Mount St. Helens: An Unpredictable Foe

Scientists had hoped to see some sign of the forthcoming major eruption that most of them expected, but it struck with unforeseen violence and without warning

The scientists who began gathering around Mount St. Helens in late March were playing a gambler's game at which no one is very good—predicting how and when a mountain will release the pressure obviously building within it. Fellow volcanologists had died beneath similar volcanoes when they guessed wrong. Mount St. Helens killed yet another researcher and about 70 other persons when it suddenly, without warning, blew out its entire north flank. The destructiveness of the blast, which was equivalent to 10 megatons of TNT, caught researchers by surprise. Although volcanologists are quick to point out that volcano forecasting is still in its infancy, many specialists had hoped, and perhaps half expected, that their particular type of observation would give a warning of the big eruption. Now, with the added clarity of hindsight, they can see the pattern of unusual behavior that was there and wonder if it should have made them a bit more cautious.

Researchers studying Mount St. Helens had some handicaps peculiar to the Cascade volcanoes of the Pacific Northwest. Although a part of the renowned "ring of fire" encircling the Pacific, the Cascades have given volcanologists few opportunities to get to know them while they are anything but quiescent piles of rock. A string of 15 major volcanoes runs from British Columbia to northern California. Eight have erupted in the past 200 years; of those, only Mount Lassen has erupted in this century, and that was a relatively minor affair. Unfortunately, only fragmentary reports of Mount St. Helens' last period of eruption in the mid-1800's are available.

A cause for the Cascades' stubborn refusal in the past to put on a good show may lie off the coast beneath the Pacific Ocean. Unlike most of the volcanoes around the edge of the Pacific, the Cascades are not fed magma by the Pacific crustal plate or one of the other major plates. Rather, it is the small Juan de Fuca plate, whose far edge is only 560 kilometers from Mount St. Helens, that slowly bends downward, slips beneath the Washington coast, shakes the Puget Sound area with earthquakes as it sticks and jerks its way deeper into the mantle, and finally melts enough to supply magma to Mount St. Helens and the other Cascade volcanoes. But the amount of magma fed to the Cascades is relatively small, according to Robin Riddihough of the Canadian Department of Energy, Mines, and Resources in Sidney, British Columbia. The Juan de Fuca plate moves too slowly (about 3 centimeters per year) to carry much rock beneath the Cascades, he believes, and it does not have a chance to thicken as older plates do before they sink into the mantle. Thus, the Cascades, starved for magma, have been less active than volcanoes in central America or the south Pacific.

With few historical reports to go on, geologists have looked to the record in the rocks of Mount St. Helens, only to find that it has not behaved at all consistently since about 400 B.C. Dwight Crandell and Donal Mullineaux of the U.S. Geological Survey (USGS) in Denver found that, unlike some better-behaved volcanoes, Mount St. Helens has swung from relatively quiet lava flows to the most violent kind of explosive ash eruptions and back again many times.

The differences between eruptions lie in the kind of magma that pushes up into the cone of the mountain. The more silica-rich the magma, the more viscous it is and the more likely it is to clog the plumbing system of the volcano. The more silicic magmas also release their gases less readily than the more fluid lavas typical of Hawaiian volcanoes. When the rock can no longer resist the pressure of the magma and the volcano "clears its throat" in a sudden eruption, a silicic magma releases these gases explosively, resulting in relatively violent ash eruptions.

Although probably the largest in 4000 years at Mount St. Helens, the violent ash eruption of 18 May was not the only one of its kind there. "Volcanism at Mount St. Helens," Crandell and Mullineaux wrote in 1975, "probably has included many brief but violent eruptive episodes like the catastrophic 'Plinian' eruption in A.D. 79 [which buried Pompeii and Herculaneum], the eruption of Mount Lamington in Papua (New Guinea) in 1951 and 1952, or the violent outbursts at Santa Maria Volcano, Guatemala, that started in 1922 and still intermittently continue." These same eruptions, plus the cone-shattering activity of Bezymianny in Soviet Kamchatka in 1956, are now being cited as some of the closest parallels to the 18 May blast at Mount St. Helens.

