

## THE VOLCANIC ACTIVITY OF LASSEN PEAK, CALIFORNIA

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NOTWITHSTANDING vague reports of early settlers it now seems practically certain that no white man had witnessed an eruption of a volcano within the limits of California until May 30, 1914. On that day Lassen Peak, a well-known old volcanic cone in the northern part of the state situated about seventy-five miles southeasterly from Mt. Shasta, suddenly burst into explosive action. During the six months that have elapsed since the first eruption took place, including one quiescent period of twenty-three days, there has been an average of one eruption every three days with no indication at the time of writing that the activity has ceased. The uniqueness of the phenomena as part of the physiographic processes of the United States<sup>1</sup> invites some detailed description for several reasons.

A natural curiosity exists concerning the events which have actually occurred and also as to the most probable developments in the future. Is this recent activity a sign of the rejuvenation of a long quiescent volcano which is once more to pour forth its floods of lava? Or are the outbursts merely the last relatively feeble, but convulsive efforts preceding the final extinction of the subterranean forces that formerly built up the old lava cone still after centuries of erosion towering nearly two miles above the level of the sea? As yet reliable forecasts of volcanic activity are not made on a scientific basis, but it is hoped that the following pages will at least give a satisfactory outline of the history of the region up to the present writing.

Lassen Peak stands in the southeastern part of Shasta County, nearly two hundred miles from San Francisco. According to the Lassen Peak topographic sheet (a reconnaissance map surveyed in 1882-84, see Fig. 1), the mountain is ten thousand four hundred and thirty-seven feet in elevation and is approximately in latitude  $40^{\circ} 30'$  N. and longitude  $121^{\circ} 30'$  W. The immediate region is the extreme southern portion of that great tertiary lava flow some two hundred and fifty thousand square miles in extent, covering not only northeastern California but portions of Oregon, Washington, Idaho and Nevada as well.

<sup>1</sup> Volcanic eruptions in Washington have been reported but apparently never studied at close range. Professor George Davidson reports seeing Mt. Baker in eruption in 1854 and in 1870. *Pacific Coast Pilot U. S. G. S., 1899.* J. C. Fremont in his journal under date November 13, 1843, writes as follows: "At this time two of the great snowy cones, Mount Regnier and St. Helens were in action. On the 23 of the preceding November, St. Helens had scattered its ashes, like a light fall of snow over the Dalles of the Columbia, 50 miles distant." *The Exploring Expedition. D. Appleton & Co., 1846.*

