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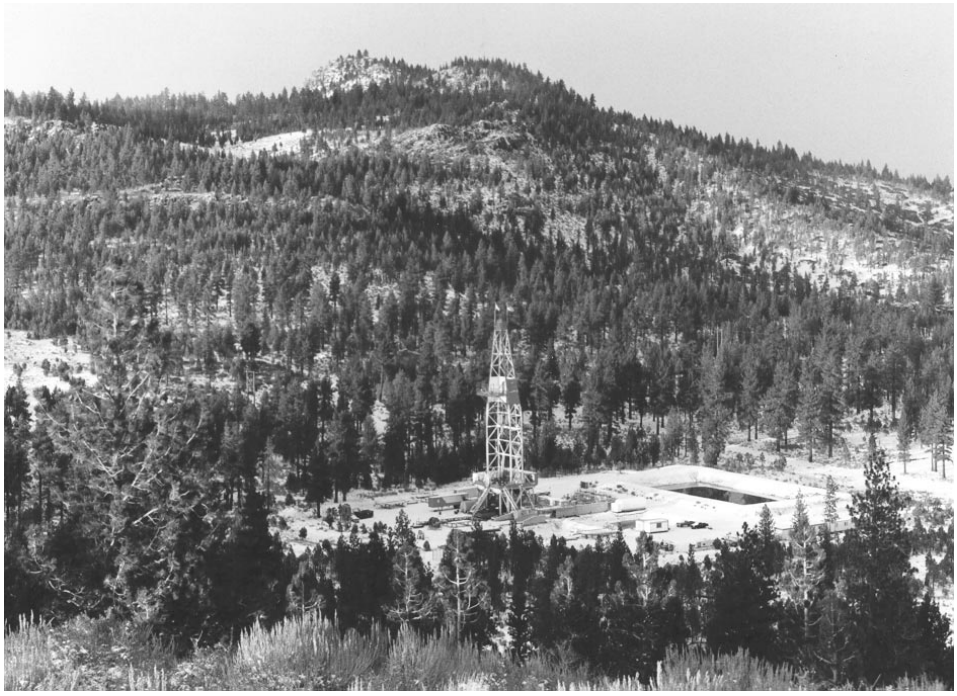
U.S. GEOLOGICAL SURVEY—REDUCING THE RISK FROM VOLCANO HAZARDS

Scientific Drilling in Long Valley, California—What Will We Learn?

Long Valley in eastern California is one of several large volcanic depressions (calderas) around the globe that have shown signs of molten rock (magma) movement at depth in the last several decades. In an effort to gather crucial data on the geologic processes occurring directly above an inflating magma chamber, scientists are deepening an existing 7,200-foot drill hole in a dome-like uplift in the center of Long Valley Caldera during the summer and fall of 1998.



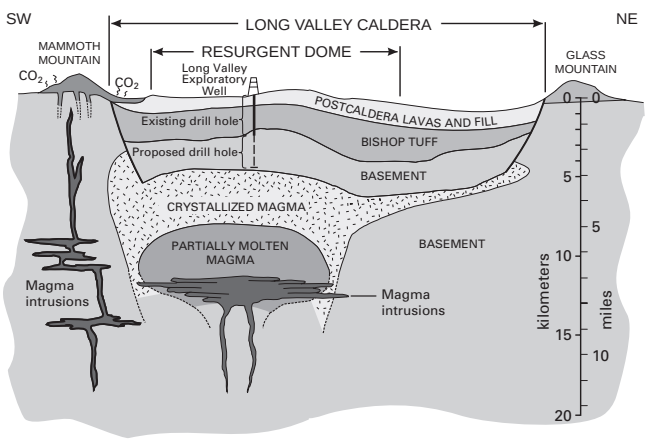
The Long Valley Exploratory Well is sited directly over the center of uplift on Long Valley Caldera's resurgent dome. Phase III drilling, begun in the summer and lasting through the fall of 1998, will extend the 7,200-foot-deep hole to between 11,500 and 13,000 feet, and greatly increase scientific knowledge of this restless volcano.

