Thrust Faults on the Crater Floor of Mount St. Helens, 1981: A Personal Account

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From somewhere high up on the fluted walls of the amphitheater behind us, we heard a low hum, like a truck motor on a distant mountain road. It was July, 1981, and I was standing on the floor of the crater of Mount St. Helens with my companions Christina Heliker and Bill Chadwick of the Crater Monitoring Team of the U.S. Geological Survey. The crater floor was a lunar landscape, devoid of any sign of vegetation or animal life. Most of the landscape was the same somber color, brownish-gray, and littered with rocks of the same dull color, with the crater floor broken here and there by steaming crevasses radiating out from the lava dome that we had been regarding.

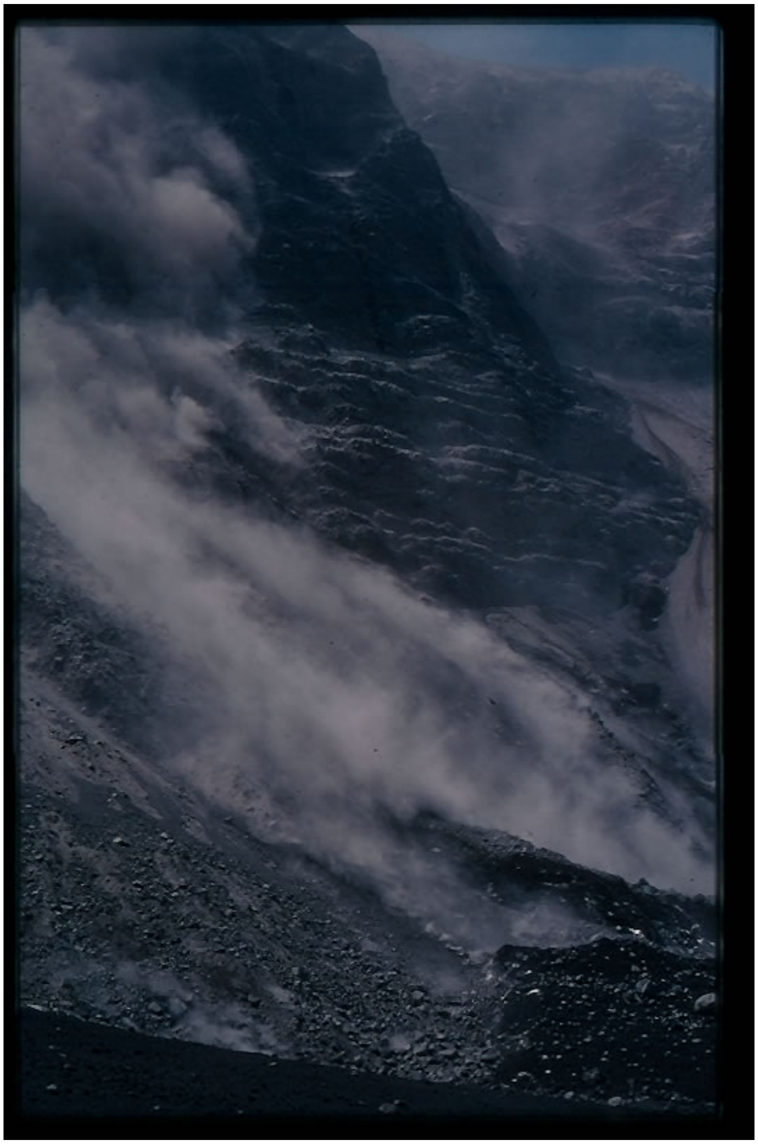
We turned away from the dome, our eyes scanning the lifeless crater walls. We knew there was no motor, no road, no sign of any human activity on those walls, which became exposed during the catastrophic blast of May 18, 1980, when Mount St. Helens blew its top northward in the direction of Spirit Lake.