As earthquake activity began to build beneath Mount St. Helens after 20 March, scientists had mainly the observations of these and other volcanoes as a guide to what might come next. Over several days, the magnitudes and rate of occurrence of earthquakes climbed rapidly to "an amazing intensity of activity," recalls Stephen Malone of the University of Washington, who has been monitoring the seismic activity. The way the activity increased later reminded him of the eruption on Mount Usu in Japan in 1977, when moderate ash eruptions came immediately after a similar period of intensifying activity. From the pattern of seismic activity, Malone became concerned that Mount St. Helens might let loose with a major eruption on 26 March—it did not. Instead, the seismic activity subsided somewhat with no sign of an eruption, which left Malone and his colleagues wondering whether it was rising magma or some other, nonvolcanic force that had started the volcano creaking. Then it spewed a relatively minor amount of ash and steam on the afternoon of the 27th, the first of many small eruptions over the next 6 weeks.

As it turned out, Mount St. Helens' seismic activity followed a pattern similar to that observed at Bezymianny, Malone says. Before the Soviet volcano's main eruption, seismic activity also reached a high peak and then tapered off over the next 3 months to a nearly constant level. A few larger quakes struck toward the end of that period, but Bezymianny gave no immediate warning before it blew off the top of its cone. Mount St. Helens likewise "had kind of stabilized at 20 to 30 earthquakes greater than magnitude 3 per day," according to Rob-

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ert Crosson of the University of Washington. Quakes greater than magnitude 4 struck the mountain frequently, the three largest being of magnitude 5.0. This seismic activity was "very violent compared to that of Central American volcanoes," according to Crosson. "Everybody was surprised by the amount of energy from below the mountain." As at Bezymianny, no significant change in seismic activity occurred before the main eruption.

Volcanologists were also keeping tabs on the gases being emitted from the crater in hopes of determining when the magma buried in the volcano would begin to release its gases to the atmosphere. At some volcanoes, such an increase in gas emissions has immediately preceded eruptions. By measuring the absorption of skylight passing through the eruption plume, Richard Stoiber, Stanley Williams, and Lawrence Malinconico of Dartmouth College found that Mount St. Helens released sulfur dioxide at a rate of about 30 tons per day during the steam eruptions of early April. This was a low rate compared with the hundreds or thousands of tons per day of other volcanoes during eruptions. Such low emissions had not been seen before during an eruption, according to Stoiber. The Dartmouth group concluded that only groundwater turned to steam by the underlying magma was producing the April eruptions, which confirmed USGS conclusions based on other types of observations. The magma itself and its potentially destructive gases appeared to remain sealed within the mountain during early April.

Almost daily observations by the USGS of sulfur dioxide emissions showed no significant changes before the main eruption, according to Robert Christiansen of the USGS in Menlo Park, the on-scene coordinator for USGS. Malinconico recalls that he had hoped they would see an increase before any eruption directly involving the magma, as he had before three eruptions of Mount Etna. With hindsight, the lack of large emissions is not surprising, he says, because it is now obvious that the mountain held in the magma and all of its trapped gases until the moment of the eruption.

The accumulation of that magma revealed itself most ominously in the steadily expanding "bulge" on the north flank of the upper part of the cone. "In retrospect, we perhaps underestimated what the bulge was trying to tell us," says Robert Wesson, an assistant director of the USGS. "If we were to see it again, we'd take the bulge a lot more seriously." The official USGS hazard warning issued 30 April named the bulge as "the most serious potential hazard posed by current volcanic activity at Mount St. Helens." That warning remained in effect until the 18 May eruption, but the "most serious potential hazard" was not considered to be an explosive eruption, but rather ice or rock sliding off the increasingly unstable bulge. The warning made no mention of the possibility of an explosive eruption resulting from a slide.