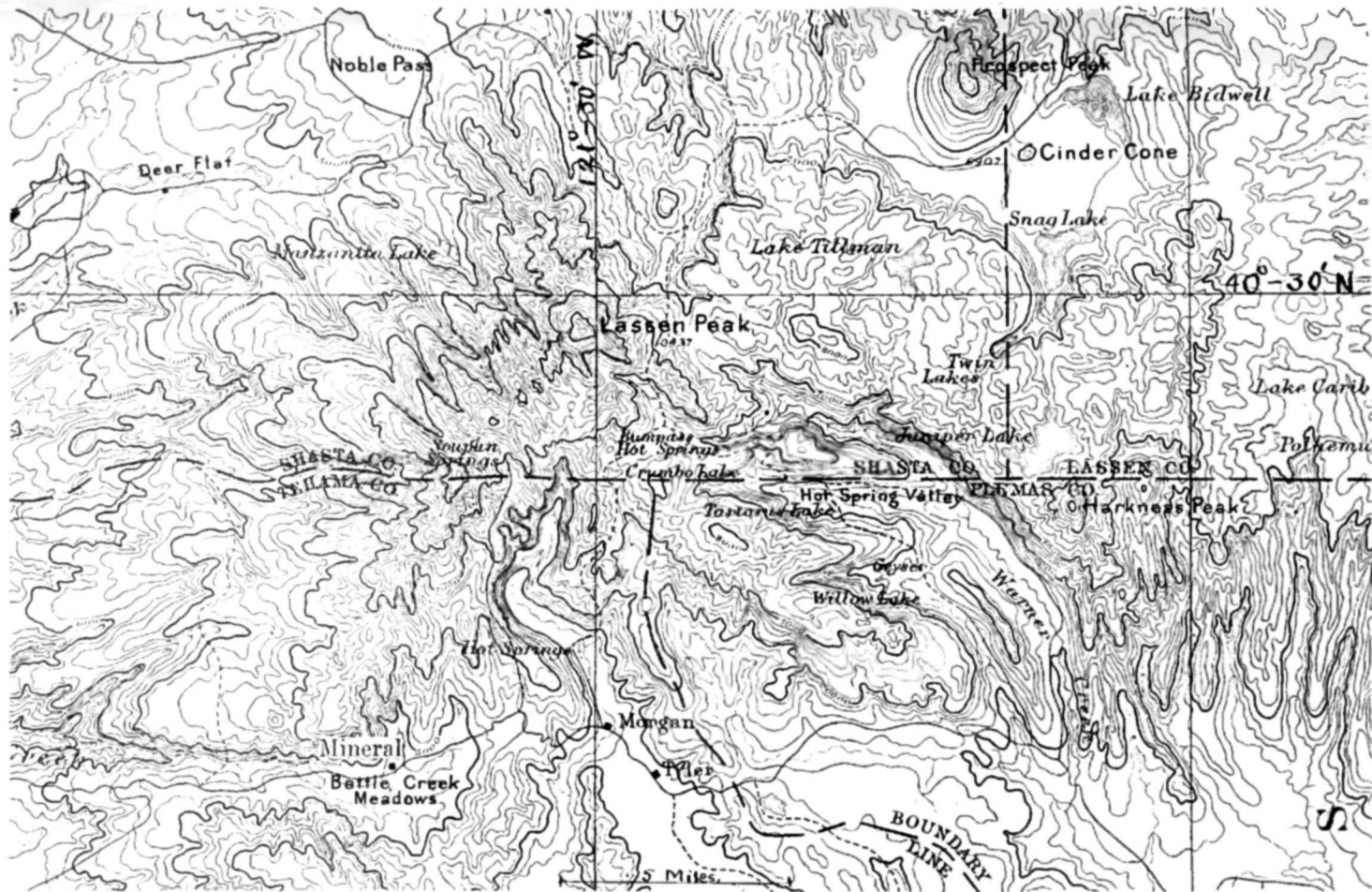


FIG. 1. LASSEN PEAK AND VICINITY. The area shown is the central portion of the Lassen Peak sheet of the U. S. Geological Survey. The quadrangle was surveyed in 1882-84. As reproduced here the scale is practically four miles to the inch.

In general, geographers consider Lassen Peak as marking approximately the southern end of the Cascade Range, and as being the last of that series of great volcanic cones of which Rainier, Adams, Hood, Three Sisters, Mazama, Pit and Shasta are familiar examples. To the southeast of Lassen the topographic gap of the Feather River separates the Cascade Range from its correlative, the Sierra Nevada, which extends four hundred miles farther to Tehachapi Pass, but whose lofty peaks owe their height primarily to uplift rather than to volcanic up-building.

The southern fifty miles of the Cascade Range extending north-westerly toward Shasta from the North Fork of the Feather River is a great volcanic ridge, about twenty-five miles wide. This ridge is studded with numerous minor volcanic cones culminating in Lassen, the dominating peak, which is guarded by a number of other major cones rising to heights varying from seven thousand to nine thousand feet above the sea. Past volcanic phenomena of the Lassen Peak region in recent geologic time have been made familiar to readers through J. S. Diller's well-known report,<sup>2</sup> which describes with considerable detail the Cinder Cone, ten miles northeasterly from the main peak, from the base of which the latest lava flow issued. Until the present outbreak, despite our knowledge of the Cinder Cone lava flows, it has been tacitly assumed in physiographic literature that Lassen Peak belonged to the class of extinct volcanoes, although the following statement by Diller in the folio just quoted shows clearly that twenty years ago he did not consider the volcano entirely extinct.

*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 two hundred 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 Suag Lake, which contained 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 Springs Valley and at Lake Tartarus and the Geysers, near Willow Lake. The Geysers is much less vigorous than formerly, and now the column of water rises scarcely a foot above its pool.

Previous to the present activity of Lassen Peak there had been numerous indefinite reports of eruptions witnessed by the Indians in that vicinity shortly before the coming of the white settlers. The most definite of these reports is given in a recent letter from Dr. J. W. Hudson, of Ukiah, California.

<sup>2</sup> Lassen Peak Folio, U. S. Geol. Survey, 1894.

I was in that region in 1904 collecting for Field Museum of Natural History, Chicago, department anthropology, and heard much of Lassen Butte. An old Indian told me that when a child and living some sixteen miles northwest of Cinder Cone, there came an earthquake at Lassen one summer day. The sun arose, but gradually faded to the darkest night and ashes came down like a heavy snowfall. Its weight finally broke in the bark houses and the natives rushed out into the darkness. The boy was taken by a grandmother to a hollow pine log where they remained till nearly famished. When the sun reappeared he was carried many miles before drinkable water was found. I presumed at that time my informant was near seventy years old and about six on the above occasion, thus approximating the date 1850 for this eruption. In many localities along the Pit river water shed I heard similar reports amongst the aged Indians. The name of this volcano in Palainian tongue is "Am blü'-kai" "Mountain ripped apart."

