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Invisible CO_2 Gas Killing Trees at Mammoth Mountain, California

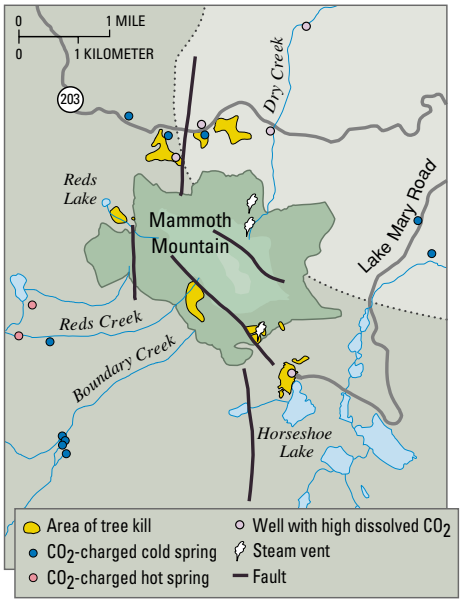
Since 1980, scientists have monitored geologic unrest in Long Valley Caldera and at adjacent Mammoth Mountain, California. After a persistent swarm of earthquakes beneath Mammoth Mountain in 1989, geologists discovered that large volumes of carbon dioxide (CO_2) gas were seeping from beneath this volcano. This gas is killing trees on the mountain and also can be a danger to people. The U.S. Geological Survey (USGS) continues to study the CO_2 emissions to help protect the public from this invisible potential hazard.

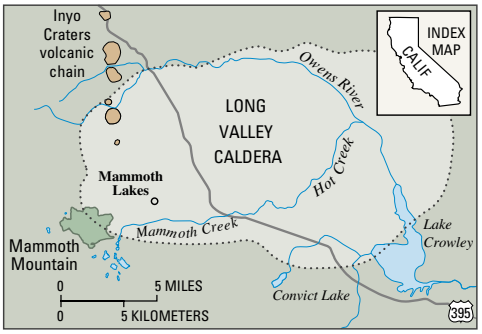
Mammoth Mountain, a young volcano in eastern California, sits on the southwest rim of Long Valley Caldera. In 1994, scientists detected high concentrations of CO_2 gas in the soil on Mammoth Mountain. This invisible gas, seeping from beneath the volcano, is killing trees on the sides of the mountain and can pose a threat to humans. Recent measurements indicate that the total rate of CO_2 gas emission at Mammoth Mountain is close to 300 tons per day. In this photo, large areas of dead and dying trees are visible near Horseshoe Lake, on the southeast flank of Mammoth Mountain. (Copyrighted photo courtesy of John D. Rogie.)

Mammoth Mountain is a young volcano on the southwest rim of Long Valley Caldera, a large volcanic depression in eastern California. The Long Valley area, well known for its superb skiing, hiking, and camping, has been volcanically active for about 4 million years. The most recent volcanic eruptions in the region occurred about 200 years ago, and earthquakes frequently shake the area. Because of this, the U.S. Geological Survey (USGS) operates an extensive network of instruments to monitor the continuing unrest in the Long Valley area.

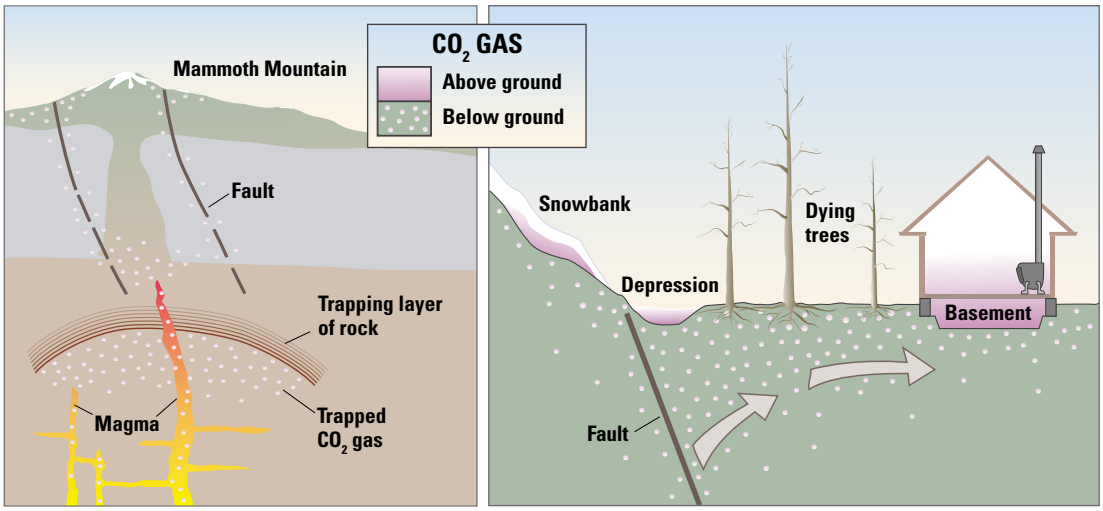
Numerous small earthquakes occurred beneath Mammoth Mountain from May to November 1989. Data collected from monitoring instruments during those months indicated that a small body of magma (molten rock) was rising through a fissure beneath the mountain. During the next year, U.S. Forest Service rangers noticed areas of dead and dying trees on the mountain. After drought and insect infestations were eliminated as causes, a geologic explanation was suspected. USGS scientists then made measurements and discovered that the roots of the trees were being killed by exceptionally high concentrations of carbon dioxide (CO_2) gas in the soil. Today, areas of dead and dying trees at Mammoth Mountain total more than 100 acres. The town of Mammoth Lakes, just east of this volcano, has not been affected.

