Volcanoes, Quakes, and the Connectedness of Things

With a major volcanic eruption in Washington and earthquakes rumbling from one end of California to the other, the West Coast has been a busy place during the last 2 years. All this activity has geophysicists wondering, for the first time in any serious way, whether there might actually be connections between such widely separated events. There are no clear answers now, but researchers have a new open-mindedness on the subject.

Prompted by the eruption of Mount St. Helens, Roy Bailey of the U.S. Geological Survey (USGS) in Reston, Virginia, has shown that the Cascade volcanoes, which are strung out along several hundred kilometers, have in the past behaved as if they are not totally independent of each other. By compiling historical accounts of volcanic activity, Bailey identified a period of about 40 years in the middle of the 19th century during which activity in the region was exceptionally high. During several years, two or three volcanoes erupted at the same time, he says. Then, the Cascades subsided into a quiescent period relieved only by the eruption of Mount Lassen in 1915. Within the past 5 years, Mount St. Helens erupted, Mount Baker began steaming, and unusual seismic activity occurred near Mount Hood and Mount Shasta. That, says Bailey, is more activity than has been seen in the previous 100 years.

U.S. Geological Survey

Other researchers searching historical records have linked such concerted volcanic activity elsewhere to the occurrence of great earthquakes. Masaki Kimura and William McCann of Lamont-Doherty Geological Observatory found the best example to be the 40 years of activity at a half dozen volcanoes on the Soviet Kamchatka peninsula that preceded the magnitude-9 earthquake of 1952. Twenty years of volcanic quiescence in that 400-kilometer-long region followed. On a finer time scale, Michael J. Carr of Rutgers University found a 10-year period of relatively few eruptions immediately before the quake.

Although they are not certain of the exact mechanism, these researchers suspect that volcanoes and great earthquakes are connected through the strain that builds up in the earth over a large region as one crustal plate dives beneath another, which happens beneath the Cascades and Kamchatka. Before the strain becomes so great that an earthquake releases it, the strain might control the flow of magma to the surface, they suggest. Fortunately for those living in the Cascades, the strain there does not seem to have ever produced a great earthquake.

In California, a regional strain change has been directly observed for the first time, perhaps in association with earthquake activity (*Science*, 15 February 1980, p. 748). In early 1979, James Savage and his group at the USGS in Menlo Park detected a slight easing of the strain that squeezes the opposite sides of the San Andreas fault together. This strain event extended along about 300 kilometers of the fault. Some researchers have suggested a connection between the October 1979 Imperial Valley earthquake in far southern California and anomalously high concentrations of natural radon gas observed in water wells 300 kilometers to the north months earlier. The logical connection, they say, would be a regional change in strain like the one observed. Soviet and Chinese researchers have used such apparent distant precursors to successfully predict earthquakes in their countries.

Although a detectable strain event did not encompass the entire state of California in 1979, that year did mark a sharp resurgence of earthquake activity throughout California and adjoining areas, according to Charles Bufe of the USGS in Reston, Virginia, and Tousson Toppozada of the California Division of Mines and Geology. The decades of the 1960's and 1970's were the quietest, with a total of four earthquakes of magnitude 6 or greater, in a record going back to 1850, he says. Seven such earthquakes have occurred since 1979. The probability that simultaneous surges in earthquake activity occurred in widely separated areas purely by chance is not zero, Bufe says, but it is quite small.

With these kinds of observations in mind, American researchers are for the first time giving serious consideration to the possibility that "unreasonable" distances of hundreds of kilometers between volcanic or seismic events do not preclude their being connected, perhaps by regional changes in crustal strain. Whether such connections could bridge the thousands of kilometers between recent California earthquakes and Mount St. Helens is the most speculative question of all.

The Mountain Is Behaving Itself—For Now

Once it settled down following its stunning eruption on 18 May 1980, Mount St. Helens took up a pattern of behavior that seems to make the prediction of eruptions easy. None of its later eruptions failed to give at least a few hours' warning, and researchers predicted the most recent one 10 days in advance.

The most useful short-term warning has been an increase in seismic activity beneath the crater. "Every single eruption has had some activity that we have at least been suspicious of and that led to the [U.S.] Geological Survey being notified," says Stephen Malone of the University of Washington. Only once has one of those notifications been a false alarm, he says.

There have now been eight significant eruptions since 18 May 1980, and seismologists find that one of two kinds of seismic activity has preceded each eruption by at least a few hours. If no dome of solidified lava capped the mouth of the crater, seismographs picked up harmonic tremors, a continuous seismic rumble apparently pro-

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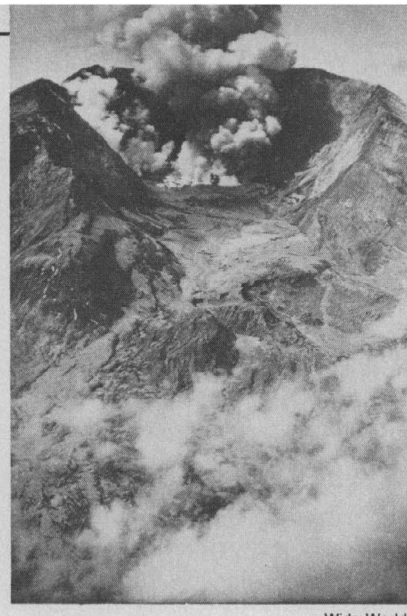
duced by the movement of magma within the mountain. If previous eruptions left a dome, the number of small, shallow earthquakes increased before a major eruption, suggesting that rock was breaking under stress. The cause of the difference in behavior is not known, Malone says, but perhaps the weight of the dome controls the style of activity. Researchers have not been able to predict what kind of eruption—an explosion of steam and ash or a quiet oozing of thick lava—will follow precursory seismic activity. That may never be possible, Malone says.

