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SEISMICITY OF THE LASSEN PEAK AREA, CALIFORNIA 1981 - 1983

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ABSTRACT

Over 700 earthquakes occurred in the vicinity of Lassen Peak, California, from February 1981 through December 1983. These earthquakes define a broad, northwest-trending seismic zone that extends from the Sierra Nevada through the Lassen Peak area and either terminates or is offset to the northeast about 20 kilometers northwest of Lassen Peak. Approximately 25% of these earthquakes are associated with the geothermal system south of Lassen Peak. Earthquakes in the geothermal area generally occur at depths shallower than 6 kilometers.

INTRODUCTION

Lassen Peak, in northern California, is the southernmost of the Quaternary Cascade volcanoes that stretch northward across Oregon and Washington into British Columbia. The last eruption of Lassen Peak occurred in 1917. It has a short-term eruption period estimated at 100-200 years or less and, after Mount St. Helens, is considered to be the most likely Cascade volcano to erupt in the future (Bailey and others, 1983).

The best-developed of any Cascade geothermal system is located directly south of Lassen Peak, primarily within the boundaries of Lassen Volcanic National Park. The preferred geothermal model consists of a central vapor-dominated reservoir that is underlain by a reservoir of hot water (Muffler and others, 1982). The vapor-dominated reservoir vents through fumaroles and hot springs located at higher elevations within Lassen Park. The hot water reservoir discharges through hot springs located at lower elevations south of the Park. The evolution of the Lassen geothermal system has been described by Sorey and Ingebritsen (1983).

Seismicity in the Lassen Peak area has been monitored since 1939 when the University Seismographic Station at Berkeley installed a seismograph at Mineral, 16 kilometers south of Lassen Peak. Using the Mineral station a large swarm of over 2300 earthquakes, including over 40 felt events, was documented between April 29 and August 31, 1946 (Robinson and Byerly, 1948). In a 14-month study Klein (1979) recorded earthquakes with a six-station network centered around the Lassen Park geothermal system. He measured an average level of seismicity of just under one locatable event per day of magnitude larger than 1.0 within 35 km of the network. Klein also recognized a broad northwest-trending seismic zone that extended through the western side of Lassen Park, as well as several concentrations of earthquakes south of Lassen Peak that he correlated with boundaries of the Mt. Tehama caldera.

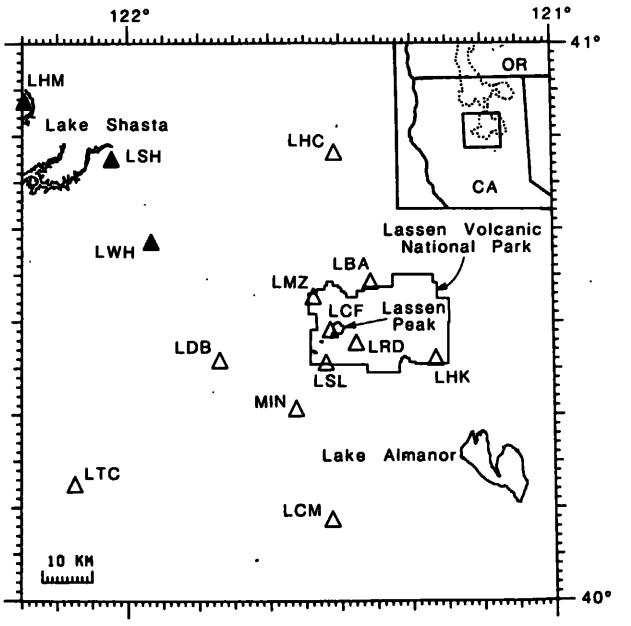


FIGURE 1

Seismograph stations in the Lassen Park area. Open triangles are stations that have been operated since at least late 1980. Solid triangles are stations operated only since 1982. Inset shows the area of the map and outlines the extent of Quaternary Cascade volcanism.

Seismicity in the Lassen area has been monitored continuously by the U.S. Geological Survey since February of 1981 using a seismographic network consisting of 14 vertical seismographs (1-sec period) arranged as shown in figure 1. Three of the seismographs are closely spaced in the geothermal area south of Lassen Peak. To locate the larger earthquakes in the Lassen area, especially those that occur in the area north of Lassen Peak, data from a nine-station seismic network around Mt. Shasta are also used. The Mt. Shasta network is located immediately northwest of the area shown in figure 1. The three northwestern seismographs shown in this figure are part of a seismic network around Lake Shasta that was installed in 1982.