Although leaves of plants produce oxygen (O_2) from CO_2 during photosynthesis, their roots need to absorb O_2 directly. The high CO_2 concentrations in the soil on Mammoth Mountain are killing trees by denying their roots O_2 and by interfering with nutrient uptake. In the areas of tree kill, CO_2 makes up about 20





Areas of dead and dying trees at Mammoth Mountain volcano total more than 100 acres. In 1990, the year after a persistent swarm of small earthquakes occurred beneath the volcano, U.S. Forest Service rangers first noticed areas of tree kill. When U.S. Geological Survey scientists investigated, they discovered that the trees are being killed by high concentrations of CO_2 gas in the soil. The seepage of CO_2 gas from below Mammoth Mountain and the continued occurrence of local earthquakes are signs of the ongoing geologic unrest in the area. The upper part of the 11,053-foot-high volcano (above 9,500 feet) is shown in darker shades of green.



CO_2 gas seeping from the ground at Mammoth Mountain is likely derived from magma (molten rock) beneath the volcano. In 1989, rising magma may have opened cracks, allowing large amounts of trapped CO_2 gas to leak upward along faults. High concentrations of CO_2 in soil can kill the roots of trees. CO_2 gas is heavier than air, and when it leaks from the soil, it can collect in snowbanks, depressions, and poorly ventilated enclosures, such as cabins and tents, posing a potential danger to people.

to 95% of the gas content of the soil; soil gas normally contains 1% or less CO_2.

When CO_2 from soil leaves the ground, it normally mixes with the air and dissipates rapidly. CO_2 is heavier than air, however, and it can collect at high concentrations in the lower parts of depressions and enclosures, posing a potential danger to people. Breathing air with more than 30% CO_2 can very quickly cause unconsciousness and death. Therefore, poorly ventilated areas above and below ground can be dangerous in areas of CO_2 seepage. Where thick snowpacks accumulate in winter, the CO_2 can be trapped within and beneath the snow. Dangerous levels of CO_2 have been measured in pits dug in the snowpack in tree-kill areas on Mammoth Mountain, and snow-cave camping in such areas is not advised.

Geologists have detected CO_2 emissions, like those at Mammoth Mountain, on the flanks of other volcanoes, including Kilauea in Hawaii and Mount Etna in Sicily. Measuring the total rate of CO_2 gas emissions on the flanks of volcanoes or within calderas is difficult and labor intensive and is commonly done using portable infrared CO_2 detectors.

Recent measurements at Mammoth Mountain indicate that the total rate of CO_2 gas emission is close to 300 tons per day. This value varies on both short (days to weeks) and long (months to years) time scales because of changes in atmospheric conditions and in the rate at which gas is being released from beneath the volcano.

Past eruptions at Mammoth Mountain, such as the phreatic (steam blast) eruptions that occurred about 700 years ago on the volcano's north flank, may have been accompanied by CO_2 emissions. Scientists think that the current episode of high CO_2 emissions is the first such activity on the mountain for at least 250 years because the oldest trees in the active tree-kill areas are about that age. Carbon-isotopic analyses of the annual growth rings in trees near the margins of the tree-kill areas imply that the gas-emission rate reached a peak in 1991, subsequently declined, and then has been relatively stable since about 1996.

CO_2 and other volcanic gases, like helium, seeping from Mammoth Mountain appear to be leaking from a large reservoir of gas supplied by repeated intrusions of magma. Tree-ring evidence from near springs on the mountain's flanks shows that some CO_2 gas was leaking before 1989 and dissolving in the ground-water system. It is likely that the latest intrusion of magma (in 1989) opened deep fractures, increasing the rate of gas seepage.

The continuing occurrence of small earthquakes and CO_2 seepage beneath Mammoth Mountain are only two of the many signs of volcanic unrest in the area. Earthquakes and ground uplift are also occurring within the central part of Long Valley Caldera, only a few miles east of Mammoth Mountain, and the Mono-Inyo Craters volcanic chain to the north has had small volcanic eruptions every few hundred years for the past 4,000 years.

Scientists with the USGS Volcano Hazards Program are closely monitoring CO_2 emissions and other geologic hazards at Mammoth Mountain. The work of these scientists is only part of the USGS Volcano Hazards Program's ongoing efforts to protect people's lives and property in all of the volcanic regions of the United States, including the Pacific Northwest, Alaska, Hawaii, and Arizona.

In 1989–90, trees in this area on the south side of Mammoth Mountain volcano began dying from high concentrations of CO_2 gas in the soil. Although leaves of plants produce oxygen (O_2) from CO_2 during photosynthesis, their roots need to absorb O_2 directly. High CO_2 concentrations in the soil kill plants by denying their roots O_2 and by interfering with nutrient uptake. In the areas of tree kill at Mammoth Mountain, CO_2 makes up about 20 to 95% of the gas content of the soil. Inset shows scientists measuring soil gas in this area.

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See also *Living With a Restless Caldera—Long Valley, California* (USGS Fact Sheet 108–96) and *Future Eruptions in California's Long Valley Area—What's Likely?* (USGS Fact Sheet 073–97)