EOS
EOS, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

VOLUME 91 NUMBER 19
11 MAY 2010
PAGES 169–180

Mount St. Helens: A 30-Year Legacy of Volcanism

PAGES 169–170

The spectacular eruption of Mount St. Helens on 18 May 1980 electrified scientists and the public. Photodocumentation of the colossal landslide, directed blast, and ensuing eruption column—which reached as high as 25 kilometers in altitude and lasted for nearly 9 hours—made news worldwide. Reconnaissance of the devastation spurred efforts to understand the power and awe of those moments (Figure 1).

The eruption remains a seminal historical event—studying it and its aftermath revolutionized the way scientists approach the field of volcanology. Not only was the eruption spectacular, but also it occurred in daytime, at an accessible volcano, in a country with the resources to transform disaster into scientific opportunity, amid a transformation in digital technology. Lives lost and the impact of the eruption on people and infrastructure downstream and downwind made it imperative for scientists to investigate events and work with communities to lessen losses from future eruptions.

Before the 1980 Eruption

Before highlighting insight gleaned from this eruption, it is important to recall the rather different state of volcano science 30 years ago. In 1980, investigation of active volcanism by the U.S. Geological Survey (USGS) was modest and focused in Hawaii—in fact the only volcano observatory in the United States was in Hawaii, where the emphasis fell naturally on basaltic volcanism. Few U.S. universities could boast integrated programs in volcanology. The University of Washington's Pacific Northwest Seismic Network (PNSN) had installed the first seismometers for regional earthquake studies in 1969, including one on the upper flank of Mount St. Helens in 1972 [*Malone et al.,* 1981]. Yet a host of technologies that we now take for granted, such as cell phones, powerful portable computers, Global Positioning System (GPS) receivers, digital cameras, satellite communications, and streaming of real-time digital seismic and geodetic data, did not exist. Individual scientists had studied volcanoes in the Cascades, including Mount St. Helens, but characterization of fragmental deposits from pyroclastic flows, tephras, and lahars to infer a volcano's history and probable future behavior was less than 2 decades old and the specialty of only a few geologists.

Few inhabitants of the Pacific Northwest knew that they lived near volcanoes that could erupt or that Mount St. Helens had last erupted in 1857. Building on stratigraphic evidence that revealed frequent eruptions of Mount St. Helens, commonly punctuated by short dormant intervals of a few hundred years or less, the USGS published in 1978 a hazard assessment of the volcano [*Crandell and Mullineaux,* 1978] that stated that an eruption was likely within the next 100 years and perhaps even before the end of the century. Geologists working on the volcano in summer 1979 could only wonder if they would live to see an eruption.

The 1980 Eruption

Onset of unrest at Mount St. Helens was swift, beginning in late March 1980 with earthquakes that heralded the volcano's reawakening after 123 years. Within a week, steam and ash blasted out, forming a summit crater. Earthquakes as large as *M* 4.7 rocked the volcano, and the north flank began

Fig. 1. View looking north of Mount St. Helens on the afternoon of 18 May 1980. U.S. Geological Survey (USGS) photo by R. M. Krimmel.

BY J. W. VALLANCE, C. A. GARDNER, W. E. SCOTT, R. M. IVERSON, AND T. C. PIERSON

bulging outward by as much as 1.5 meters per day in response to a shallow intrusion of magma. USGS, PNSN, and university scientists assembled at the volcano, one that few of them knew well. As they scrambled to install new instruments during late winter weather and acquire and interpret data, they faced the challenge of providing short-term forecasts of possible activity. A critical partner in the response, and one that provided office space and vital logistical support to scientists, was the U.S. Forest Service, which had experience with coordinating response to large wildfires but not to an erupting volcano. Crisis response in the spotlight of the national and international media was a new experience for scientists, and most had to learn on the fly.