The region about Lassen Peak for many miles is very rugged, the few valleys suitable for agriculture lying at an elevation of from 5,000 to 7,000 feet. Naturally it is sparsely settled, and this year, on the date of the first eruption, the snow was still very deep, obscuring all roads and trails down to the six-thousand-foot level. On account of the unusually late season, the summer influx of cattlemen, lumbermen and campers had not yet begun; probably the nearest occupied house was at least eight miles distant from the mountain top.

Prompt investigation of the first eruption is due to the fortunate fact that the mountain is included in the Lassen Peak National Forest and that the United States Forest Service<sup>3</sup> had built a fire look-out station on the topmost crag of Lassen Peak itself. The summer headquarters of the forest supervisor, Mr. W. J. Rushing, are in Battle Creek Meadows, near Mineral postoffice, a little more than ten miles in an air line from the top of the mountain. The look-out house on Lassen and the other stations also are connected with the supervisor's headquarters by the government telephone lines which extend to the town of Red Bluff, nearly fifty miles to the westward, giving direct communication with San Francisco. When the eruptions began the fire look-out station on Lassen had not yet been occupied for the summer season of 1914, but it was the property of the Forest Service and a station of importance. It will be seen then that the interests and resources of the Forestry Service as indicated above were such that reports of volcanic activity on Lassen were investigated at once and definite records kept of the reports brought in to headquarters.

The following extracts are from the report of Forest Supervisor W. J. Rushing to the District Forester at San Francisco, made June 9.

Such wild stories are being circulated concerning Mt. Lassen that I am

<sup>3</sup> The writer wishes to express his appreciation of the assistance and courtesies extended him in connection with his field work not only by District Forester DuBois, of San Francisco, and Supervisor Rushing, of Mineral, but also by various members of the staff in each place.

sending you the results of our observations to date. Saturday, May 30, the first outbreak occurred at 5 P.M. This was witnessed by Bert McKenzie, of Chester, who was looking directly at it when it occurred. Ranger Harvey Abbey investigated it on Sunday, May 31, finding a hole 25 x 40 feet in size and of unknown depth. Sand, rocks as large as a sack of flour, and mud had been ejected. The heavier material was thrown over an area three hundred feet across, while the ash, or cement-like material, was scattered over an area one quarter mile across. . . . No molten material was thrown out at all. 5:05 A.M., June 1, a second outburst occurred, throwing out large quantities of the same material. Some boulders weighing all of a ton were thrown out. The vent was enlarged to 60 x 275 feet. . . . Boerker, Abbey, and Macomber went up June 4, remained on top at the lookout house over night, and came back June 5.

June 8, heavier volumes of steam were noted, and at night apparently another eruption took place, throwing out more ashes or fine material, which could be seen on the new snow.

Heavy volumes of steam are coming out of the vent today. We have watched it carefully and at no time have we been able to see any flame or indication of fire. . . . The vent is about one quarter mile from the fire lookout house, and if it continues eastward, as it has so far, it will finally break out on the east side.

Mr. Ben Macomber, one of the party mentioned in the report above as spending the night on the mountain top, has given the following description of the crater as it was after the early eruptions:

When I saw the new crater on Lassen on June 4 and 5, the vent, by an engineer's tape, measured 275 feet long. It was then in one of the pauses between the heavy explosions. Thick volumes of steam, laden with sulphur smoke, were rising, and cracks were appearing in the ground. From three different places on the edge I looked down into the crater. Sixty or seventy feet down a pile of rocks was visible in the center of the vent, but at either end was a huge dark hole from which the steam clouds poured. The walls were absolutely perpendicular, and around the top were hung with huge icicles formed by the condensation of steam in the chill air of the peak.

On the west side of the crater everything was buried beneath a heavy fall of light gray ash, into which we sank over our boot tops. So light was this rock powder that it flew into the air at every step. On the east side the same material seemed to have been thrown out in the form of mud and lay frozen hard as rock. What little snow remained near the crater was buried under a layer of stones and boulders. (San Francisco Chronicle, June 28.)

The eruption of June 14 was heavier than any which had preceded it, and the only serious injuries suffered by visitors during the six months covered by this article, occurred during the outburst beginning at 9:15 A.M. Extracts from a letter from Mr. B. F. Loomis written a month after the events gives a brief summary of the experiences of the party that was caught by this eruption, as told to him by the different members.

