PERSPECTIVES: VOLCANOLOGY

Mount St. Helens, Master Teacher

Christopher G. Newhall

On the morning of 18 May 1980, the bulging north flank of Mount St. Helens collapsed into the valley below. Within seconds, the summit followed. Suddenly unroofed, magma and rocks saturated with superheated groundwater exploded and swept northward across 600 km^2 of forested valleys and ridges (*1*) (see the figure). A roiling ash cloud enveloped the mountain after the first 30 seconds, hiding further events from view, but landslide deposits in the valley recorded three rapid-fire stages of collapse also seen in photographs of the first few seconds (*2*). Intricate patterns of more than 10 million uprooted trees recorded the speed, path, and temperature of the blast (*3*). Fifty-seven persons died in the maelstrom. Ash from the blast cloud and from a subsequent 25-km-high eruption column fell as far away as Montana and Colorado. As the ash blew eastward, great slurries of mud and trees bore down rivers to the west. The Columbia River channel filled with so much sediment that shipping had to be halted until a new channel could be dredged.

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Simultaneously, a blast of excitement swept through the volcanology community. The eruption enabled unprecedented data to be gathered, leading to renewed interest in explosive eruptions. Tragic as it was, the eruption was also a volcanologist's dream: Old outcrops were swept clean, and fresh deposits could be correlated directly with observed phenomena. The interior of the stratovolcano, built of 3000-year old lava domes draped with more lava, ash, and pumice, was open for inspection. Continuing volcanic activity invited studies of magma ascent and eruption.

As at Krakatau (Indonesia) in 1883 and Mt. Pelée (Martinique) in 1902, Mount St. Helens' eruption elucidated phenomena that were poorly understood and previously thought rare. The Krakatau eruption served as a reminder of how a large eruption can create a void in the magma reservoir, into which a roof several kilometers in thickness can collapse. It also showed how eruptions beneath and into the sea can generate deadly local tsunamis. Mt. Pelée demonstrated so-called nuées ardentes or pyroclastic flows, fast-moving avalanches of hot rock fragments and volcanic gases. Mount St. Helens in turn featured a giant volcanic landslide—a debris avalanche—and the associated lateral blast (see the figure).

With the giant landslide of Mount St. Helens came a resounding "aha!" in the volcanology community. Suddenly, the origin of puzzling, hummocky deposits around many volcanoes became clear. Before 1980, perhaps half a dozen giant landslides had been inferred, and even fewer witnessed. Since 1980, with the debris avalanche of Mount St. Helens as a reference, volcanologists have recognized evidence for more than 400 prehistoric debris avalanches (*4*). Gravitational collapse of volcano flanks and summits is now seen as common rather than rare (*4*, *5*).

A path of destruction. Blast-downed trees (foreground), hummocky debris avalanche deposit (valley floor), and beheaded Mount St. Helens. A giant landslide in 1980 carried the upper north flank, formerly conical summit, and a large scallop of the volcano's interior into adjoining Spirit Lake (upper left, not visible) and valley of the North fork Toutle River (foreground).

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Mount St. Helens also highlighted the large-scale hydrologic changes associated with eruptions, which potentially have even greater effects on populations than the eruptions themselves. On snow- and ice-clad volcanoes, pyroclastic flows can erode, mix with, and melt the frozen carapace to create sediment-laden flash floods (called lahars) (*6*). These incorporate more sediment and water as they scour their way downstream, increasing several times in volume. Numerous small- to moderate-sized lahars formed in this way at Mount St. Helens. In 1985, a small eruption of Nevado del Ruíz (Colombia) spawned similar lahars that claimed about 22,000 lives.

As a result of the explosive eruption of Mount St. Helens in 1980, infiltration of rainfall into ash-covered soil slowed by more than an order of magnitude, runoff and erosion increased sharply, and annual sediment yields were among the highest ever observed (*7*). Today, the river draining the debris avalanche deposit of Mount St. Helens still carries one to two orders of magnitude more suspended sediment than before the eruption, requiring a large dam just to keep this sediment out of lowland channels.

Following the 18 May 1980 eruption, the growing lava dome and other products and processes of Mount St. Helens were studied as never before (*8*). Patterns of small earthquakes suggested that the magma reservoir was smaller and deeper than inferred from exhumed roots of older strato-volcanoes (*9*). The roles of magma supply and ascent rates, degassing and crystallization, and other controls on explosive eruptions and dome growth were tested and quantified (*10*). New monitoring techniques were developed (*11*), and a whole new generation of volcanologists was launched. Lessons were also learned about the effects of ash on machines such as jet aircraft, electronics, crops, and human health (*12*–*14*). A geoscience bibliography of Mount St. Helens filled a book, now available on CD (*15*). Equally fascinating research opportunities arose for ecologists (see the accompanying Perspective on page 1183) (*16*).