The Long Valley Caldera region, located at the boundary between the Sierra Nevada and the Basin and Range Province in eastern California, encompasses a large volcanic complex whose eruptive history began nearly 4 million years ago. Volcanic activity in the area occurs on an average of every few hundred years, with the last eruption happening as recently as 250 years ago.

Long Valley Caldera was produced by a catastrophic eruption about 760,000 years ago and has recently been showing signs of unrest. Since 1980, when renewed earthquake activity and ground deformation caused concern over a possible volcanic eruption, scientists with the U.S. Geological Survey (USGS) have been closely monitoring the Long Valley region. Recurring earthquake swarms and uplift of the central section of the caldera (resurgent dome) continue today. This activity has also been accompanied by increased carbon dioxide (CO_2) gas emissions on Mammoth Mountain and changes in hot springs in the region.

Evidence from a range of USGS studies indicates that current volcanic unrest is driven by molten rock (magma) intrusions in at least two areas underground—one beneath the resurgent dome and a second beneath Mammoth Mountain at the southwest margin of the caldera.

CROSS SECTION OF LONG VALLEY CALDERA



Phase III drilling in Long Valley Caldera will extend the existing drill hole to between 11,500 and 13,000 feet, providing the possibility of penetrating the thick, rapidly cooled ("chilled") roof zone of crystallized magma that lies beneath the caldera's resurgent dome. Data from the roof zone may be a key to understanding the present developmental stage of this magma system.

Drillsite History

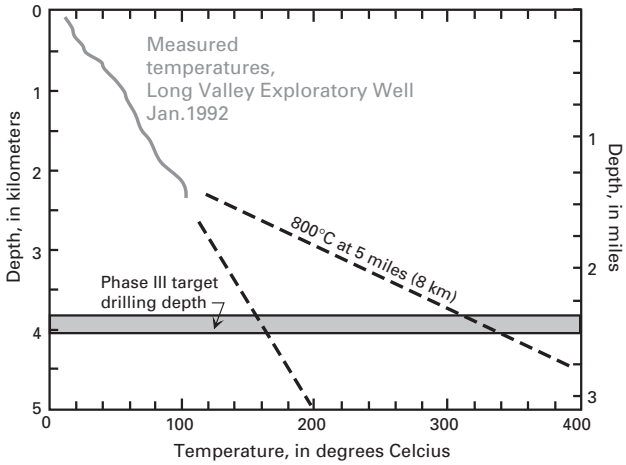
The Long Valley Exploratory Well (LVEW) is located on Long Valley Caldera's resurgent dome, directly over the center of inflation (total uplift since 1980 is more than 2 feet) and at the northern margin of recent earthquake swarm activity.

Drilling at LVEW began in 1989 (Phase I) with plans to explore geothermal energy extraction at high temperatures from near a magma chamber. Phase I drilling was completed to a depth of 2,560 feet, and in 1991 Phase II was completed to a depth of 7,200 feet. A number of scientific experiments were performed in the drill hole, with emphasis on investigating the geothermal energy potential. Data from Phase II demonstrated that downhole temperatures were too cold for economically viable geothermal power generation.

Numerous scientific accomplishments resulted from the first two phases of LVEW drilling. Information from rock cores taken out of the hole enabled scientists to better define the geologic origin, history, and structure of Long Valley

Caldera. Borehole televiewer images and downhole temperature recordings provided important information on the stress within the resurgent dome and on the physical properties of the caldera rocks.

In an attempt to obtain additional information on magmatic processes at depth, LVEW Phase III, begun in the summer and lasting through the fall of 1998, will extend the 7,200-foot-deep hole to between 11,500 and 13,000 feet. Phase III is a collaborative effort of USGS and other scientists to acquire subsurface data that will complement results obtained from surface studies and previous drilling phases. On-site science experiments are scheduled and coordinated by the USGS.