Mr. Phelps's party had just reached the rim of the old crater and sat down to rest a short time, watching the smoke from the crater, when the eruption began. Without any warning or explosion that could be heard, a huge column of black smoke shot upward with a roar, such as would be caused by a rushing mighty wind, and in an instant the air was filled with smoke, ashes and flying rocks

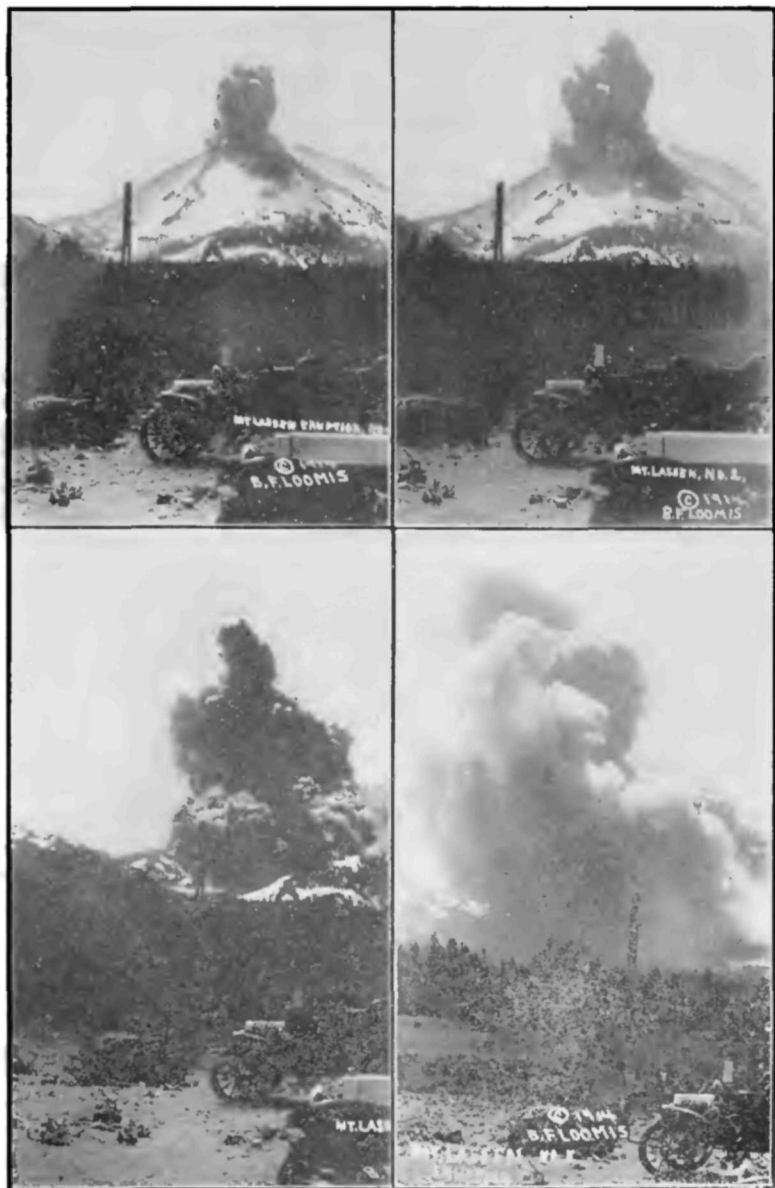


FIG. 2. THE ERUPTION OF JUNE 14, 1914. This series, showing four stages in the eruption beginning at 9:45 a. m., was obtained by Mr. B. F. Loomis, of Viola, from a point about six miles to the northwest at an elevation of nearly 5,000 feet. The time interval represented by the four views of the plate is about fifteen minutes.

from the crater. They all ran for their lives. Mr. Phelps hid under an overhanging rock, which sheltered him from the rocks which brushed past him as they fell. Lance Graham was a few feet away and was struck by a flying rock, which cut a great gash in his shoulder, piercing the thoracic cavity, and broke his collarbone. He was left on the mountain for dead for a time, but was afterward removed with great difficulty, and is now recovered. Another of their party ran down the mountain and, coming to a snowdrift, slid down the mountain like a shot. The cloud of smoke kept pace with him, and when he reached the bottom of the snowdrift he found a clump of bushes and, diving into it, buried his face in the snow to keep out the blinding smoke and ashes. The smoke is described as causing the blackest darkness, black as the darkest night.