The humming sound was caused by a huge rock, loosened from high on the upper wall, spinning in free fall through space, then striking the talus cone far below to release a puff of ash. This was the prelude to a gigantic rockslide, caused by the instability of those amphitheater walls. Steep cliffs are normally composed of hard rock resistant to erosion, and they are carved by the action of running water over tens of thousands of years. The amphitheater walls of Mount St. Helens are composed of poorly-consolidated volcanic rocks, including lavas and fragmental breccias of which the volcano had built its symmetrical cone over the past two thousand years. The heart of the volcano had been wrenched out in a matter of minutes, and now, through the erosive forces of nature, the steep cliffs were beginning to break down to form a gentler slope more in equilibrium with the strength of the weak rocks composing them.

The humming sound was overwhelmed by the sharp crackle and thunder of falling rock, and new ash puffs rose from the talus pile as more boulders rained down from the heights. We could see individual rocks now, bouncing end over end high in the air in slow motion, seeming to float in the air at the apex of the bounce, then spinning toward us on the crater floor below.

To our left, we could make out a broad expanse of jagged boulders formed during a rockslide the previous month, on June 27. That rockslide had started like this one, but it dislodged a huge mass of the crater wall which disintegrated and collapsed into a churning sea of boulders that advanced out onto the floor of the crater and banked up against the side of the lava dome. If this rockfall grew to become as large as that one, we were lost.

The roar of the rockfall, punctuated by sharp cracks from unusually large boulders, rose in a crescendo so that we could hardly hear our own voices. The puffs of ash coalesced into a gray curtain that drifted up from the sea of moving boulders and partially obscured the walls of the amphitheater in the background. Closer to us, spinning



boulders the size of automobiles bounced high in the air like giant ping-pong balls as they approached us on the crater floor below. Then, just as I began to look for some sort of escape route, the thunder began to slowly die away, the dust pall drifted up the amphitheater walls, and the rockslide was over.

My colleagues, Christina and Bill, weren't as concerned as I was. Every day that weather permitted the helicopters to fly them into the crater, they came and made their measurements, and rockfalls like the one we had just observed were a relatively common occurrence. Yet they, too, would also wonder if the next rockfall would be like June 27.

A visit to the crater of Mount St. Helens begins at Pearson Air Park in Vancouver, Washington, near the headquarters of the Cascades Volcano Observatory of the U.S. Geological Survey. The Bell Jet Ranger helicopter rises over the restored parade ground of old Fort Vancouver and flies north-northeast past the suburbs of Vancouver over rolling farmland and the timbered, clear-cut-scarred foothills of the southern Cascade Mountains.

Most of the southern Cascades are covered by wooded ridges, the deeply-eroded roots of a chain of volcanoes that became extinct millions of years ago. Astride these ridges are the grand pyramids of the modern Cascade volcanoes, glacier-clad Mount Rainier and, to our far right, Mount Adams. Mount St. Helens from the south is less impressive than either Rainier or Adams, a broad, rounded dark hump bearing little resemblance to the symmetrical snow cone that was once known as America's Fujiyama and one of the loveliest mountains on Earth. A lazy plume of steam drifts over the hump, the only reminder that we are approaching a violently active volcano.

Soon the great, rounded mass of St. Helens fills the window in front of us, and the blocky crests of lava flows hundreds of years old pass beneath us. Now we are skirting the volcano on its east side. Smooth slopes are dissected by great gorges, all the same brownish-gray color. Only the dirty white blocks of the Shoestring Glacier break the monotony. Now there are no more trees, only the swirling patterns of fallen stripped trunks of Douglas fir, the victims of the searing blast of May 18, 1980.

Abruptly, the helicopter banks and turns west toward the volcano, past the Dog's Head, a rocky prominence on the pre-1980 cone that survived the blast. Now, suddenly, the true nature of Mount St. Helens is revealed. It is hollow, a huge gaping amphitheater with high walls that reach out toward a ruined Spirit Lake, off to our right. The amphitheater falls away toward the lake as a grooved, striated sloping surface called The Steps. The grooves are giant drag marks formed by the north side of the old cone as it was blown out laterally toward Spirit Lake on the morning of May 18.