Although striking even to the naked eye after the first eruption of 27 March, the bulge particularly impressed those who worked near it. By comparing separate contour maps drawn from a series of aerial photographs and by repeatedly surveying 14 targets placed on the bulge, James Moore and Donald Swanson of the USGS in Menlo Park and Peter Lipman of the USGS in Denver could follow the 1.5-meter-per-day expansion of the bulge, which was first confirmed in mid-April. By then, an area of 1.3 square kilometers had expanded at least 25 meters and a smaller area had pushed outward about 100 meters. "It was just incredible," reports Albert Eggers of Puget Sound University. "You could see the mountain go up" just by looking through a surveyor's telescope, "and here we were working just a half of a mile away."

The expansion of the bulge "was very dramatic, very rapid, and absolutely uniform" in its rate, Moore recalls. David Johnston, the USGS volcanologist who died in the blast of the main eruption, was monitoring the bulge on the morning of the 18th as it continued to fill with a few million cubic meters of magma per day, which it had been doing for weeks. "Up until 1 hour before failure [which was the last data report by Johnston] there was no change in the rate of expansion," Moore says. Moore and his colleagues were looking for a change as a signal that the mountainside was about to give way and produce a landslide. "That is the normal pattern of landslides," Moore notes.

Mount St. Helens and its bulge never had a chance to follow a "normal" pattern, if indeed they would have, given the opportunity. Instead, a magnitude 5.0 earthquake cut short the bulge's expansion and sent it sliding into the valley of the Toutle River. According to current thinking, the removal of this cap of ice and rock sharply reduced the pressure on the hot groundwater overlying the pocket of magma, allowing the groundwater to flash to steam. It was "more like a ruptured steam boiler than a true blast," according to Robert Decker, director of the USGS Hawaiian Volcano Observatory. The escaping steam rushed down the slopes at several hundred kilometers per hour, carrying the pulverized rock of the mountainside as hot ash and leveling everything before it. Only as the steam explosion removed more of the overlying rock were the gases explosively released from the magma, like popping the top on a can of

Thermal infrared image, including the summit crater and bulge, obtained at 5 a.m. on 16 May, 2 days before the main eruption. White areas are relatively hot, with a total temperature range of −12° to +12°C. North is toward the top in this view from directly over the mountain. The arc crossing the bottom of this image is a fault marking the southern boundary of the summit graben or depression. The complex hot areas north of this fault are within the summit crater. To the north of the crater, numerous warm spots show that the bulge had become perforated with heat leaks within the previous month, indicating extensive near-surface heating from the underlying magma. [Source: U.S. Geological Survey and the Department of Energy] warm Coke. This created a vertical, ash-laden plume.

"Everyone realized the potential of the tinderbox we were working on," Moore says, "we realized the possibility of a landslide being followed rapidly by an explosive eruption." But to most researchers monitoring the mountain in mid-May, that seemed a distant prospect, if it were to happen at all. Decker left the area on the 14th expecting, as many did, that the large eruption to come would probably take more time to build up and be preceded by increasingly violent eruptive activity. "In a way, we were anticipating a large landslide and then a gradually intensifying series of eruptions."

Investigators searching on the 16th for new hot spots on the mountain did not sense any particular urgency either, according to Hugh Kieffer of the USGS in Flagstaff. Rather than absorb the extra cost of having the infrared images processed over the weekend, they put them aside until Monday. Once processed, the images revealed that the bulge had become "perforated with a dozen or more thermal leaks" through which steam heated by the intruding magma was probably passing. If the images had been available before the main eruption, Kieffer says, they would have "at the very least been more concerned about the possibility of a landslide" because of the lubricating effect of the glacial meltwater formed by the heat.