On the morning of 18 May, the unrest culminated in a cataclysmic eruption, which was economically the most destructive volcanic event in U.S. history. The 2.8-cubic-kilometer landslide reduced the summit by 400 meters. Sudden decompression of shallow gaseous magma caused a directed blast that traveled about 500 kilometers per hour northward and blew down or scorched 625 square kilometers of forest within 3 minutes. Within 15 minutes, a vertical plume of volcanic ash rose to an altitude of 25 kilometers. By afternoon, the dense ash cloud dumped centimeters of ash in eastern Washington and so darkened skies that lights came on in cities downwind. The plume crossed the United States in 3 days and circled the Earth in 15 days. Lahars filled nearby rivers with mud and debris, damaging or destroying 27 bridges and 200 homes. Lahar deposits in shipping lanes stranded 31 ships in ports upstream and cut off ports such as Portland, Oreg., and Vancouver, Wash., for a week.

Clear weather provided scientists and the public unparalleled views of the landslide, directed blast, eruption plume, pyroclastic flows, and lahars. Most aspects of the explosive eruption were forecast well, but the scale of the landslide and the blast's 180° arc of devastation to the north were unforeseen. Also surprising were troublesome secondary effects, such as the economic consequences of distal ashfall in far-flung communities and infill of the Columbia River shipping channel by lahar sediment.

The magnitude of devastation motivated a redoubling of scientific studies and hazard assessments. Five smaller explosive eruptions from 25 May to 18 October spread ash in all directions, some of it toward large metropolitan areas, including Portland, Oreg., and Olympia, Wash. Scientists received sufficient resources to study all aspects of the 18 May eruption and the ensuing explosive eruptive sequence in more detail and with more techniques than in any previous eruption.

Early Ash and Aircraft Incidents

In the wake of the ash plumes that spread over Europe in April 2010 from Iceland's Eyjafjallajökull volcano, causing widespread disruption of air traffic, it is surprising to recall that the devastating impact of atmospheric ash on aircraft was poorly understood and not well documented 30 years ago. Nonetheless, awareness was about to dawn.

Thanks to clear daytime conditions, most air traffic successfully avoided the Mount St. Helens 18 May 1980 ash cloud as it tracked eastward. Despite the favorable conditions, one jetliner strayed into the ash cloud and was badly damaged [*International Civil Aviation Organization,* 2001]. Only a week later, during the 25 May eruption, a turboprop C-130 unknowingly entered an ash cloud in foul weather and recorded the first documented example of temporary in-flight engine failure owing to ash intake. The C-130 regained power after losing altitude and was able to land safely, but its engines were ruined. Nonetheless, it took almost 10 more years and several more nearly disastrous ash-aircraft encounters before the airline industry and various government agencies responsible for air traffic fully understood the threat that ash posed to aircraft.

The Next Decade

Within a year, a monograph of initial observations and interpretations of the 18 May cataclysm and summer events was published [*Lipman and Mullineaux,* 1981]. News of the eruption fueled interest of veteran scientists and fired imaginations of aspiring volcanologists around the world. The USGS responded by establishing Cascades Volcano Observatory and tasking the observatory not only with monitoring the ongoing eruption of Mount St. Helens but also with assessing hazards and monitoring volcanoes throughout the Pacific Northwest and northern California. Another consequence of the Mount St. Helens eruption, in conjunction with the tragic 1985 eruption of Nevado del Ruiz in Colombia, was that USGS and the United States Agency for International Development jointly developed the Volcano Disaster Assistance Program (VDAP) for the purpose of rapid response to volcanic crises in developing countries around the world. By 1991, when Mount Pinatubo entered a state of unrest, VDAP and other scientists at USGS were prepared to respond. The response brought state-of-the-art equipment and experience that were crucial to helping Philippine scientists respond successfully to Pinatubo's paroxysmal eruption of 12–15 June 1991.

Newhall [2000] summarized the principal scientific lessons of the 1980 eruption: the "aha" moment of associating hummocky topography, long noticed around scores of volcanoes such as at Mount Shasta in California and Galunggung in Indonesia, with deposits from volcano flank failures; the idea that sudden removal of overburden from shallow gaseous magma decompresses it explosively to form devastating blasts, such as at Bezymianny, Kamchatka, in 1956 and Mount Lamington, Papua New Guinea, in 1951; and the realization that continuing lahars and fluvial redistribution of sediment can cause downstream aggradation into populated areas years after eruptions cease, such as at Mount Pinatubo after 1991. The 1980 eruptions were of equal significance to ecologists who studied revegetation and repopulation of the devastated areas and thus learned about the natural reclamation of disturbed landscapes.