The six photographs taken of this eruption by Mr. Loomis from a point at an elevation of about 5,000 feet and nearly six miles to the northwest of Lassen Peak are among the best that have been taken. The view reproduced in figure 2 is number three of the series and shows the steam and ash at about one half the height to which they were projected some ten or fifteen minutes later.

The writer's first trip to the mountain since the eruptions began was made by the Southern Pacific railroad to Red Bluff, thence by stage to Morgan Springs, a resort nine miles southerly in an air line from the peak and located in a valley nearly 5,000 feet above the sea. The week from June 21 to 28 during which no eruption occurred was spent on the mountain or at its base. Some of the hot springs and solfataras at the base of Lassen Peak were visited on the twenty-first and found to exhibit no unusual activity (see Figs. 7 and 8). From June 23 to 25, rainstorms, with snow on the higher levels, prevented a visit to the crater, with any possibility of photographic work. On the twenty-sixth, and the twenty-eighth, the sky was clear, and the new crater was visited and photographed from various points of view. Both trips were made from the hotel at Morgan as a base. The ride on horseback to the foot of the volcanic cone proper at that time took almost four hours, the latter half being over snow from ten to twenty feet deep. After leaving the horses the climb to the top can be made in less than an hour. The new crater has frequently been described as being located on the south slope of the north peak; this peak, however, is merely a fragment of the northern portion of the walls of the ancient crater. The relations of the new opening to the old volcano are better appreciated by describing it as an opening not in the center, but on the north side of the much eroded bowl of the crater. The central depression of the old crater is probably over three hundred feet below the higher points of the old rim. The wall of the old crater has been deeply breached both on the east and on the west, and in summer the melting snow in the depression now drains westward, although there is not enough surface water to make any regular channel. Volcanic dust or "ash" from the different eruptions has been reported as falling from ten to twenty miles from the peak, the amount and direction varying with the wind.



The limit of the heavy fall of ash not wind-borne was quite definitely marked on June 26 and was probably within a circle of less than a mile. It had not, however, a uniform border. In making the ascent on that day, instead of the regular trail a more easterly route was taken, leading up the southeasterly ridge directly to the fire lookout station. This ridge, which lies in the general direction of the longitudinal opening of the crater itself, was found to be much more heavily covered with ash than the regular trail. While the main outbursts were usually directly upward in the eruption described, irregular streaks of ash such as the one just noted prove that there were minor outshoots of volcanic dust in various directions. Exaggerated reports of the distance to which stones were thrown seem to have been based upon their being



FIG. 3. THE NORTHWESTERLY END OF THE CRATER ON JUNE 28. Whenever the steam was blown aside, a crack was visible extending in the line of steam jets.

found on the outer slopes of the old crater resting upon the surface of the snow, but the fact that stones are constantly being dislodged from the cliffs by ordinary weathering processes and are rolling down the mountain side shows the need of additional criteria. To avoid mistaking such stones for those thrown through the air by eruption, careful search was made on level patches of the old snow so located that it was impossible for stones to roll down upon them. Whenever such level surfaces were found there was no evidence at that time of ejected stones falling at a much greater distance than to the lookout house, certainly at no point over a half mile from the crater.

In climbing Lassen Peak from the southeast up to the crag upon which the Forest Service station is built the slope is so steep and rugged that the final ascent is made without any glimpse of what is ahead. As the last rocks are scaled and one stands on the wind-swept crag by the fragments of the little frame building once bound down to the rocks by



wire cables there suddenly yawns below the climber the bowl of the ancient crater, and he looks directly into the irregular naked chasm of the new vent torn in the opposite slope (Fig. 3). It is impossible for a camera with its narrow field of view to give correct impressions of the conditions of the mountain top. The observer standing upon that solitary, sharp, rocky pinnacle, although he narrows his vision to the new crater steaming below, is conscious of the steep slopes behind him and he also sees subconsciously the surrounding ragged edge of the bowl of the ancient crater.

Descending into the irregular basin, the new vent was photographed at closer range from various directions. No appreciable change occurred between June 26 and June 28, except the rapid disappearance of the new snow as a result of the warmer weather. The northwesterly end of the new crater (Fig. 2) was of most interest because of escaping steam. On close approach, the sulphur fumes became oppressive and yellow sulphur deposits near the vents were distinctly noticeable. The crater was apparently being extended longitudinally along cracks at either end. The northern wall showed also a transverse crack running back from the vent more than a hundred feet. The depth of the crater did not seem to be over eighty feet, but the continually caving sides suggested that the present bottom is but piled up debris. No suggestion could be obtained of the depth of the holes from which steam was escaping. By pacing a line parallel to the side and some fifty feet distant the length of the crater on June 28 was estimated at somewhat more than four hundred feet. This estimate is less than that given by some observers, but agrees closely with that made by Mr. Diller on June 20.

