Mammoth Lakes Quiet but Concern Persists

Another earthquake swarm has ended, but that has not diminished the possibility of a volcanic eruption or a major earthquake

There was no eruption, and the largest earthquakes mostly knocked a bit of merchandise off the shelves. But seismologists and volcanologists view this latest episode in the Mammoth Lakes area as all too typical of events that can presage devastating developments. If experience at similar areas around the world is any guide, there could be years of such rumblings ahead.

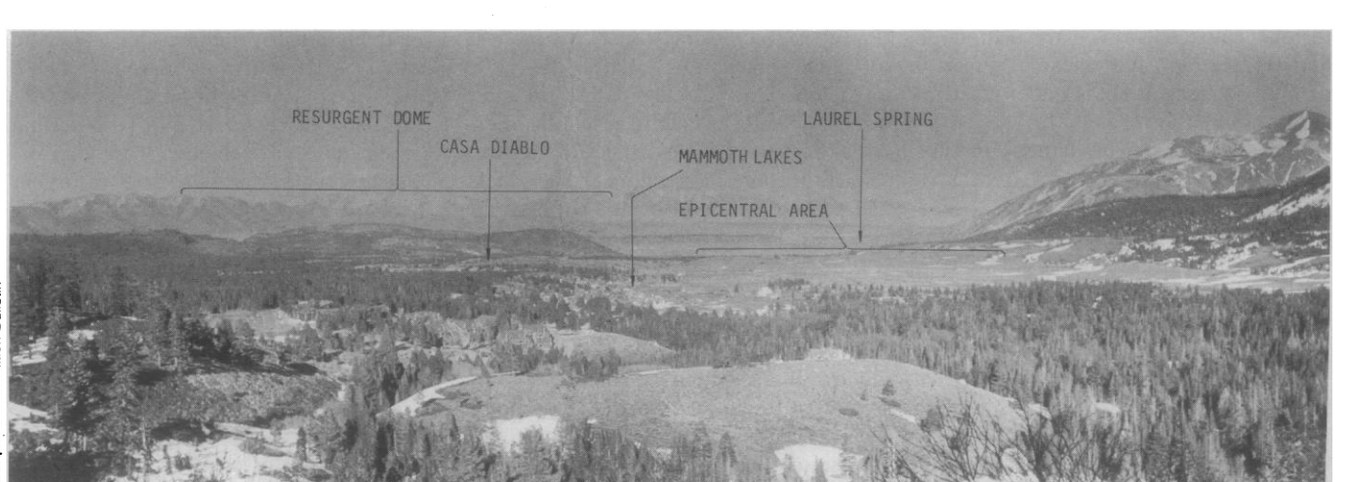
Most investigators firmly link the swarm of earthquakes that began the evening of 6 January to the magma chamber buried about 8 kilometers beneath Long Valley caldera near Mammoth Lakes. The southern edge of the 32- by 15-kilometer caldera, a broad depression dating from a gargantuan eruption 700,000 years ago, has been shaken since 1978 by an unusual series of earthquakes. The recent activity is only the latest, although among the strongest. After the four largest earthquakes in the series struck in May 1980, geophysicists resurveyed part of the caldera and found that the ancient bulge, or resurgent dome, over the magma chamber had risen 25 centimeters since 1975. By mid-1982, the 30-kilometer-wide uplift had risen another 7 centimeters, according to Jacob Messing, Francis Riley, and Roger Denlinger of the U.S. Geological Survey (USGS) in Denver. In fact, the entire caldera floor seems to have risen as much as 18 to 20 centimeters.

One of the simplest explanations for the recent swarm would be that it was releasing the stress created by the expansion of the magma chamber and the resulting uplift (*Science*, 18 June 1982, p. 1302). The swarm covered an elongated zone cutting northwest to southeast across the southern edge of the caldera southeast of the village of Mammoth Lakes. According to David Hill of the USGS in Menlo Park, California, the fault movements determined by preliminary analysis of a few of the larger earthquakes suggests, in a qualitative way, that they could have been relieving such magma-induced stress. If that is true, the movement of magma often cited as the underlying cause of the swarm would be deep beneath the magma chamber.

Although they are not yet ruling out the possibility, researchers have found no new evidence that a tongue of magma is moving toward the surface a few kilometers from the village of Mammoth Lakes, as seemed to be the case last spring. In early May, an intense earthquake swarm began in a small area at depths as shallow as 3.5 kilometers. It appeared to be the latest in a series of progressively shallower swarms. The resemblance of the swarms to the spasmodic tremor of moving magma and the appearance of new steam vents nearby prompted fears that magma was pushing toward the surface. A formal notice of volcanic hazard followed.

In hindsight, the possibility of a shallow tongue of magma is less substantial than once thought. Seismologists are raising questions about what constitutes spasmodic tremor and what these small, rapid-fire earthquakes really mean. In reviewing his seismic data, Alan Ryall of the University of Nevada finds that the trend from swarm to swarm was not strictly a progression toward the surface, although the May 1982 swarm was the shallowest detected to that time. The most recent swarm covered a much broader area that included the area of the May swarm, but this one extended from near the surface to a depth of 10 kilometers. Preliminary results from geophysical surveys in the area of the swarm show only the small amount of localized ground deformation expected from the earthquakes. Geothermal activity remains unchanged. And when a group at Brown University headed by G. Neumann searched last May for the suspected magma tongue using magnetotelluric techniques, they found nothing unusual in the area of the swarm. The magma tongue, if any exists, must be some way from breaking through to the surface.