Vitally important was learning how to respond to volcanic crises. Scientists built credibility by disseminating consistent messages and explaining the nature of the activity and hazards in plain language. Hazard coordinators assumed responsibility for

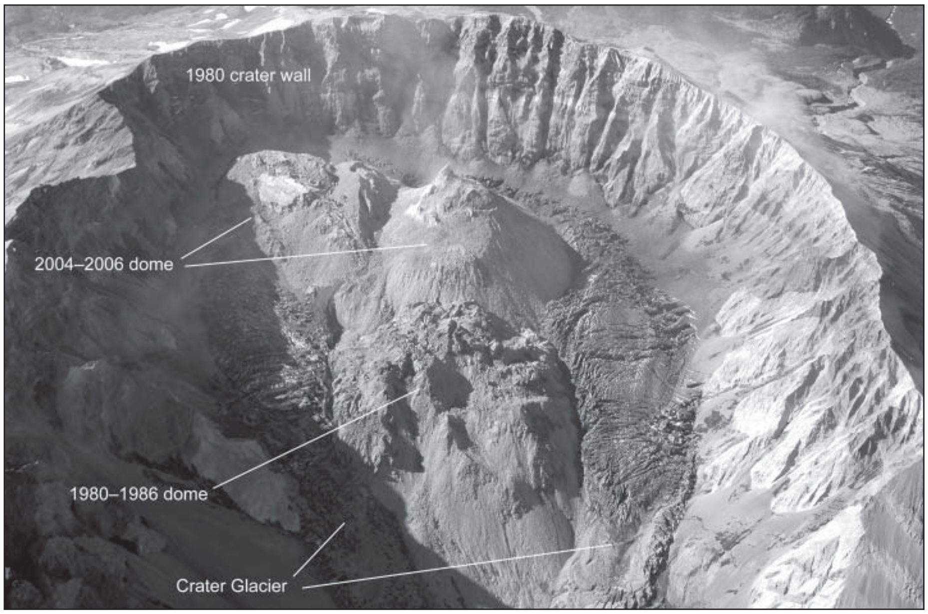

Fig. 2. View into the crater of Mount St. Helens on 12 September 2006 showing the 1980–1986 lava dome, the complex dome that began growing in mid-October 2004, and the greatly deformed arms of Crater Glacier. USGS photo by W. E. Scott.

providing information to public officials to help them decide how to respond to the threat of an eruption, such as by restricting access to and evacuating potentially dangerous areas, but avoided making such decisions themselves. This division in responsibilities allowed the scientists to focus on monitoring, interpreting, and forecasting the volcano's activity and separated them from the political aspects of decision making. Scientists learned that they needed to inform people quickly and accurately of developments at the volcano and to quickly quash false rumors [*Miller et al.,* 1981].

The 1980 unrest and ensuing eruption of Mount St. Helens ended in October 1986 after 6 years of intermittent lava dome growth [*Swanson and Holcomb,* 1990]. Lava dome extrusion was more benign than earlier explosive eruptions. Nonetheless, explosions and collapses of hot dome rock occasionally sent ash plumes to jet-cruising altitudes and spawned new lahars that spilled from the crater. Between 1989 and 1991, at least six unheralded explosions from the cooling dome produced ash plumes and minor fallout. This continuing activity taught scientists and the public that eruptive activity, unlike many hazardous natural events, can last for years, affect areas distant from the volcano, and disrupt air travel.

Reawakening

The reawakening of Mount St. Helens between 2004 and 2008 (Figure 2) [*Sherrod et al.,* 2008] involved a different style of lava dome emplacement, this time through the 150-meter-thick Crater Glacier, which had grown between the 1980s dome and the steep 1980 crater walls. As in 1980, the onset of activity in late September 2004 was swift and within about a week led to explosions and notable localized deformation. These phenomena indicated the shallow presence of rising magma, as demonstrated within 2 weeks of the first precursors when lava spines extruded from a vent concealed beneath the glacier. Vent location on the southern slope of the 1980s dome, topographic surfaces, and previous spine remnants appeared to control spine growth. The presence of thick glacier ice was insufficient to divert or slow spine growth.