During the last week in July the writer again spent several days at the base of Lassen, this time approaching the mountain by the Susanville auto road which terminates at Drakesbad, a resort in Hot Springs Valley at the southeastern base of the peak. Unfortunately, the time of the second visit proved to be a period of quiescence, as had the first. In the month since the previous visit thirteen eruptions had taken place, the one on July 18 being reported by the Forest Service as "by far the most violent eruption to date. Ash, steam, etc., arose to a height of 11,000 feet. Duration practically the entire morning." Newspaper accounts of this eruption stated that the crater had been greatly enlarged yet the writer's photographs of July 25 compared with those taken June 26, with the same camera and from the same viewpoint were strikingly similar at first glance. Careful comparison indicated a lengthening of the crater of from forty to sixty feet and a proportionate widening, but the general shape and appearance were similar. The linear extension of the crater was evidently along the same crack marked by the steam jets in the June photograph (Fig. 3), and a sharp

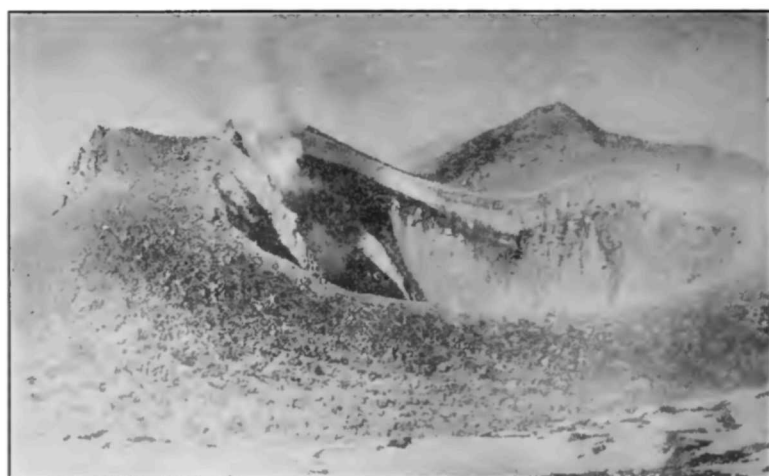


FIG. 4. GRADUAL ENLARGEMENT OF THE FIRST CRATER DEVELOPED ON LASSEN PEAK DURING THE ERUPTIONS OF 1914. (a) (above) the new crater on June 4, 1914. Photograph by R. H. Boerker. (Below) (b) the crater on July 25, 1914.

notch in the northern end suggested that the movement was likely to continue.

The winter's snow had largely disappeared, although the trail still passed over deep snow banks for nearly a mile in crossing the plateau-like shoulder at the south base of the peak proper. Near the top of the mountain snow was to be found only in patches and beneath the covering of ashes. Such areas moist from the melting snow, from a distance appeared almost black in comparison with the light gray of the dry dust found over the greater part of the mountain. This dust was so fine that it was easily moved by the wind. At times a strong gust would send immense clouds into the air, giving the appearance of an

eruption to casual observers at a distance. With the intense sunshine of a July day at that elevation and with the dry air marked differences in temperature occurred between sunlight and shadow and between wet and dry areas. Under these circumstances strong whirlwinds developed at intervals which sent the dust high into the air in columns strongly resembling steam jets. In fact, the writer when within two miles of the peak on July 25 for a time mistook them for new steam vents, all the more readily since they were situated along the line of reported extensions of the crater. Actual inspection of the area showed the real character of the columns and also that no new vents had been formed in that locality. Probably several of the incorrect reports of eruptions and of new craters came from the same failure to distinguish wind-formed dust clouds from steam explosions.

During the month of August there were but eight eruptions, fewer than either of the preceding months, and seven of the eight, all quite severe occurred August 19-23, inclusive, two of them throwing ash columns to a height of over 10,000 feet. The record for September shows seventeen eruptions, the largest number for any of the six months covered by the tabular list. During the month there was a continuous enlargement of the vent within the basin of the old crater and there were also new vents opened (see Fig. 4) on the outer slopes of the main cone. These vents are clearly identified from photographs taken by Mr. Jack Robertson of Oakland as being in line with the main axis of the first opening. Mr. Robertson had an interesting experience. He was at *Drakesbad* on the evening of September 19 when he heard a "tremendous explosion" during the night. The next morning he climbed the mountain and had the good fortune to watch at close range the eruption beginning at 11:30 A.M. (eruption no. 46) without receiving any serious injury. The crater was belching smoke at short intervals every few minutes and while he was quite near, steam and ashes poured out from its entire length. The ashes were so hot that they burned his feet as he walked over them. He reports having heard the roar and rumble of the explosions, but was not conscious of any apparent quaking of the ground.