At the top of The Steps is the crater, open to the north, and in its center squats a dark, steaming mass of rock, the growing lava dome. The dome resembles a sacrificial altar on a monstrous Aztec pyramid, menacing and incredibly ugly, but we fly toward it like moths drawn to a flame. Nothing grows in this place, so we have no concept of scale as we gain altitude to enter the crater. The dome is steep-walled, its top a jumble of dacite blocks, its base a sloping talus formed by solid masses of lava cascading down during an eruption. Some of these blocks, as large as mountain cabins, have rolled down to the base of the dome, and these have been given informal names by the Survey: Immense Rock; the Federal Building.

Now we are high enough to enter the crater itself. The dome is off to our left, the crater floor is directly below us, and the walls of the crater rise twenty-five hundred feet above the floor, on the right. The crater is U-shaped, and it would be open to the north except for the fact that this opening is blocked by the great lava dome.

The history of the lava dome reflects the changing character of the eruption. The May 18 blast was too explosive and gas-charged to produce a dome. Like spray from a giant aerosol can, the molten magma was ejected at high pressure as a towering cloud of fine particles, producing a column of ash that drifted eastward across Washington, Idaho, and Montana and around the Earth, and also as pyroclastic flows, gas-charged slurries of pumice that roiled out of the crater and down the north slope at high speed and high temperature. The first dome appeared in June, 1980, but it was blown away by an explosive eruption the following month. A second dome was blown out in October, 1980, but this was followed by a third dome that became the nucleus of the composite dome we see today. Successive dome eruptions in December, 1980, and February, April, and June, 1981, completely covered the October lobe and enlarged the dome so that it now spills down onto the upper part of The Steps.

The October, 1980, eruption left a smooth crater floor covered by layer upon layer of new ash. By July, 1981, the crater floor has changed drastically. Only one smooth area remains on the southeast side of the dome, called the Ephemeral Lake because it had been covered with water early in 1981. Now the lake floor is criss-crossed with mud cracks like an ancient desert playa. The Ephemeral Lake is the favorite landing spot for helicopter pilots, a smooth surface in an otherwise desolate lunar landscape.

Open fractures radiate out from the lava dome like spokes on a wheel. Columns of steam rise from many of these fractures, evidence of hot rock below. Others are rimmed with a yellow stain produced by sulfur sublimates from now-dead steam plumes. The fractures are evidence that the crater floor is expanding as the lava dome forces its way to the surface.

Finally, the crater floor is broken by a series of curving scarps produced by faults that crumpled the floor as the dome continues to grow and expand. These faults have brought me to Mount St. Helens.

As a structural geologist at nearby Oregon State University, I am particularly interested in active faults, faults that may at any moment rupture the ground surface accompanied by an earthquake. Abrupt movement on the San Andreas fault caused two catastrophic earthquakes in California, one in 1857 shortly after the Gold Rush, and a more famous one in 1906 that destroyed much of the City of San Francisco. But there are many kinds of faults: strike-slip faults like the San Andreas that make a straight-line furrow across the countryside visible from space, marking horizontal motion, normal faults on which the ground is pulled apart, and thrust faults in which the ground is pushed together such that one slab of rock rides up over another. Do all of these fault result in the same degree of earthquake danger? Do some of them move without producing large earthquakes?

In December, 1980, Don Swanson of the U.S. Geological Survey first observed the new ruptures of the crater floor that seemed to be related to emplacement of the December lobe of the lava dome. More ruptures appeared in early 1981, and these also seemed to be related in some way to the dome. There were earthquakes at the time of faulting, hut some of them appeared to be in the vicinity of the dome itself, and others appeared to be localized at the faults.

Don’s most startling observation was that these are reverse faults, with most of the fault scarps facing out away from the dome. It appears as though the dome is expanding outward in addition to upward, crushing the crater floor between the dome and the walls of the amphitheater. Don knew that volcanoes are generally characterized by normal faults, not reverse faults. Was this a phenomenon unique to Mount St. Helens, or were we fortunate enough to observe a structural feature common to volcanoes but never before observed because of difficulties in access? Naturally, I was intrigued.

It was clear to Don Swanson and to Don Peterson, chief scientist of the USGS office in Vancouver, now called the Cascades Volcano Observatory, that these faults might be a key to understanding this stage of the eruption. Because the faults appeared to be most active just prior to dome-building eruptions, the two Dons thought that the faults might help predict the time of the next dome eruption, if they could be studied by means of repeated surveys to show ground motion. And so the Crater Monitoring Team was born.