Unlike dome growth eruptions of the 1980s, that of 2004–2008 involved continuous extrusion of degassed magma spines that had apparently solidified at less than 1 kilometer beneath the surface. Spine growth divided the glacier into two arms, bulldozed it hundreds of meters first east and then west, and then heaped it more than 100 meters higher than its original altitude. The extrusion failed to melt the glacier appreciably despite the proximity of hot rock, but it did cause the west glacier snout to advance at an accelerated rate of 115 meters per year, 110 meters per year greater than before the eruption. Increased internal flow from uplift and steepening of the glacier surface slope, not basal slip, caused the acceleration.

Another remarkable feature of the renewed eruption was the months-long persistence of repetitive, shallow (<1-kilometer) earthquakes, dubbed "drumbeats" because of their regular occurrence at intervals of 30–300 seconds. Such repetitive earthquakes are now known to be common during dome-building eruptions, but never have they been as long lasting as those at Mount St. Helens in 2004–2008.

The volcano's swift reawakening in September 2004 was surprising because the 4 preceding years were seismically the quietest of the 1986–2004 dormant interval. Campaign-style GPS surveys had detected no flank deformation, and a continuous GPS station 9 kilometers north of the volcano had shown no response between 1997 and September 2004. Nor did increases in steaming, volcanic gas or any other phenomena foretell that the volcano would rekindle. The eruption was abnormally gas poor, and painstaking petrologic studies suggest only hints of magma recharge. Most parameters indicated that the recent eruption was merely a continuation of the 1980–1986 eruptive cycle and involved little addition from a deeper source. Petrologic and geodetic modeling studies suggest that the 2004–2008 eruption was fueled by a magma source about 5 kilometers deep; apparently, old thoroughly degassed magma moved to the surface in the more recent eruptions from this depth without significant recharge of fresh magma. The triggering mechanism for such an eruption remains enigmatic, but a model describing forces driving and resisting dome extrusion implies a balance between magma pressure and friction so delicate that even slight changes could have altered the eruption character [*Iverson et al.,* 2006].

The Legacy of Mount St. Helens

The 18 May 1980 eruption of Mount St. Helens, possibly the most studied modern volcanic event ever, initiated numerous lines of scientific investigation that continue today. Careful investigation of deformation and seismicity in the 1980s showed how a slow but steady rise of magma preceded each lava dome eruption and permitted most to be predicted [*Swanson et al.,* 1983]. It also showed the necessity of having monitoring instruments close to the vent. Detailed petrological studies of amphibole breakdown [*Rutherford and Hill,* 1983] and microlite crystallization [*Cashman,* 1992] led to estimations of magma rise rates and the roles of ascent rate, decompressive degassing, and crystallization in modulating eruptive style. Monitoring volcanic gases, especially sulfur dioxide, throughout the 1980s eruption cycle highlighted the importance of volcanic emissions for interpreting processes of unrest and eruption [*McGee and Casadevall,* 1994]. Mount St. Helens also spurred scientists to investigate basic flowage and depositional processes—such as lahars, debris avalanches, and pyroclastic flows, which are among the most common and deadliest hazards at arc volcanoes—and to develop models to investigate basic mechanics and delineate hazard zones. The detailed documentation of many aspects of the eruption, such as tephra fall, remains invaluable as scientists strive to develop improved models to forecast more accurately the downstream and downwind effects of eruptions.

Not only has the style of volcanism at Mount St. Helens evolved during the past 30 years, but monitoring and modeling technology have also. Broadband seismometers, vastly improved telemetry using satellite and microwave technology, and powerful real-time data processing and analysis have replaced laborious manual analysis of seismic records. Simple accelerometers and GPS instruments can now be installed on portable stands called spiders and slung quickly by helicopter to dangerous places. Telemetered GPS stations can monitor deformation, which previously was painstakingly surveyed in the field. Additional technological innovations have facilitated the measurement of volcano gas emission rates.

Accompanying the revolution in geodetic measurements is a revolution in visualization and positioning that includes lidar (light detecting and ranging) and photogrammetric generation of successive digital elevation models throughout an eruptive sequence. Besides enabling GPS surveying, satellites allow radar measurement of deformation, new ways of tracking eruptive plumes, and detection of thermal changes. Digital cameras have made possible inexpensive, remote time-lapse photography.