Signals from all network stations are telemetered to the USGS in Menlo Park where they are recorded and processed. Earthquake hypocenters and magnitudes are calculated with the modified HYPO71 earthquake location program (Lee and Lahr, 1975). A velocity model of the Lassen area was developed for use with HYPO71 by inverting the arrival times of P-waves from local earthquakes to simultaneously estimate hypocenter parameters, station-corrections, and velocity model parameters (Crosson, 1976). Seventy-seven well-located earthquakes and three explosions of known origin time and location were used in the inversion. This velocity model is shown in Table 1.

To estimate the accuracy of the earthquake hypocenters, three near-surface explosions were relocated using this model. The relocated hypocenter of the explosion near station LRD had an epicentral error of about 50 meters and a focal depth error of 0.5 km. Thus we feel confident that epicenters of earthquakes occurring within the geothermal system are accurate to within 0.5 km. Focal depths are probably accurate to within 1.0 km. The epicentral accuracy is also quite good to the north of the park, as indicated by the relocation of an explosion 25 km northwest of Lassen Peak. The epicentral error was about 0.6 km with the depth placed at 0.5 km. The hypocentral accuracy is poorest to the southeast of Lassen Park where the Lassen volcanic rocks are bounded by the faster granitic rocks of the northern Sierra Nevada. Here the epicentral error for an explosion 20 km southeast of Lassen Peak was 1.5 km. Part of this error may have resulted from poor depth control which kept the earthquake at the trial focal depth of 3.0 km. In general, these absolute location errors correspond well with the relative residual errors (RMS) calculated by the HYPO71 location program. The location accuracy is less well determined for earthquakes that occurred in the western Lassen area, where no explosion data were available.

Lassen Model

Depth(km)	Velocity(km/sec)
0.0	4.3
2.0	5.5
4.5	6.0
6.0	6.17
9.0	6.35
24.5	7.2

TABLE 1.

Velocity model used in locating Lassen area earthquakes with the location program HYPO71 (Lee and Lahr,1975).