The most marked changes in the new crater since the middle of June occurred during the month of September. The inner vent is reported to have grown to 900 feet in length and photographs taken early in October show that the area of the opening had become fully five times its area at the end of June. The severity of the September eruptions is also attested by the fact the lookout house (Fig. 5 and 6) was completely demolished on the twenty-ninth, no part of the walls being left standing. During the same eruption the forest lookout on Turner Mountain distinctly saw luminous bodies thrown out which appeared to him to be red-hot stones. This report is con-



FIG. 5. THE FIRE LOOKOUT STATION OF THE U. S. FOREST SERVICE ON JUNE 26, 1914. The holes in the roof were probably made during the eruption of June 14. The house has been entirely destroyed by later eruptions.

firmed by other observers, some of whom declare they saw flames. So far as known to the writer, this is the only reliable observation during these eruptions which may possibly be interpreted as indicating that there has ever been an approach to the temperature of molten lava. The coming of winter with frequent snowstorms at that elevation has prevented any search for ejected rocks bearing any evidence of recent subjection to great heat, and consequently the character of the luminous bodies remains undetermined.

The maximum severity for the entire period apparently occurred in September, but this is uncertain, since the record for October and No-



FIG. 6. THE LOOKOUT STATION AS SEEN ON OCTOBER 7.

vember is doubtless far from complete—the region extending from 15 to 20 miles around the mountain being almost if not entirely deserted by the last of October. The resort at Drakesbad at the southeastern base of the mountain closed for the season on September 21 and the headquarters of the forest service were removed to Red Bluff on October 12. The houses on the stock ranches in the vicinity are also deserted during the winter and the few wagon roads are blocked by deep snow until late in spring. Under the conditions indicated, the fact that October and November together are credited with but sixteen recorded eruptions furnishes no basis for any inference that volcanic activity on Lassen Peak is decreasing. At the date of reading proof the activity continues. A dispatch published in the *San Francisco Chronicle*, January 23, 1915, describes an eruption from a new crater on the east as equal to any which have gone before. The dispatch adds that no one has visited the volcano's summit for over two months.

An interesting suggestion concerning the November record comes in a private letter from Mr. Rushing. The eruptions from the summit which were observed during November were all ranked as medium in severity. The suggestion is that this may be explained by the fact that a new vent has been opened at a much lower level. The eruption of November 18 as seen by two observers at stations situated north of west from Lassen came from a point on the north slope of the mountain about a mile from the top and presumably near timber line. A comparison of distant observations from the north and from the south may soon test the correctness of this supposition.

Some further idea of the magnitude of the eruptions of Lassen Peak may be gained from the record of distant observers. A letter from Professor Charles F. Shaw, who was at Amadec about 65 miles eastward from Lassen Peak on October 23, contains particularly interesting observations. The eruption began at 5:40 P.M. The mountain showed plainly over the tops of the nearer hills and the smoke of the eruption was clearly silhouetted against the western sky, extending directly upward from the peak.

The smoke rolled up until practically the entire height [12,000 ft.; see list of eruptions] was reached before any change in form occurred, when just below the top of the column there was a tendency to stratification and a layer extended out toward the south and toward the north. When this appeared, the smoke column began to lean toward the north and from our point of vision, apparently toward the northeast and with this inclination of the column, distortion took place, the upper part spreading out into streamers. As soon as the inclination of the smoke column became very plain, we could readily distinguish indications of falling material. The lower two thirds of the column seemed to be dropping some material that was falling in a slightly oblique line, the obliqueness pointing back toward the mountain peak. As the eruption continued and the smoke column blew out more toward the north, the streaked condition indicating falling material became more and more apparent, but as the light was failing it became rather hard to distinguish the exact outlines of the lower portion of the column.



FIG. 7. SOUPAX SPRINGS SOUTHWEST OF LASSEN PEAK.

The falling matter must have been the stones and coarser material in distinction from the fine ash forming the top of the column of smoke. Professor Shaw's observation is the only one received by the writer that indicates the height to which the heavier fragments were thrown. "Two thirds" of the column would indicate a height of 8,000 feet.

There seems to be entire agreement by all the competent observers who were fortunately situated that in none of the eruptions has there been any molten lava emitted. Sunset glow upon the steam clouds has most probably accounted for some of the "flames" reported to the newspapers. Samples of the ash were submitted to Professor A. S. Eakle, of the Mineralogy Department of the University of California, and his report follows.