Sweeping improvements in numerical modeling tools have helped to codify scientific understanding and formalize methods of hazards forecasting. Models remain imperfect, but seismological, geomechanical, geochemical, ash dispersal, and flow dynamics models are now used routinely as a basis for data interpretation and forecasting. This accelerating merger of insights from monitoring and modeling may pave the way for volcanological advances of the future.

Its past record suggests that Mount St. Helens will continue to erupt frequently and is likely to erupt again this century. Not only has Mount St. Helens been the most active volcano in the Cascade Range during the past 4000 years [*Crandell and Mullineaux,* 1978], but also nearly all of its visible edifice is less than 3000 years old. When the volcano's edifice last collapsed (~2500 years ago), it then erupted repeatedly, rebuilding its edifice within several hundred years [*Clynne et al.,* 2005]. So far the volcano has rebuilt only 7% of the volume it lost to the landslide on 18 May 1980; it is sure to continue its reconstruction.

For 30 years, Mount St. Helens has been a world-renowned natural laboratory for study of volcanic processes and landscape responses. Doubtless its next eruption, like previous ones, will generate surprises, opportunities for innovation, and new research possibilities.

References

Cashman, K. V. (1992), Groundmass crystallization of Mount St. Helens dacite, 1980–1986: A tool for interpreting shallow magmatic processes, *Contrib. Mineral. Petrol., 109*(4), 431–449, doi:10.1007/BF00306547.

Clynne, M. A., D. W. Ramsey, and E. W. Wolfe (2005), Pre-eruptive history of Mount St. Helens, Washington, *U.S. Geol. Surv. Fact Sheet, 2005-3045,* 4 pp.

Crandell, D. R., and D. R. Mullineaux (1978), Potential hazards from future eruptions of Mount St. Helens volcano, Washington, *U.S. Geol. Surv. Bull., 1383-C,* 26 pp.

International Civil Aviation Organization (2001), Manual on volcanic ash, radioactive material and toxic chemical clouds, *ICAO Doc. 9691-AN/954,* Montreal, Que., Canada. (Available at http://www2.icao.int/en/anb/met-aim/met/iavwopsg/Documents/)

Iverson, R. M., et al. (2006), Dynamics of seismogenic volcanic extrusion at Mount St. Helens in 2004–05, *Nature, 444*(7118), 439–443, doi:10.1038/nature05322.

Lipman, P. W., and D. R. Mullineaux (Eds.) (1981), The 1980 eruptions of Mount St. Helens, Washington, *U.S. Geol. Surv. Prof. Pap., 1250,* 844 pp.

Malone, S. D., E. T. Endo, C. S. Weaver, and J. W. Ramey (1981), Seismic monitoring for eruption prediction, in *The 1980 Eruptions of Mount St. Helens, Washington,* edited by P. W. Lipman and D. R. Mullineaux, *U.S. Geol. Surv. Prof. Pap., 1250,* 803–813.

McGee, K. A., and T. J. Casadevall (1994), A compilation of sulfur dioxide and carbon-dioxide emission-rate data from Mount St. Helens during 1980–1988, *U.S. Geol. Surv. Open File Rep., 94-212,* 24 pp.

Miller, C. D., D. R. Mullineaux, and D. R. Crandell (1981), Hazards assessments at Mount St. Helens, in *The 1980 Eruptions of Mount St. Helens, Washington,* edited by P. W. Lipman and D. R. Mullineaux, *U.S. Geol. Surv. Prof. Pap., 1250,* 789–802.

Newhall, C. G. (2000), Mount St. Helens, master teacher, *Science, 288*(5469), 1181–1183.

Rutherford, M. J., and P. M. Hill (1993), Magma ascent rates from amphibole breakdown: An experimental study applied to the 1980–1986 Mount St. Helens eruptions, *J. Geophys. Res., 98*(B11), 19,667–19,685.

Sherrod, D. R., W. E. Scott, and P. H. Stauffer (Eds.) (2008), A volcano rekindled: The renewed eruption of Mount St. Helens, 2004–2006, *U.S. Geol. Surv. Prof. Pap., 1750,* 856 pp.