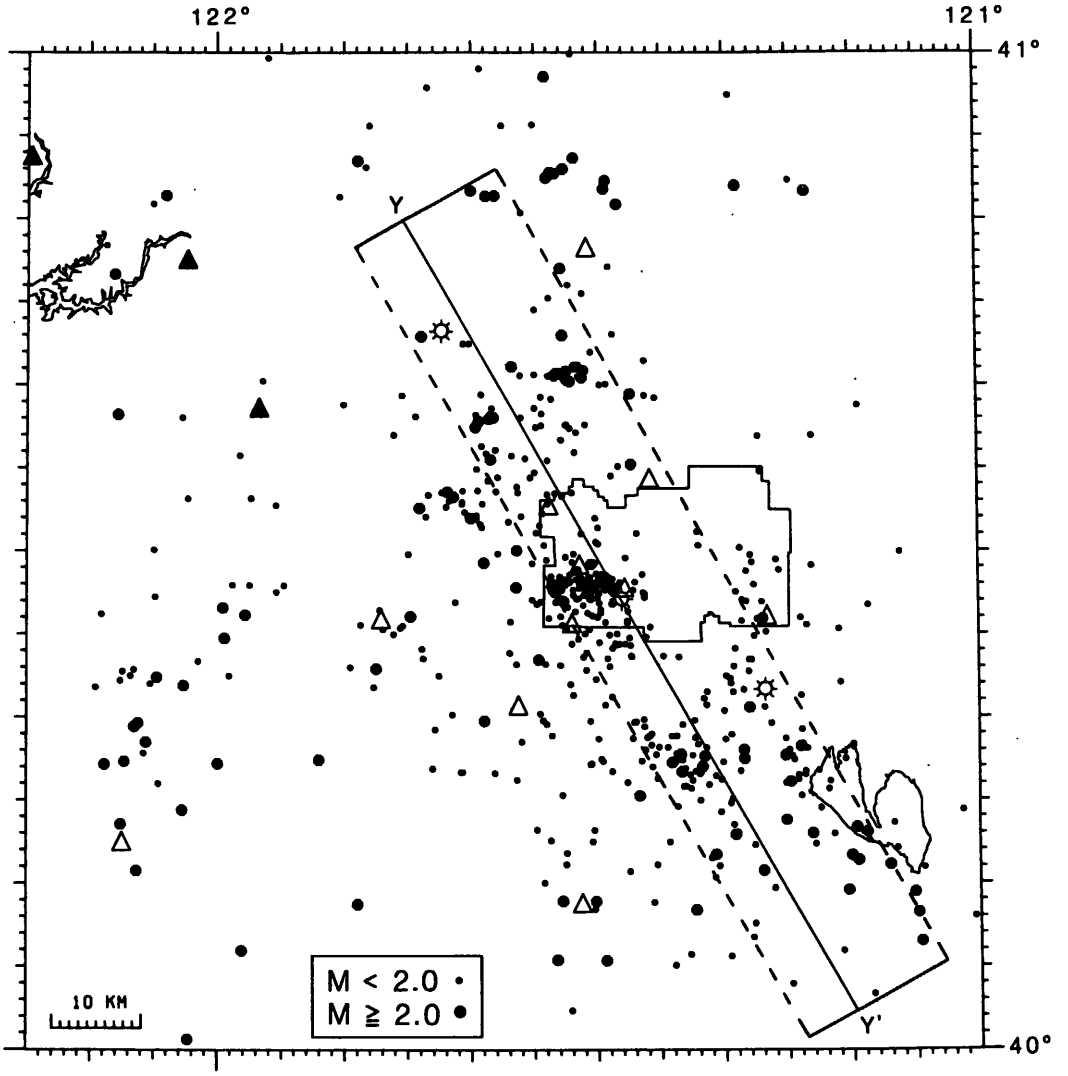
SEISMICITY OUTSIDE LASSEN PARK

Between February 1981 and December 1983, a total of 723 micro-earthquakes were located in the Lassen Peak area. Of these, only 18% were larger than magnitude 2.0, with only one earthquake of magnitude larger than 3.0.

Earthquakes in the Lassen area occur in several clearly defined zones (figure 2). The area of highest seismicity occurs directly south of Lassen Peak, within the boundaries of the Lassen Park geothermal system, as noted by Klein (1979). This activity occurs within a larger seismic zone that extends southeast toward the Sierra Nevada, previously described by Bolt and Miller (1971) and Klein (1979). The seismicity data presented in this paper suggest that this major zone terminates, or is offset, in an area roughly 22 kilometers northwest of Lassen Peak. In this area, seismicity has been characterized by earthquake swarms with numerous events larger than magnitude 2.0 (figure 2). In cross section (figure 3), they define a more or less vertical zone between 2 and 8 km depth. Few earthquakes occur to the northwest of these swarms along the trend of the major seismic zone. However, earthquakes do occur in a more diffuse pattern to the north, toward Mt. Shasta, apparently offset to the east from the northwesterly trend.

FIGURE 2

Earthquakes located in the vicinity of Lassen Peak between February 1981 and December 1983. Triangles show station locations as in Figure 1. ☼ show locations of seismic refraction explosions.



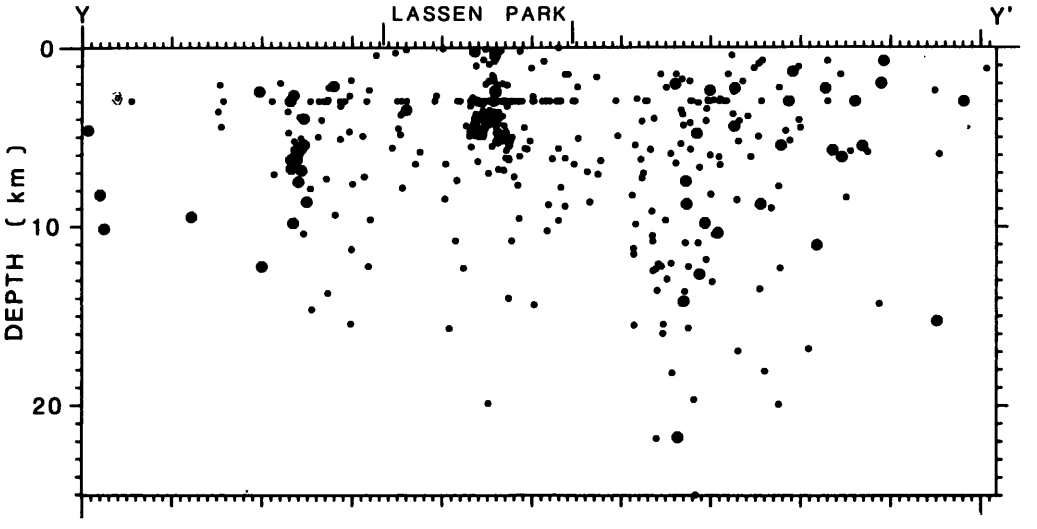


FIGURE 3

Cross section along the region Y - Y' shown in figure 2. Earthquakes whose depths are not resolved remain at the trial focal depth of 3 km. The horizontal scale is in kilometers.

