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U.S. GEOLOGICAL SURVEY — REDUCING THE RISK FROM VOLCANO HAZARDS

Mount St. Helens Erupts Again

Activity from September 2004 through March 2005

Eruptive activity at Mount St. Helens captured the world's attention in 1980 when the largest historical landslide on Earth and a powerful explosion reshaped the volcano, created its distinctive crater, and dramatically modified the surrounding landscape. Over the next 6 years, episodic extrusions of lava built a large dome in the crater. From 1987 to 2004, Mount St. Helens returned to a period of relative quiet, interrupted by occasional, short-lived seismic swarms that lasted minutes to days, by months-to-years-long increases in background seismicity that probably reflected replenishment of magma deep underground, and by minor steam explosions as late as 1991. During this period a new glacier grew in the crater and wrapped around and partly buried the lava dome. Although the volcano was relatively quiet, scientists with the U.S. Geological Survey and University of Washington's Pacific Northwest Seismograph Network continued to closely monitor it for signs of renewed activity.

View westward of the steam-and-ash explosion of October 1, 2004. Note the dark-colored ash and white steam emerging simultaneously from a vent through the glacier. Also note the fractured and slightly uplifted glacier ice immediately east of the vent and south of the 1980-1986 lava dome. (USGS photo, October 1, 2004)

