Earth Sciences

Stefi Weisburd reports from San Francisco at the meeting of the American Geophysical Union

Quake gave lava chemistry the shakes

When the chemical composition of lava from a volcano has changed over time, geochemists typically look for causes inside the volcano — magma from different parts of the magma reservoir may have mixed together, for example, or the surrounding rocks might have contaminated the melt. But now volcanologist Robert Tilling of the U.S. Geological Survey in Reston, Va., is urging geochemists to consider larger tectonic forces that might trigger lava changes. In particular, he suspects that a marked change about 200 years ago in the concentration of titanium and other elements in lavas from Mauna Loa volcano in Hawaii was caused by a magnitude 7.5 earthquake, the largest to hit Hawaii in historic times.

Tilling and other researchers, analyzing the chemistry of lava flows that occurred over the last two centuries, have noted a very gradual decrease in the levels of several elements in Mauna Loa lavas. But the studies show that in 1868, after the large earthquake jostled the ongoing eruption at Mauna Loa (and triggered two eruptions in the nearby Kilauea volcano), concentrations of some elements suddenly dropped even more and lava production rates fell. Either all of these events are merely coincidental, says Tilling, or the earthquake really did affect lava chemistry.

He suspects that the earthquake disrupted the system, which feeds magma to an upper reservoir where lava is stored before it is ejected. The result was that lavas erupting just after the earthquake were coming directly from and had the chemistry of magmas in the mantle rather than the composition of lavas that have been sitting in the shallow reservoir. With time, the shallow reservoir began to build up again, but according to Tilling, the concentrations of some elements have yet to recover to their pre-earthquake levels. If he is correct, then this is the first documented case of a tectonic force affecting the chemistry of a volcano for decades after the event.

Damage in Mexico: A double quake

The big question nagging seismologists and engineers since the Sept. 19 earthquake devastated sections of Mexico City and killed almost 10,000 people (SN: 9/28/85, p. 196) has been why this quake caused so much damage. One factor is that the ground-shaking was amplified — scientists now say by about five times — because Mexico City lies on an old lake bed that resonates with the seismic waves. The thickness of the bed is such that the seismic waves that are the most amplified are the low-frequency signals, which can do the most damage to taller buildings. Other notable quakes may not have been as devastating, scientists say, because there were not as many tall buildings in the past.

But recently, seismologists have come to think that the deadliness of the Sept. 19 quake was also due in part to its long duration. In fact, the mainshock of the magnitude 8.1 quake was really a double event, consisting of two 16-second tremors spaced about 26 seconds apart. The rupture started in the northwest part of the Michoacan gap — a segment of the Mexican subduction zone (where the Cocos oceanic plate is plunging beneath the North American plate) that had been tagged as a likely place for an earthquake. The second tremor was triggered by the first, 90 kilometers to the southeast. According to James Beck at Caltech in Pasadena, Calif., the unusually long period of shaking allowed more time for the lake bed to amplify ground motion and made some buildings more flexible so that they resonated more easily with the low-frequency seismic waves. Beck notes that the building codes in Mexico City had taken into account the effect of low-frequency waves, but Jorge Prince of the National Autonomous University of Mexico adds that none of these codes had specified the number of cycles of shaking that a building should withstand.

Seismologists say the Sept. 19 earthquake is one of the best-documented quakes in history. "This is the first time we can make a good comparison between the source region of such a big earthquake and the energy radiated out to large distances," observes James Brune at Caltech. With strong motion instruments, Brune and his co-workers found that ground motion near the fault was actually quite low, about 15 percent of the acceleration due to gravity (g). In comparison, the ground motion near California faults can reach values six to seven times that. Brune says the acceleration, which had dropped to about 4 percent g outside of Mexico City, was boosted to about 20 percent g inside the city. While scientists had known that the lake bed would resonate, they had little idea of what the amplification would be, he adds.

Because the Mexico earthquake had little or no precursory signals, Brune thinks seismologists should concentrate on ground-motion monitoring so that engineers designing buildings know what to expect when an earthquake does come. And now that the Michoacan gap has ruptured, all eyes are turned to the Guerrero gap to the south, which has been ominously quiet since 1911.

Missing: Earthquakes in the oceans

Last January, people living on the island of Kosrae in the Pacific Ocean felt a large earthquake. But neither the Tsunami Warning Center in Honolulu nor the National Earthquake Information Service in Boulder, Colo., had any record of the quake. Daniel Walker and his co-workers at the Hawaii Institute of Geophysics in Honolulu estimate that about 25 such oceanic earthquakes, many of which have magnitudes exceeding 5.0, go undetected every year by the conventional continental network of seismic stations.

"There's a lot more seismicity in the world's oceans than we currently think," says Walker. As a result, he says, scientists are missing an opportunity to learn about the tectonics of ocean plates, to improve tsunami warning capabilities and to bolster their ability to monitor nuclear explosions in the oceans.

Walker's group was in fact able to detect the January Kosrae earthquake and other large oceanic earthquakes because it has an array of 11 hydrophones situated near Wake Island in the center of the western Pacific. This array, perhaps the deepest in the world, is the only seismic network covering a region comparable in size to the entire North American continent. Walker thinks it has detected oceanic earthquakes missed by the continental networks because the oceanic crust — and perhaps the ocean, too — acts as a wave guide, preventing seismic waves from traveling very far into the continents. The Wake Island array also has the advantage of being on the ocean floor, where the crust, which Walker says "mucks signals up and attenuates their energies and frequencies," is thin.

Most of the earthquakes detected by the Wake array since October 1982 have occurred in and along the western Pacific basin. On the basis of a string of earthquakes detected near Kosrae Island in the southwestern Pacific by the Wake array, together with the geology of the region and other reported earthquakes to the north and south of the Kosrae string, Walker and Loren W. Kroenke, also at the Hawaii Institute of Geophysics, have proposed a new subduction zone, which they call the Micronesian trench. As discussed a paper to be published in an upcoming issue of EOS, the researchers believe that this trench results from a northward shift in the convergence of the Indo-Australia and Pacific plates. Walker and Kroenke say that if their hypothesis is correct, the Micronesian trench would be the longest single continuous-arc segment in the world and may also be a "heretofore unrecognized tsunami-generating zone within the Pacific basin."