The eruption of Mount St. Helens opened the eyes and linked the arms of specialists from many different disciplines. Geologists, geophysicists, geochemists, and hydrologists worked as teams to integrate information across time windows that ranged from centuries to seconds. The U.S. Geological Survey convinced the U.S. Congress to establish a long-sought Cas-

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cades Volcano Observatory, where many of these specialists worked side by side to capture all possible lessons of this rare event. Before 1980, some saw sharp divisions between hazards work and basic volcano research, between monitoring and geological studies, between statistics-based forecasts and process-based predictions. Today, forecasts improve as we try to marry a respect for the geologic and historical past, monitoring of the present, and fresh research into a volcano's internal and surficial processes.

Since the eruption, hundreds of volcanologists from around the world have come to study Mount St. Helens. Scientists from the United States have in turn traveled around the world to share the experience of Mount St. Helens and seek lessons from other volcanoes. The U.S. Agency for International Development (USAID) and the U.S. Geological Survey now co-fund a life-saving Volcano Disaster Assistance Program.

Mount St. Helens continues to awe and inspire those who visit. Its lessons are pillars of efforts to better understand and forecast explosive volcanism, its surprises a humbling reminder that nature's repertoire can easily exceed our imagination. Should we worry? More than 500 million people live within striking range of potentially lethal volcanoes, and the number increases by millions each year (*17*). Every success in eruption forecasting raises public expectations that the safety of these millions is assured. Forecasts are improving, but uncertainties remain high. Imagine if the next major volcanic crisis replete with uncertainty is in or near a major city, not a forest. Imagine if the trees of Mount St. Helens had been people.

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PERSPECTIVES: ECOLOGY

Messages from a Mountain

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The eruptive episode of Mount St. Helens that began on 18 May 1980 created an unprecedented natural laboratory for studying the effects of large disturbances on ecosystems and the processes that affect ecological recovery. Its richness lay not only in its size but also in the complexity of the disturbance (comprising a decapitating landslide, the blast, pyroclastic and debris flows, and volcanic ash depositions) and in the interaction of subsequent eruptive events over space and time. Following the eruption, ecologists likened themselves to "kids in the candy shop" as the complexity and richness of disturbance impacts and ecological responses revealed themselves.

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Many predictions were made about the natural ecological responses expected in the gray, ash-covered moonscape visible immediately after the cataclysmic event, assuming no human intervention. According to extant theory, recovery—or "ecological succession"—would begin with the dispersal of plants, animals, and microbes into the devastated zone from adjacent unaffected areas. Hardy, specially adapted pioneer species would lead the way and create conditions that would facilitate the establishment of species characteristic of more advanced stages of succession. Recovery in the 600-km^2 area would occur primarily by migration from the edges.

Reality defied predictions. Biologists were confounded by the richly varied and often surprising circumstances that not only left organisms alive but also allowed biotic processes and structures to persist. As a result, ecosystem recovery proceeded rapidly and by diverse pathways.

Excepting only the sites of pyroclastic flows and lava extrusions, organisms survived almost everywhere as complete individuals, perenating parts (such as rhizomes or roots), seeds, and spores (*1*). Not all survivors persisted, but many did, including species representing all trophic levels, most life forms, and all successional stages—pioneer and late successional. In the soil, animals such as pocket gophers and deer mice survived; pocket gophers proved important in mixing old soil with new volcanic ash and disseminating spores of mycorrhizal fungi (*2*). Late-lying snowbanks melted away to reveal intact beds of tree saplings and shrubs that immediately resumed growth. Amphibians emerged from the sediments of lakes and ponds to reproduce.

Organisms did disperse from long distances into the devastated zone, and many established themselves. These again included species considered to be pioneers as well as those characteristic of the late-successional forest, such as Pacific silver fir and western hemlock trees. Site preparation or facilitation by pioneers did occur, as with azotobacter-hosting lupines on the pumice plain (*3*), but just as often it did not. Many solitary tree seedlings established on the pyroclastic flows, for example.

There were immense legacies of organic structures, most notably blast-flattened tree boles and standing dead trees (snags). Classical ecological theory has largely ignored ecosystem structure—the individual and collective architecture of the components—in favor of composition. Yet structural complexity is a major factor in biological diversity and ecosystem processes (*4*). Structural legacies at Mount St. Helens influenced geomorphic processes,

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