The Volcano Reawakens

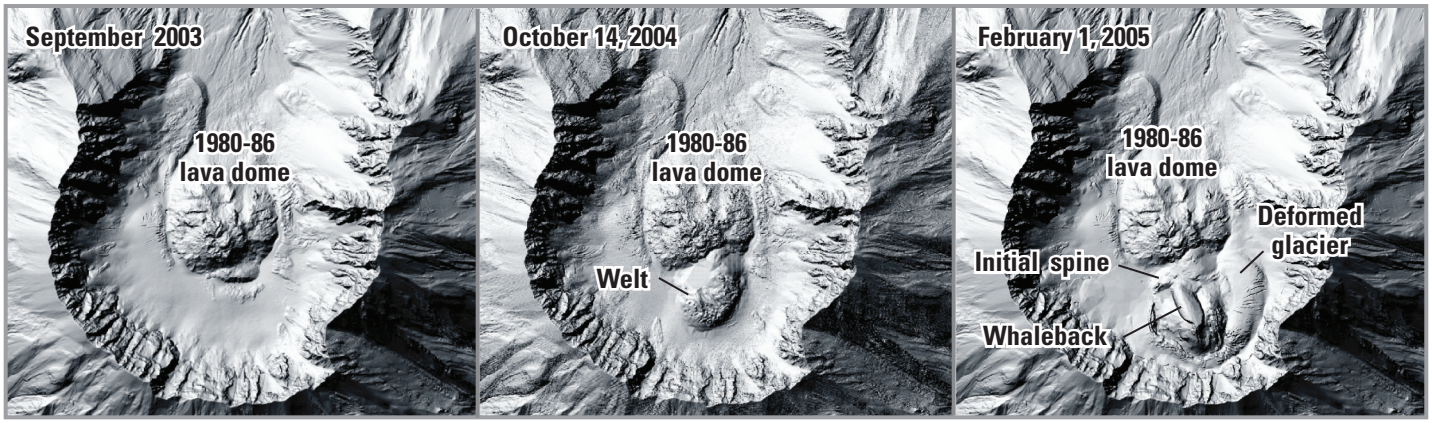
September 23-October 1, 2004

After 18 years of relative quiescence, Mount St. Helens volcano recaptured the world's attention when it showed signs of reawakening in September 2004. On September 23 a swarm of small (less than magnitude (M) 0), shallow (less than 1.5 miles below the surface) earthquakes began in and beneath the 1980-1986 lava dome. Initially this swarm resembled previous swarms that had not led to eruption. By September 24 many hundreds of earthquakes had occurred. Earthquake rates peaked that day at about 2 to 3 per minute then gradually declined, and it appeared that the swarm was ending. But on September 25 shallow earthquakes increased again in both size and rate. This reinvigorated level of seismicity prompted scientists to issue a notice of volcanic unrest for the first time since 1986. The release of energy by earthquakes increased dramatically during the next several days, and by October 1 earthquakes occurred nearly continuously. Peak sizes reached M3.5, and earthquakes larger than M2.5 occurred about once per minute. Concurrently, parts of the glacier south of the lava dome rose and cracked noticeably, creating a broad welt. The accelerated size and frequency of earthquakes and noticeable deformation of the glacier indicated that molten rock (magma) was rising toward the surface, and this prompted scientists to issue several types of hazard notifications in collaboration with the Gifford Pinchot National Forest and Washington State Emergency Management Division.

Steam and Ash Explosions

October 1-October 5, 2004

On October 1, an explosion lofted steam and ash several thousand feet above a vent blasted through the fractured glacier, and hurled rock fragments at least ½ mile across the western half of the glacier and 1980-1986 lava dome. Four more steam and ash explosions occurred through October 5. Of those five explosions, three produced noticeable fine-ash fallout downwind. Only the ashfall of October 5 affected populated areas: a light dusting of ash extended downwind (NNE) as much as 60 miles to the northeast part of Mount Rainier National Park. The size



Topographic changes of the Mount St. Helens crater measured from aerial photographs and laser imaging (Lidar). Images show the rapid growth of the welt and new lava dome, the whaleback-shaped extrusion, and the deformed glacier. (October 14, 2004, image courtesy of NASA)

and frequency of earthquakes dropped following the first four explosions, but in each case built back within hours to pre-explosion levels. The level of earthquake activity dropped a final time after the largest explosion on October 5. From October 5 through March 2005, earthquake rates and sizes waxed and waned but never regained the peak levels of September 29 through October 5.

Lava Dome Growth

October 6, 2004-March 31, 2005, and continuing

Following the brief series of steam-and-ash explosions, the volcano settled into a quieter phase during which the welt continued to grow and a new lava dome appeared. Growth of the welt along with detection of volcanic gases (CO_2, SO_2, H_2S) in early October provided clear evidence that magma had risen to or close to the level of the 1980 crater floor. On October 11, a spine of solid, but still hot, lava punctured the surface of the welt. As this initial spine grew upward, several smaller spines appeared nearby. In late October, a larger whaleback-shaped extrusion of solid lava emerged immediately southeast of the initial spine. The early spines plus the whaleback extrusion are referred to as the new lava dome. By early February 2005, the welt and new lava dome grew to a combined volume of about 50 million cubic yards, almost one-half the volume of the 1980-1986 lava dome. By then, the top of the new lava dome reached nearly 1,400 feet (taller than the Empire State Building) above the level of the 1980 crater floor, and the welt and new lava dome together covered an area equivalent to about 60 city blocks.

Unlike lava domes at many other volcanoes, which form when lava accumulates and slowly flows over and around a volcanic vent, the new dome at Mount St. Helens has extruded as a solid mass, much like a piston being pushed from the ground. In contrast, during the 1980s dome growth at the volcano occurred when magma extruded onto the surface and formed short (650-1,300 feet), thick (65-130 feet) lava flows.