Not only the timing of the main eruption but also its size took many volcanologists by surprise. Moore, Swanson, and Eggers estimated that Mount St. Helens blasted out 2.5 cubic kilometers of rock and ash during the eruption, making it the largest eruption there in the last 4000 years. Nothing about the observed activity before the 18th alerted the scientists on the scene to the possibility of such a large eruption. The bulge impressed everyone, but bulges elsewhere had usually produced no explosions or only moderate ones, according to Jurgen Kienle of the University of Alaska. During the eruptive activity of Mount Usu in 1977 and 1978 in Japan, for example, anyone could see with the naked eye that a large area of the cone was expanding, but only moderate explosions resulted.

The key to the difference, Kienle says, is whether the gases trapped in the magma have the time and opportunity to escape more slowly. The low rate of sulfur dioxide emission found by the Dartmouth group puzzled some researchers, Decker recalls, because a shallow intrusion of magma like the bulge would be expected to release some of its gases. But no one had ever seen a bulge like this one before, so no one could say exactly what it meant.

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The direction of the initial blast, being out to the side rather than up, surprised everyone the most. The lethal rush of gas and ash spread well beyond the boundaries of the hazardous area as defined by the 4000-year-long geological record, killing everything within a 400-square-kilometer area. Although unusual, such horizontally directed blasts have been observed before. Bezymianny lost even more of its cone to a directed blast than Mount St. Helens did. Mount Lamington in Papua New Guinea killed 7000 persons in 1951 with its directed blast and subsequent ash flow, an event cited by Crandell and Mullineaux in 1975 as an example of the type of eruption Mount St. Helens had probably experienced in the past.

"In hindsight, the mountain may have been trying to tell us something [about the direction of the eruption], but then, I'm not sure why you get a directed blast," says William Rose of Michigan Technological University in Houghton. The reasons for it at Mount St. Helens are only now becoming clearer, but there were several indications before the main eruption of a tendency for greater activity on the north flank. The most recent activity prior to this year formed the pile of lava called Goat Rocks, which the blast obliterated. The rapidly expanding bulge was also on the north flank. And Malone notes that the seismic activity was offset northward from the center of the cone. "We're kicking ourselves a bit. In retrospect, we can begin to understand the directionality of the blast," he says.

Although they failed to anticipate the destructiveness of the blast, scientists are taking some justifiable pride in the general warning that they were able to give. Hundreds or perhaps thousands are alive today because volcanologists could give some idea of what Mount St. Helens is capable of. Even more would have survived if they had taken the warnings more seriously.

Even so, hindsight has been a bitter pill for scientists who followed the progress of Mount St. Helens. The last-minute warnings that many had hoped for did not materialize. The least likely event, on a historical basis, did occur. USGS scientists had considered the possibility of such a severe directed blast, Christiansen says, but "perhaps we did not give sufficient consideration to that." In a similar vein, Malone says "If a mistake was made, it was that the worst case scenario was not mentioned more often by scientists." Many volcanologists would agree with a USGS scientist who said, "Maybe, in retrospect, we could perhaps have drawn a conclusion that the worst case was more likely" than the geologic record at Mount St. Helens suggested.

What now appears to have been an ominous buildup of destructive forces within Mount St. Helens awaiting a trigger to set them off seemed less ominous and less obvious before 18 May. But as one researcher puts it, "We knew something had to give."

What scientists were willing to say about the future eruption depended not only on the sketchy scientific evidence, but also perhaps on the likely consequences of an incorrect forecast. Volcanologists remember the 1976 evacuation from the vicinity of the rumbling Caribbean volcano La Soufrière. The experts did not agree on the need for an evacuation, but the authorities, recalling how another Caribbean volcano named Mount Pelée had killed 30,000 people in 1902, moved 74,000 people from their homes and businesses for 15 weeks. Nothing ever happened. In spite of USGS warnings, the pressure on state and local authorities from property owners and business interests to allow access to the hazardous zone around Mount St. Helens was great. Many more would have died if the main eruption had not come early on a Sunday morning when loggers and residents did not happen to be in the hazardous zone. Like those who predict earthquakes or the paths of hurricanes, volcanologists in the United States will be facing the problem of balancing the possible natural disaster against the practical consequences of a forecast.—RICHARD A. KERR