lapilli, and cinders are arranged in layers parallel to the slopes of the cone, and occasionally they alternate with small streams of lava descending from the well-developed crater on the summit or from fissures in its sides. Within the crater the molten material is accessible, and tourists may see it ladled out and impressed with coins for souvenirs.

The crater always shows signs of activity within, and generally these signs may be seen at night from Naples, a distance of about 10 miles. As seen from Naples they vary greatly in intensity, ranging from the faint, interrupted glimmer in the sky above the crater, through brilliant but moderate ejections thrown up high into the air and illuminating the height of the cone, to paroxysmal eruptions which are often terrible in their wide-spread disastrous effects.

As a result of this continued activity the crater of Vesuvius is ever changing. Small cinder cones are formed within the larger crater, only to be blown out when the eruption becomes more vigorous. Small streams of lava escape from the crater and course down the steep slopes of the cone, which is built up by the addition of successive sheets of ejected and effused material. Much of this growth may go on in comparative quiet. So far as the people of Naples are concerned they see only the glow by night and the smoke by day.

Previous to the year 79 Vesuvius was not recognized by the Greeks and Romans as an active volcano. At that time the summit of the mountain was a large crater, of whose rim Monte Somma is a remnant. Within, there was a circular, depressed plane, where the upper cone now rises. The change toward the present aspect of the mountain took place in the year 79, when the southern part of the rim was blown away and its place was occupied by a new cone, partly encircled by Monte Somma. Vast quantities of ashes were thrown out at that time and fell upon the mountain slopes. Torrents of accompanying rain saturated the loose material, and great mud-flows were formed. They descended the slopes of Vesuvius to the plains and buried the city of Herculaneum. Pompeii and Stabiæ were destroyed by the same eruption. No streams of melted rock flowed out in connection with this explosive eruption; the material was wholly fragmental. Pliny the younger, who tells how his father perished, gives a graphic account of the darkness, blacker and more dismal than night, caused by the showers of ashes obscuring the sun. The first warning of the approaching eruption was the earthquake in the year 63. Moderate earthquakes continued at intervals, and the disturbance culminated in the great eruption of 79. About Vesuvius, and also in other volcanic regions, earthquakes are frequently associated with eruptions.

With long periods of repose Vesuvius continued moderately active until December, 1631, when another great eruption occurred. Vast quantities of ashes and stones were ejected and seven streams of lava descended the mountain slope. A number of villages and 18,000 people were destroyed. In October, 1822, another notable eruption occurred. The top of the cone fell in, and this was succeeded by the emission of a stream of lava a mile in width. So great was the quantity of ashes and cinders ejected at that time that the country for 20 miles about Vesuvius was overshadowed by darkness. Some of the ashes were carried over 100 miles from Vesuvius. Six hundred feet of the top of the cone was blown away, and a crater nearly 1,000 feet deep was produced.

In 1828 a small cone arose until it was as high as Monte Somma, but in 1834 it was destroyed and a copious stream of lava 9 miles in length buried the village of Camposecco. One stream of lava took the direction of Pompeii, and in 1850 another coulée, 1½ miles broad, followed the same course.

In 1855 a long, narrow stream of very fluid lava, issuing from the side of the cone, reached almost to the suburbs of Naples. Another eruption occurred three years later, and still another in 1861. The last issued from near the base of the mountain toward the bay. At that time ten small craters were formed and great quantities of ashes were ejected.

A long-continued, irregular eruption occurred in 1867–8, furnishing many small streams of lava and contributing material to the elevation of the summit cone. In 1872 a violent eruption occurred. Lava burst forth at a number of points on the cone, while terrific discharges, accompanied by lightning and loud bellowings and thunderings, were taking place at its summit. Upon the south and eastern side of the mountain the streams of lava did not extend farther than the borders of the cultivated fields, but upon the western side several villages were destroyed and fertile gardens and fields laid waste.

Since the first historic eruption of Vesuvius in 79, although there have been many hundreds of moderate outbreaks, often accompanied by small streams of lava, gradually upbuilding the mountain, only about fifty-four eruptions are considered of sufficient size to be classed as paroxysmal.

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