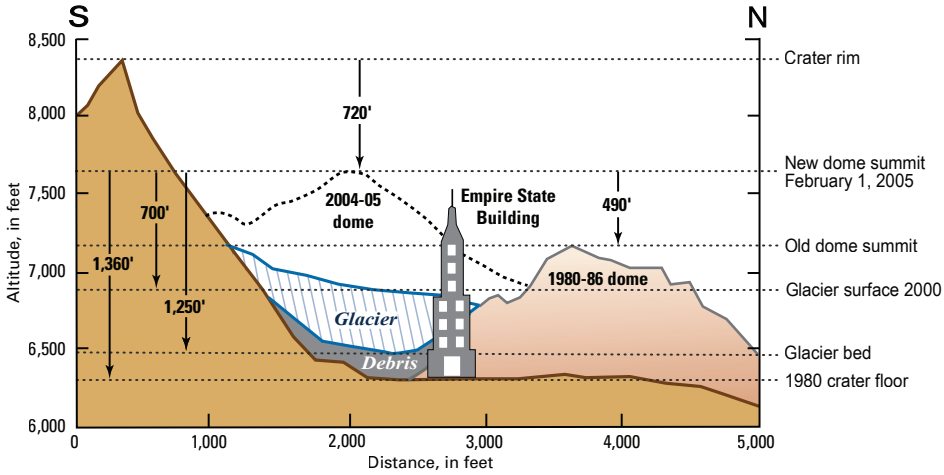
The new lava dome extruded from the ground rapidly. Global Positioning System (GPS) stations slung into place on top of the dome by helicopter showed that in November 2004 a point on the whaleback moved southward as much as 35 feet per day. In January 2005 the rate of movement had slowed slightly to about 30 feet per day, and by mid-February 2005, motion had slowed to about 20 feet per day.

Effects of the Eruption on the New Glacier

Deformation associated with intrusion of magma and extrusion of the new lava dome cleaved the crater glacier into two arms. The eastern arm of the glacier, pinched between the new lava dome and the east crater wall, bulged, fractured,

View to southeast of Mount St. Helens' crater. A whaleback-shaped extrusion (part of the new lava dome) emerges from the ground and moves southward (arrow). As it grows southward its edges fracture and crumble, creating a broad apron of blocky debris, over which the extrusion continues to move. Note how the glacier to east is being squeezed and fractured by the growing lava dome. (USGS photo, February 22, 2005)

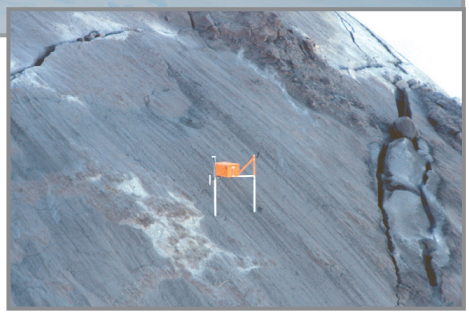
and flowed northward rapidly (about 4 feet per day) in response. At many other volcanoes where lava has intruded into glacier ice, large floods have occurred. Despite losing at least 5% to 10% of the glacier ice volume (as of February 2005) to vaporization and melt, water flow from the crater of Mount St. Helens has changed little during the 2004-2005 eruption. In addition to losing steam to the atmosphere, the highly porous and permeable crater floor has presumably absorbed melt water like a giant sponge and allowed it to pass into the ground-water system within the volcano rather than pond at the base of, or within, the glacier and burst forth in a large flood.



Topographic profiles along a N-S axis through Mount St. Helens' crater. Profiles show geometry of new lava dome relative to south crater rim, 1980 crater floor, 1980-1986 lava dome, and 2000 glacier surface.

New Technologies for Monitoring Eruptions

The remarkably rapid, but nearly steady, rate of dome growth and changes in the glacier surface, coupled with potential hazards from unheralded explosions, prompted development of new technologies to monitor the state of the volcano. Advances in digital technology allowed development of self-contained instrument packages that could be slung to the volcano by helicopter and placed in a variety of settings. These packages have included seismometers to measure earthquakes, GPS units to track surface movement, and gas sensors. Such technological innovations have allowed scientists to gather critical data in the crater without compromising their own safety. In addition to the data gathered by these remotely deployed packages, conventional and digital photography, including vertical, oblique, fixed-station, and thermal imaging, have been used to document and quantify dome growth and surface changes. The various data are used not only to monitor the volcano but also to help refine ideas and models that explain how the volcano works.