Seismologists emphasize that there is probably no way to pin down the ultimate cause of the Mammoth Lakes activity. The uplift does seem to fit the



Earthquake Information Bulletin

Inside the Long Valley caldera

From left to right are: the resurgent dome that overlies the magma chamber and is the center of the current uplift; Casa Diablo, a center of hot springs; the village of Mammoth Lakes; and the epicentral area of the 1980–1982 swarms.

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Mono Craters, Mono Lake, and the Sierra Nevada

This chain of young volcanic craters snakes 30 kilometers into Long Valley caldera.

calculated response to an expanding magma chamber, as suggested by James Savage and Malcolm Clark of the USGS in Menlo Park. And swarms are usually associated with magmatic activity, or at least the disturbance it can cause in overlying hydrothermal systems, which Long Valley has in abundance. But this caldera also lies on the edge of a major seismic zone, where mountain-building forces have been shoving the Sierra Nevada upward as the Owens Valley drops downward. From this tectonic rather than volcanic viewpoint, regional tectonic stress may well have touched off the May 1980 earthquakes, seismologists say; that in turn could have prompted an injection of magma into the chamber, the inflation, and the subsequent swarms. There might still be an eruption, according to this view, but it would have a tectonic cause. However, the distinction between tectonic and volcanic causes, if it could be made at all, is rather academic, most agree.

The tectonic viewpoint does involve more than a philosophical exercise—it also reveals the hazard of a major earthquake (magnitude 7 or larger). One of the three largest earthquakes to hit California in historic times released the tectonic stress along a stretch of the fault zone south of Long Valley in 1872. Stress along a section to the north was released in 1932. In between, the earth has been acting strangely of late, notes Ryall. Not only has the Mammoth Lakes area been exceptionally active since 1978, but three other areas in the gap between historic major earthquakes have been six times more active since 1978 than during the previous 10 years. The earthquake history of this fault zone is not as well known as that of Central America, where such unusual activity would be taken as a possible harbinger of a future large earthquake. Still, seismologists take the possibility of a major earthquake seriously, especially since they recognize the pattern of recent activity as one that preceded the 1954 Fairview Peak–Dixie Valley earthquakes in Nevada.

A hint that purely tectonic stresses might have prodded the Mammoth Lakes area comes from the Coso caldera 150 kilometers to the south. Although it is smaller than Long Valley caldera and its volcanic activity is less recent, Coso is another geothermal area along the east front of the Sierra Nevada believed to harbor a residual magma chamber. According to Carl Johnson of the USGS in Pasadena, increasingly energetic swarms of earthquakes have struck the Coso area during the past 20 months. The most recent episode has yet to reach the intensity of previous ones, but the October swarm included a magnitude 5.2 shock. That Coso, which is located south of the 1872 break, and Long Valley both came to life at about the same time suggests the possibility of a physical connection, Johnson says; what it might be he does not know. One candidate would be a change in stress that affected the entire region of the fault zone.

Coso caldera's behavior is intriguing, but seismologists and volcanologists are eager to find calderas resembling Long Valley that have a long record of similar behavior in historic times. Mount St. Helens erupted before a systematic search for analogs to its behavior was made, but Mammoth Lakes has been more accommodating.

An ongoing search for analogs by Christopher Newhall of the USGS in Vancouver, Washington, is turning up some interesting possibilities. One is a large caldera called the Ahlegraean Fields beneath the Italian town of Pozzuoli, a suburb of Naples. An episode of uplift and seismic swarms that began in 1969 raised Pozzuoli 170 centimeters; a slow deflation has been under way since 1972. Subsurface magma intrusions or changes in the underlying hydrothermal system appear to have caused past uplifts, Newhall says. Another likely analog is Rabaul caldera on the island of New Britain northeast of New Guinea. Volcanoes in and around the caldera erupted in 1850, 1878, 1937, and 1941, each time preceded by a few meters of uplift and considerable seismic activity. The most recent episode of uplift began in 1971. No volcano has erupted yet.

An important analog to the Mammoth Lakes activity that is closer to home is Yellowstone caldera, says Newhall. Robert Smith of the University of Utah notes that those fascinating geysers and hot springs of the national park are nestled within a 35- by 65-kilometer caldera sitting on top of a suspected magma chamber. Like Long Valley, Yellowstone is shaken by both earthquake swarms and larger felt earthquakes; the largest recent shock was one of magnitude 7.1 in 1959. The entire floor of the caldera rose a maximum of 70 centimeters between 1921 and 1975; this uplift was, like Long Valley's, greatest over the caldera's resurgent domes.

Newhall's preliminary conclusions offer some reassurance but do nothing to ease concerns about a possible eruption at Long Valley. It appears, he says, that relatively small proddings by magmatic activity "can cause uplift over a much larger area than might be expected, because the caldera and its hydrothermal system are so sensitive" to thermal changes. Thus, uplift over a resurgent dome or even the entire caldera floor does not imply that the whole volcanic system is going to let loose, he says. But the recent swarms and uplift must be taken seriously because they are so similar to the precursors of some—but not all—eruptions in similar settings. It is also obvious, he says, that "When dealing with a very large system like this, the manifestations of unrest can go on for a long time before anything occurs at the surface." If Long Valley is building up to anything, the prelude could be a lengthy one.—**RICHARD A. KERR**