Conveniently for volcano forecasters, researchers have identified an intermediate-term warning that seems to be independent of the short-term seismic warning. Donald Swanson and Robin Holcomb of the U.S. Geological Survey in Vancouver, Washington, predicted the 10 April eruption 10 days in advance from the swelling of the crater. Swanson and Holcomb detected sudden surges in the swelling of the upper cone about 2 weeks before eruptions in December and February. When the swelling surged again in late March, to a rate of about 2 centimeters per day, they felt confident enough to call for an "extended advisory" warning of the "likelihood of an eruption within 2 weeks."

Although the frequency of eruptions has not changed, the last three have been of the quieter dome-building variety. But no one is saying that Mount St. Helens cannot revitalize itself. The Soviet volcano Bezymianny, which blew out part of its cone in 1956, experienced one of its largest eruptions in 1979. Anticipating such dramatic shifts in the pattern of behavior will likely be the volcano-watchers' next challenge.



Wide World

Gauging Volcanic Blast Hazards Not So Simple

Scientists who studied the geologic record of volcanic deposits surrounding Mount St. Helens did not anticipate the 28-kilometer reach of the 18 May 1980 blast, which devastated 600 square kilometers of forest. In spite of their destructive nature, blasts have been among the most poorly understood volcanic phenomena in the geologic record. With Mount St. Helens as an example, geologists can now see why. That blast left only a thin, fragile layer of debris, which is now falling prey to erosion. Even with a fresh example to study, forecasting the threat from future blasts is liable to be an uncertain business.

At least one relatively small blast from Mount St. Helens probably preceded the 1980 event. In a 1978 publication in which they evaluated the potential hazards at Mount St. Helens, Dwight Crandell and Donal Mullineaux of the U.S. Geological Survey (USGS) in Denver briefly noted a 1000-year-old deposit from a "strong laterally directed explosion [that] threw rock debris from side of dome (Sugarbowl) NE to [a] distance of $\geq$ 6 km." The debris layer was thin and contained bits of soil and charred wood, suggesting the violent passage of hot ash and gases along the ground. Crandell and Mullineaux observed that the potential hazards of an eruption would include the carrying of "steam and rock fragments from the dome outward at a high speed to distances of at least 10 km."

One problem with such forecasting of future hazards is gauging the area of destruction from the area of deposit that remains, according to C. Dan Miller of the USGS in Denver, who has been studying the 1980 blast deposit with his colleague, Richard Hoblitt. The eruption 1000 years ago may have devastated land much farther than 6 kilometers from the mountain, Miller says, because more distant deposits contain relatively coarse pebbles and ash. The blast in 1980 deposited only a few centimeters of fine ash in some distant areas, but it was still deadly enough at those distances to kill people. Because of erosion, little or none of that lethal ash will appear in the geologic record, he believes.

Today, erosion is already well under way at Mount St. Helens. "A remarkable amount of deposit has eroded already," Miller says. When undisturbed, the deposit is up to 1 meter thick over most of the blast area. Coarse ash and rock fragments, mixed with predominantly uncharred bits of wood and pine needles, lie next to the ground, covered by layers of progressively finer ash. Away from the mountain, the coarse lower layer appears only sporadically, and the layer of fine ash is less than 15 centimeters thick.

How much of this will be preserved after a few thousand years, no one is able to say. It will certainly be only a small fraction of the original deposit. Whether the more erosion-resistant portions that remain can be used to estimate the potential reach of a volcanic eruption remains to be seen. Study of the 1980 blast deposit, especially of the variation of particle size with distance from the crater, may help.

The Mount St. Helens deposit should also help determine how often destructive lateral blasts actually occur. The problem has been that few geologists agree on what a true blast deposit looks like. The Soviet volcano Bezymianny blew off part of its cone in 1956, much as Mount St. Helens did. In 1951, Mount Lamington generated an "ash hurricane" that reportedly bent flagpoles, snapped trees, and obliterated villages for 6 to 12 kilometers in all directions. But the deposits from these events have not yet been described in detail.

Volcanologists could see that certain deposits marked the passage of some sort of violent phenomenon, Stephen Sparks of Cambridge University says, but their significance was not always clear. There were disagreements about whether to call them ash hurricanes, base surges, pyroclastic flows, or nuée ardentes. After visiting Mount St. Helens, Sparks believes that he has seen similar deposits at Vesuvius, in the West Indies, and at Santorini in the Aegean Sea. "These things are not uncommon at other volcanoes," he says.

Richard A. Kerr