View of north side of the new lava dome from a location immediately south of 1980-1986 lava dome. Circle shows the location of an instrument station on the dome. Inset shows the instrument station, a "tilt-leg spider" package named CDAN, on top of the north-face of the new dome. This station housed a GPS unit and a seismometer until it was destroyed by an explosion on January 16, 2005, 36-hours after placement. (USGS photos, January 14, 2005).

Potential Hazards Associated With Eruptive Activity

Throughout its history Mount St. Helens has produced a wide variety of eruptive products, including lava flows, lava domes, and deposits of airfall pumice and ash, pyroclastic flows (swift avalanches of hot ash, pumice, and gas), landslides, and lahars (volcanic mudflows). The volcano is notorious for its gigantic landslide and subsequent powerful explosion on May 18, 1980, which claimed 57 lives, but smaller events are also potentially hazardous.

The 2004-2005 dome-growth eruption has been benign so far compared to the May 18, 1980, eruption. Between October 2004 and March 2005, however, it produced two more notable explosions (January 16 and March 8, 2005) that lofted ash plumes (one to nearly 7 miles above sea level, which drifted hundreds of miles downwind) and hurled rock fragments (to about 1 foot diameter) up to a mile across the crater. Continued growth and occasional collapse of the new lava dome may produce additional small explosions and also avalanches of hot debris that sweep out from the dome. Both explosions and hot rock avalanches can create ash clouds that drift downwind, which can endanger aircraft and affect people on the ground.

Summary of volcano, lava dome, and glacier dimensions 1980-2005

Volcano	
Elevation of summit	9,677 feet before 1980; 8,363 after; 1,314 feet removed
Volume removed by May 18, 1980, eruption	0.67 cubic miles (3.7 billion cubic yards)
Crater dimensions	1.2 miles (east-west); 1.8 miles (north-south); 2,084 feet deep
Crater floor elevation	6,279 feet
Crater glacier area (September 2000)	0.4 square miles
Crater glacier ice volume (September 2000)	105 million cubic yards
Maximum glacier thickness (September 2000)	650 feet
1980-1986 Lava Dome	
Elevation of top of dome	7,155 feet
Height	876 feet above 1980 crater floor
Diameter	About 3,500 feet
Volume	97 million cubic yards
2004-2005 Lava Dome (as of February 1, 2005)	
Elevation of top of dome	7,642 feet
Height	1,363 feet above 1980 crater floor; 700 feet above 2000 glacier surface
Dimensions of "whaleback"	About 1,550 feet long, 500 feet wide
Diameter of lava dome and welt deformed by magma intrusion, excluding deformed east glacier arm	About 1,700 feet
Volume of lava dome and welt deformed by magma intrusion, including deformed east glacier arm	50 million cubic yards
Approximate percentage of crater glacier ice removed	5% to 10%

rock avalanches or small explosions that spew hot gases and ash can also swiftly melt snow and ice and form floods or lahars that surge out of the crater. Such floods and lahars can endanger people along the upper North Fork Toutle River.

Status of the Eruption and Outlook

As of March 2005, dome growth that began in late 2004 continues. Although the rate of lava extrusion has waned slightly between November 2004 and March 2005, the new dome continues to build at a remarkable rate. Previous periods of dome-growth at the volcano have persisted (intermittently) for years to decades, punctuated by small-to-moderate explosive activity. Someday, episodic dome growth may eventually rebuild Mount St. Helens to a volcano resembling the near-perfect pre-1980 cone.

View southwest of Mount St. Helens' crater minutes after onset of the March 8, 2005, explosion. The photograph was taken by a remote camera installed on the "Sugar Bowl" dome at the northeast margin of the crater mouth. The dark cloud to the left consists of a rain of ash and blocks (to about 1 foot diameter) from the eruption plume. The light colored cloud to the right is a plume lofting from a small ash flow moving northward away from the new lava dome. The snow-clad 1980-1986 lava dome is visible in the foreground. The red streaks in the upper right corner are the result of camera imperfections. (USGS photo)

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See also *Mount St. Helens—From the 1980 Eruption to 2000* (USGS Fact Sheet 036-00)