FIG. 8. TARTARUS LAKE (BOILING LAKE) IN HOT SPRING VALLEY.

An examination of the dust from the volcanic eruption of Mt. Lassen shows it to be made up of fine dust and broken fragments of an acid volcanic rock which has been shattered to pieces by a violent explosion. Under the microscope there are to be seen many small angular fragments of quartz, pieces of triclinic feldspar showing twinning structure, perhaps oligoclase in composition frayed sections of brown biotite and grains of magnetite. The original rock could not have been more basic than a dacite and the presence of so much quartz rather suggests a rhyolite. The dust is not an ash in the sense of being a fine residual product of a cinder and there is no evidence of its having come from the cooling of a molten mass. The original rock seems from the appearance of the largest fragments to have been a volcanic tuff formed at some previous activity of the volcano, and the late eruption has simply blown this tuff to dust.

The eruptions of Mt. Lassen while volcanic in their general classification are in the same category as geyser eruptions the difference existing mainly in the fact that the explosions of pent-up steam are so violent as to shatter and throw rock debris in the form of boulders and dust. It is a question whether the explosions are very deep seated.

Some of the mud from the locality is of the same nature as the dust and probably formed from it.

Numerous inquiries have come to the writer as to whether the eruptions of Lassen Peak are to be considered as truly volcanic, and Professor Eakle indirectly raises the same point. This is naturally a question of definition merely. A volcano is primarily an opening in the ground from which the internal forces of the earth project various materials, molten rock being an essential product *at some period* in the history of the volcano.

Many of the type examples of volcanic eruptions given in standard college text-books are, however, of the explosive type, in which no molten lava is ejected. The noted eruption of Bandai-San in Japan, on July 15, 1888, is an instance. This old volcanic cone, nearly 180 miles from Yokohama, had been without sign of life for a thousand years of recorded history, yet with only a few minutes of warning consisting of rumblings and moderate earthquake shocks the entire top of the mountain was blown away in some fifteen to twenty explosions lasting less than a half hour. There was no fresh lava or pumice thrown out. Ash and steam were projected upward about 1,000 feet, but the main force of the explosion was nearly horizontal, carrying destruction in a northerly direction for about four miles. The quantity of material blown away has been estimated at one third of a cubic mile.

In the case of Lassen Peak the period of quiescence had probably been greater than a thousand years, judging from the effect of erosion on the old cone. The force of the steam explosions to date has been distributed through six months, yet the height of the ash-laden column has several times reached two miles above the mountains. Had the steam been confined more effectively in Lassen and the force, instead



of being gradually liberated during the six months, been freed during a few minutes, the results would undoubtedly have been comparable to those at Bandai-San. The point, however, is that the difference is qualitative merely and that the nature and magnitude of the eruptions of Lassen Peak fully justify classing them as volcanic.

A study of the tabular summary of the eruptions gives little upon which to base an opinion as to whether the future will bring a fresh lava flow or whether there is being formed a new solfataric basin. The longest period of quiescence was from July 18 to August 10, twenty-three days. The eruptions in November, so far as observations have been made, do not differ materially from those in June. The fact that Soupan Hot Springs, Morgan Hot Springs and those in Hot Springs Valley are situated in valleys at so much lower levels than the new crater, and are apparently unconnected with Lassen, suggests the idea that the recent activity was due to a column of lava working its way upward along the core of the main peak and that this lava may yet issue as a surface flow. It is confessed, however, that the idea is based more on hope than on any scientific data. A visit in July to Bumpass' Hell showed a crater-like depression filled with hot springs, boiling mud pots, and solfataras, yet it is situated on the crest of a high ridge, some two or three thousand feet above Hot Springs Valley and Morgan Hot Springs. The longest diameter of the oval depression is about a quarter of a mile and the height of walls and general appearance are similar to those of the old crater on Lassen Peak. There was no indication that fresh lava flows had ever issued from the crater of Bumpass' Hell; on the contrary, there was strong suggestion that the depression had developed in the old lava by a process the initial stages of which must have strongly resembled the present condition of Lassen Peak.

If the writer were to offer any forecast it would be that the changes going on at the top of Lassen seem likely to form a solfataric basin of the same general character as that of Bumpass' Hell. However, while there is volcanic life there is a possibility of renewed lava flows. Meantime the physiographer has an opportunity of seeing within the United States, at least one phase of volcanic activity and that on a mountain recently occupied by alpine glaciers and standing in a great lava flow studded with minor volcanic cones, many of them almost untouched by erosion—the whole offering a most inviting field for scientific investigation.