Temperature profile from Long Valley Exploratory Well. The two dashed extensions of the existing profile show the extremes of temperature that might be expected in the deeper hole. If downward movement of surface and shallow groundwater persists, then temperatures of 160°C (320°F), as predicted by the lower curve, can be expected at the target depth of Phase III drilling. However, if there is a substantial body of near-molten rock at a depth of 5 miles and no downward movement of relatively cool water, then temperatures as high as 320°C (600°F) might be recorded at the target depth.

Why Drill Deeper?

The ability to make direct geologic and geophysical observations at greater depths could potentially answer a number of long-standing questions on the nature of actively deforming volcanic areas such as Long Valley. The drilling may provide data crucial to assessing the possibility of future volcanic eruptions and their associated hazards, including earthquakes, as well as a better evaluation of geothermal potential in the Long Valley area.

Further drilling provides the possibility of penetrating the thick, rapidly cooled ("chilled") roof zone of the Long Valley magma chamber. Data from the roof zone may be a key to understanding the present developmental stage of the magma system in the region. Should the drilling intersect very young magma intrusions (dikes), it could greatly increase understanding of the underlying magma chamber.

An important goal of this project is to retrieve a continuous cylinder of rock (core) from the newly deepened hole. An onsite core facility will house a lab for doing preliminary analysis of the core. Complete descriptions of fractures, mineralogy, and rock type will be made, as well as a photographic record of the core and an analysis of fluids. Core obtained will ultimately be archived in the USGS core repository in Denver, Colorado, and be available to future investigators.

By drilling deeper, scientists may be able to resolve uncertainties in the temperature profile beneath the resurgent dome. Temperatures of 50 to 60°C (90 to 120°F) higher than the 100°C (212°F) measured at the current depth of 7,200 feet should be expected. Earthquakes under the resurgent dome occur no deeper than 3 miles, and this depth cut-off is believed to be temperature controlled. Elsewhere in Long Valley area, earthquakes occur deeper than 6 miles.

Could the Drilling Trigger an Eruption?

The specified temperature and environmental conditions that are considered limiting factors to Phase III drilling make triggering an eruption extremely improbable. Drilling will be stopped if (1) bottomhole temperature exceeds 320°C (600°F), which is still well below the temperature of magma (800°C/1470°F), (2) unusual seismic activity occurs, or (3) an influx of gas into the well is detected. The well will be equipped with a blowout preventer, a series of devices mounted at the top of the hole. If a pressure surge is detected, the blowout preventer devices close off the drill hole, so that no gases escape.

Long Term Science

Following completion of Phase III drilling in the fall of 1998, the drill hole will be left for about a year to allow a series of temperature records to be obtained. After a year, temperature disturbances from the drilling process should have largely subsided, allowing a satisfactory "equilibrium" temperature profile to be established. Once this has been done, the hole can be used to monitor changing conditions beneath the resurgent dome. Temperatures, water levels, and gas emissions will continue to be measured periodically. A downhole seismometer will record earthquakes, and other instruments will record ground deformation beneath the dome.

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COOPERATING ORGANIZATIONS
(Principal Funding Agencies for Phase III drilling**)

[1]United States Geological Survey**
California Energy Commission**
Deep Observation and Sampling of the Earth's Continental Crust
Duke University
International Continental Drilling Program**
Lawrence Livermore National Laboratories
Mono County
Niedersächsisches Landesamt für Bodenforschung
Ocean Drilling Program
[2]Sandia National Laboratories**
[4]Stanford University
Town of Mammoth Lakes
United States Bureau of Land Management
United States Forest Service
[3]University of Wisconsin

An important goal of Phase III drilling at the Long Valley Exploratory Well is to retrieve a continuous cylinder of rock (core) from the newly deepened hole. Diamond coring bits (right) will be used to cut lengths of core (left) as long as 30 feet.

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http://quake.wr.usgs.gov/VOLCANOES/LongValley/

See also

Living With a Restless Caldera—Long Valley, California (USGS Fact Sheet 108-96),

Invisible CO_2 Gas Killing Trees at Mammoth Mountain, California (USGS Fact Sheet 172-96), and

Future Eruptions in California's Long Valley Area—What's Likely? (USGS Fact Sheet 73-97)