How do you monitor an active volcano? Nothing stands still. The dome expands, and pieces of it roll down the sides. The crater floor splits in radial crevasses and is crushed by thrust faults. The amphitheater walls crumble in rockslides.

One way is to set up a station at a stable area away from the volcano and take sights using a laser beam on targets in the crater. A station was set up at Harry's Ridge, named for old Harry Truman, whose destroyed lodge had been situated along the shores of the previous incarnation of Spirit Lake. These measurements show changes in the distance between Harry's Ridge and the crater targets, evidence of expansion or contraction of the crater floor and nearby features. This technique doesn't permit measurements of detailed changes on the crater floor, however.

The Crater Monitoring Team set up a series of iron bars, painted orange to stand out against the drab background, and located on opposite sides of the new fault scarps. The team then tapes the distances between these bars and measures any changes in elevation from one bar to another. Follow-up surveys are compared with earlier surveys, and the differences denote movement on the faults. These measurements tell a remarkable story.

Several weeks before a dome-building eruption, some of the faults begin to move. The movement is slow at first, a few millimeters a day, but gradually the pace quickens. One of the most active faults is Christina's thrust, named informally for Christina Heliker. Its rate of movement increases to ten, fifteen, twenty-five centimeters *per day*, a staggeringly high rate when compared with the San Andreas fault, which, near where it is creeping south of San Francisco Bay, is known to move only a few centimeters *per year*.

Other signs that a dome-building eruption is forthcoming are found on Harry's Ridge, where the laser-beam theodolite records an increase in activity. Tiltmeters around the base of the volcano also show changes. The highly-sensitive seismographs run by the University of Washington begin to pick up small earthquakes located beneath the dome, as if the volcano had a growling, upset stomach.

Then, abruptly, new lava appears, the faults stop moving, and the seismicity stops. The lava squeezes up like partially set-up concrete, fragmenting into hot blocks that slide or roll down the flanks of the dome. A dull red glow appears in some of the cracks, and there is a lot of steam. Another new lobe has formed, another huge mass of dacite lava. We can feel the heat radiating like a reflector oven from the walls of the lobe, and new fractures form spontaneously as the walls of the dome cool down.

The faults seem to be the most accurate bellwethers, the icing on the prediction cake, although the laser-beam surveys, tiltmeters, and seismometers tell a story, too. Now the USGS will issue an extended advisory, indicating the likelihood of an eruption in the next two weeks, probably toward the end of the period. Various members of the Crater Monitoring Team make private estimates of the day and hour of the onset of the eruption, and these are tabulated in the office. Then a short-term advisory is issued, indicating the probability of an eruption in the next 24 to 48 hours. Finally, an alert is sounded, and the mountain is cleared of scientists and logging personnel. Then, right on schedule, a new lobe of the dome appears.

Determining just when the eruption starts can be an aggravating problem because of the weather. Mount St. Helens is in the path of prevailing westerly winds from the Pacific Ocean that dump great quantities of rain and snow on the Cascades throughout the year, especially in the winter. One of the greatest frustrations of the USGS is to issue an extended advisory, then be kept off the mountain because of a long siege of bad weather so that Survey scientists cannot tell if the eruption has taken place or not. Helicopters cannot fly without fairly good visibility, and nobody wants to be stuck up there in the crater with no way to get out.

As it turned out, the thrust faults had only a short lifespan. A later mudflow, called a lahar, swept down the crater floor on both sides of the dome, erasing the evidence for the thrust faults. Continued dome construction was accompanied by more faulting, but it was never as spectacular as it was in 1981. In 1986, dome building came to a close, only to restart years later south of the 1980s dome, an episode that is still in progress. Most geologists feel that this is one long eruption sequence that began on March 20, 1980 with a swarm of earthquakes, reached a climax with the cataclysmic blast of May 18, 1980, and continues today. There is probably only one magma chamber below, and every so often, it discharges another load of dacite.

Very likely, the dome building will continue until the amphitheater is filled with dacite, and the summit of Mount St. Helens is restored to its former grandeur. It is a work in progress.

References

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