Swanson, D. A., and R. T. Holcomb (1990), Regularities in growth of the Mount St. Helens dacite dome, 1980–1986, in *Lava Flows and Domes: Emplacement Mechanisms and Hazard Implications, IAVCEI Proc. Volcanol.,* vol. 2, edited by J. H. Fink, pp. 3–24, Springer, Berlin.

Swanson, D. A., T. J. Casadevall, D. Dzurisin, S. D. Malone, C. G. Newhall, and C. S. Weaver (1983), Predicting eruptions at Mount St. Helens, June 1980 through December 1982, *Science, 221*(4618), 1369–1375.

Author Information

James W. Vallance, Cynthia A. Gardner, William E. Scott, Richard M. Iverson, and Thomas C. Pierson, David A. Johnston Cascades Volcano Observatory, USGS, Vancouver, Wash.; E-mail jvallance@usgs.gov

---

NEWS

Haiti Quake Increased Stress Along Fault

PAGE 170

The destructive magnitude 7.0 earthquake that ruptured a 40-kilometer segment of the Enriquillo fault 15 kilometers from Port au Prince, Haiti, on 12 January 2010 has dangerously increased the failure stress on an adjacent eastern segment of that fault, according to research presented on 3 May at the European Geosciences Union General Assembly in Vienna, Austria.

Jian Lin, a senior scientist with the Geology and Geophysics Department at Woods Hole Oceanographic Institution (WHOI), in Massachusetts, explained that the Haiti quake brought the eastern segment about 2–5 bars closer to failure. With 1 bar equal to atmospheric pressure at sea level, a 2- to 5-bar increase may not seem significant, Lin said. However, the fault has not ruptured for about 240 years, and it has built up about 1.5–2 meters of stress, at an estimated rate of 7–8 millimeters per year. An increase of just a few bars could act as a trigger, he said. “It’s just like your car is on the edge. Now just give a kick and it’s going to fall,” he told *Eos*.

If the 40- to 60-kilometer eastern segment ruptures together, “it could create a magnitude earthquake similar to January 12,” Lin said. One key difference is that the January event was 15 kilometers away from the Haitian capital of Port au Prince; the eastern segment comes within about 5 kilometers of the city.

The WHOI scientist told *Eos* that there is no scientific evidence to indicate the eastern segment is a creeping zone that gradually releases stress, rather than a locked zone, and that the stress along the segment has not been relieved. “Port au Prince has been destroyed at least three times now: 1751, 1770, 2010. When is the next one? I think the writing is on the wall. No one has convinced me that it is not going to happen.”

The January quake also brought a segment west of that event 1–2 bars closer to failure and slightly increased stress on other faults including the Septentrional fault on Hispaniola, Lin said. Another concern is what the threat might be to Kingston, Jamaica, which is at the western end of the fault.

Lin noted that the research conducted by him and his colleagues depends on input provided by seismologists and geodesists and that there are discrepancies between the two models. However, he said the inference of stress increase on the section of the Enriquillo fault to the east of the 12 January event “is relatively robust regardless of the specific seismic and geodetic slip models used.”

The 2010 event was the deadliest quake in 34 years, killing an estimated 230,000 people and collapsing or damaging about 200,000 buildings. The magnitude 7.8 quake that struck Tangshan in northern China in 1976 killed nearly 243,000 people and destroyed or damaged 95% of the city’s buildings. Lin, at that time a high-school student living in southern China, told *Eos* that the quake “affected me as profoundly as 9/11 affected American kids” and influenced his decision to become a seismologist. Bamboo trees from his town were sent to Tangshan for building temporary housing. A factory in his town produced plastic bags in which to bury the dead.

Lin said he hopes there is not another devastating quake in Haiti but that he is very concerned. There is historical evidence of a previous major earthquake cluster along the fault in the 1700s. He noted that if the historical quakes occurred farther west along the Enriquillo fault than had been thought previously, as some other researchers recently have indicated, it could mean the eastern segment has been accumulating stress for a longer period. Lin said it is unknown, though, whether another quake could occur soon or years from now. “Earthquakes do interact. Earthquakes do talk to each other,” he said. “It’s just that how they talk to each other sometimes is complicated, sometimes is obvious.”

For more information, see http://pubs.usgs.gov/of/2010/1019/.

—Randy Showstack, Staff Writer