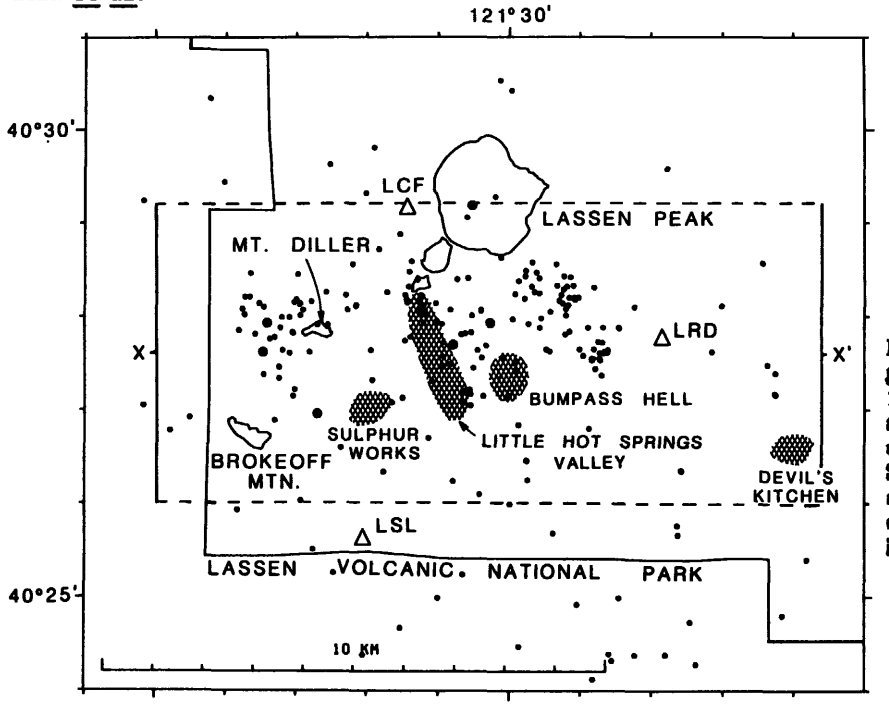


FIGURE 4

Earthquakes located in the Lassen Park geothermal area between February 1981 and December 1983. Major peaks are indicated by the 9,000-foot contour and hot spring areas are cross-hatched. Seismograph stations are shown by triangles. The dashed box is the area included in the cross section X - X', shown in figure 5.

LASSEN PARK SEISMICITY

Between 1981 and 1983, 175 earthquakes occurred in the geothermal area of Lassen Peak, nearly 25% of all Lassen area earthquakes (Figure 4). The seismicity in this zone typically occurs as small swarms of 10 to 25 earthquakes within periods of 1 to 3 days. Earthquakes in the geothermal area are shallow; nearly 95% occur at depths less than 6 kilometers (figure 5). However, there seems to be little seismic activity directly associated with the well-known hotsprings of Sulfur Works, Devil's Kitchen, and Bumpass Hell (figure 4). Similarly, few earthquakes occurred beneath Lassen Peak itself, the site of the 1915 eruption, nor in the dacite dome field that extends northward from Lassen Peak. The only hotspring area that closely correlates with the observed seismicity is Little Hot Springs Valley, where there is a general northwest- southeast trend in the distribution of earthquakes. Elsewhere seismicity was most intense beneath Mt. Diller and in the area between Lassen Peak and station LRD. The Mt. Diller activity occurred primarily at depths between 3 and 5 kilometers whereas that southeast of Lassen Peak extended from 6 kilometers to the surface.

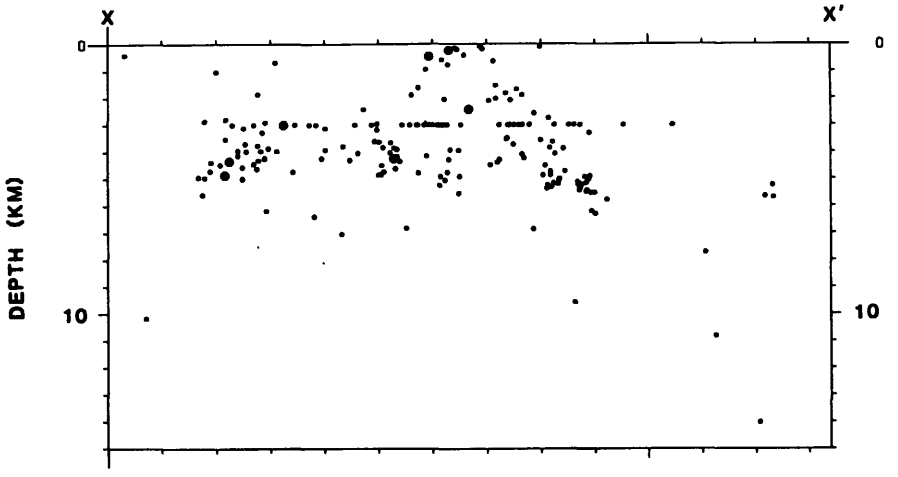


FIGURE 5

Cross section of earthquakes in the Lassen Park geothermal area, along the region X - X' shown in figure 4. The horizontal scale is in kilometers.

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