VOLCANOES

REVISED AND UPDATED EDITION

Robert Decker and Barbara Decker

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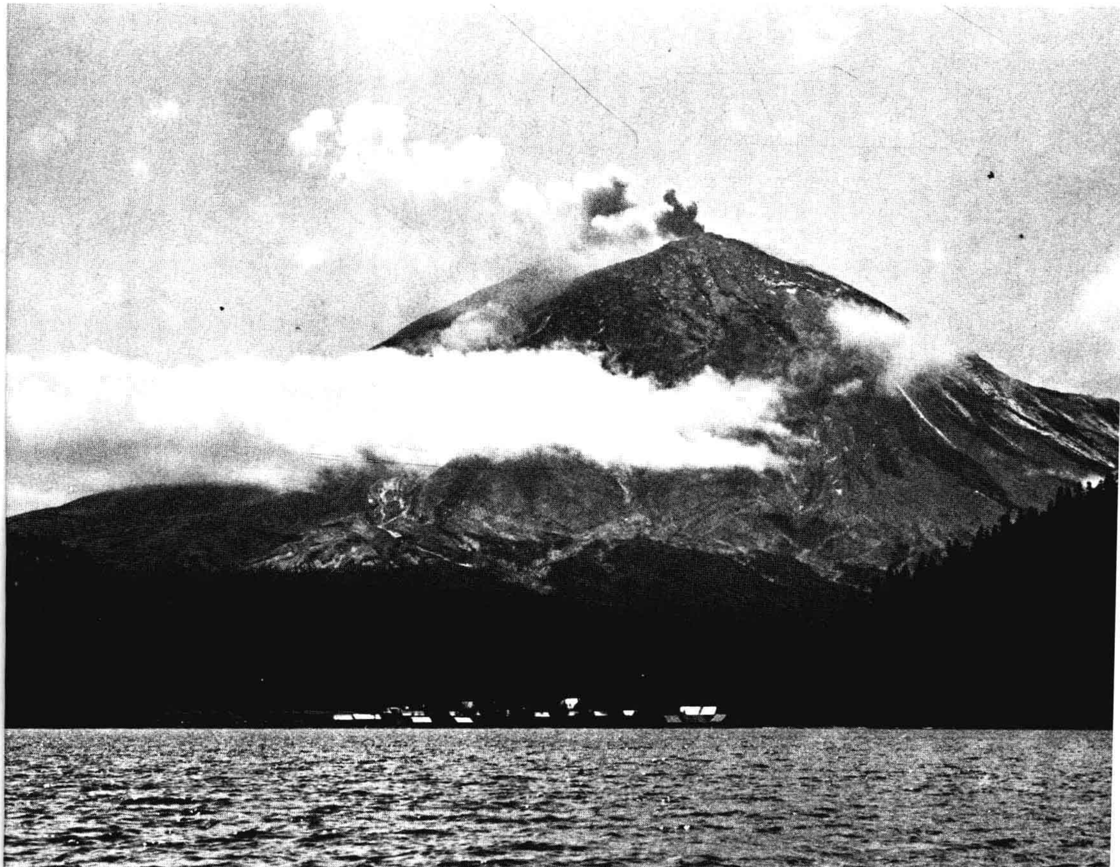
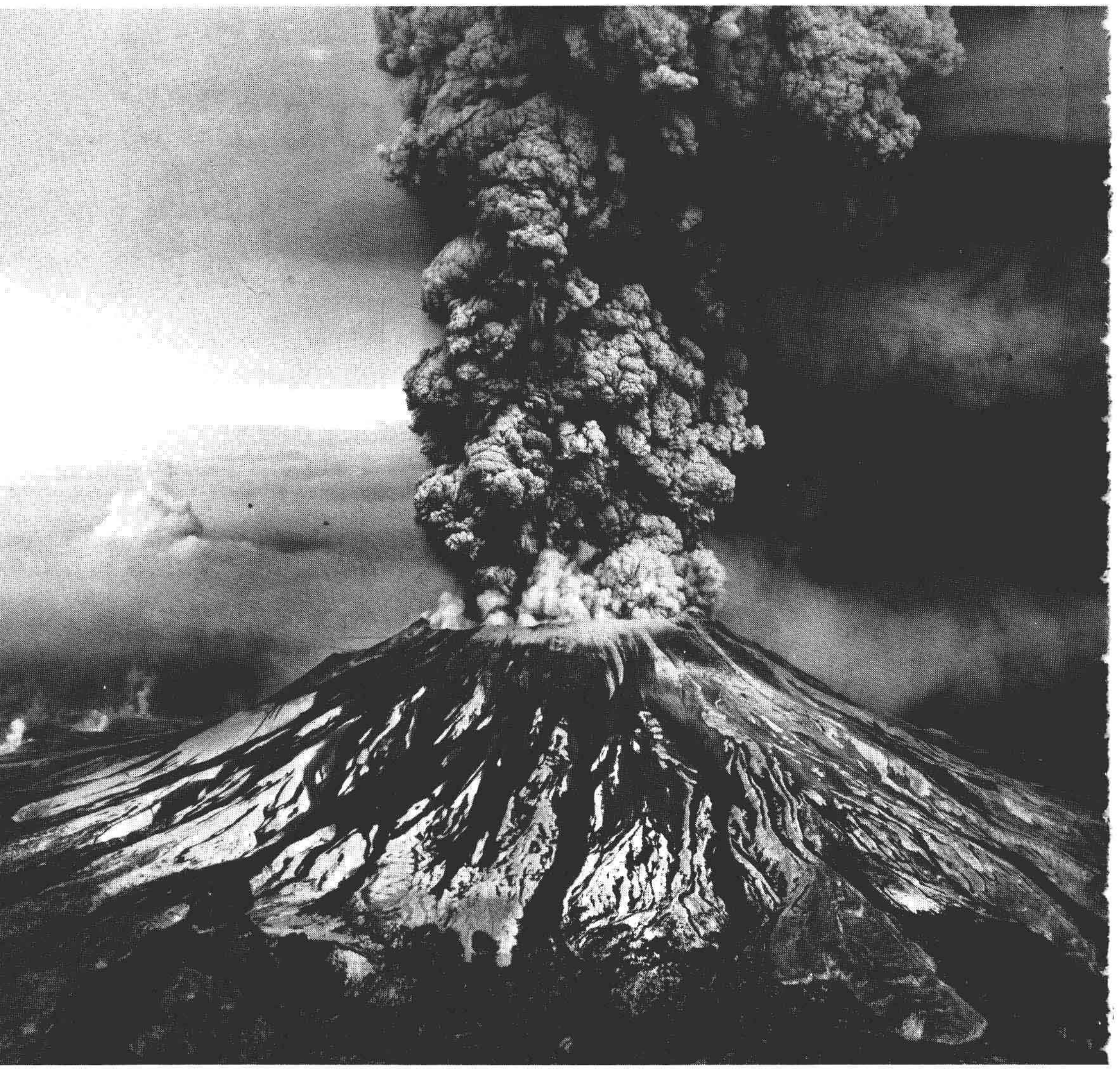


Geology is largely history, but volcanoes are as current as life and death. Spirit Lake, formed during eruptions of Mount St. Helens about 1000 B.C., was alive with spring on May 12, 1980, and undisturbed by small new eruptions from the volcano's summit. (Photograph by U.S. Geological Survey.)



On May 18, 1980, a giant explosive eruption and avalanche destroyed the entire region surrounding Spirit Lake below Mount St. Helens in moments. Not a tree is left standing; everywhere is barrenness. But Earth abides; life will return to Spirit Lake over the centuries as it did before. (Photograph by the U.S. Geological Survey.)

Preface

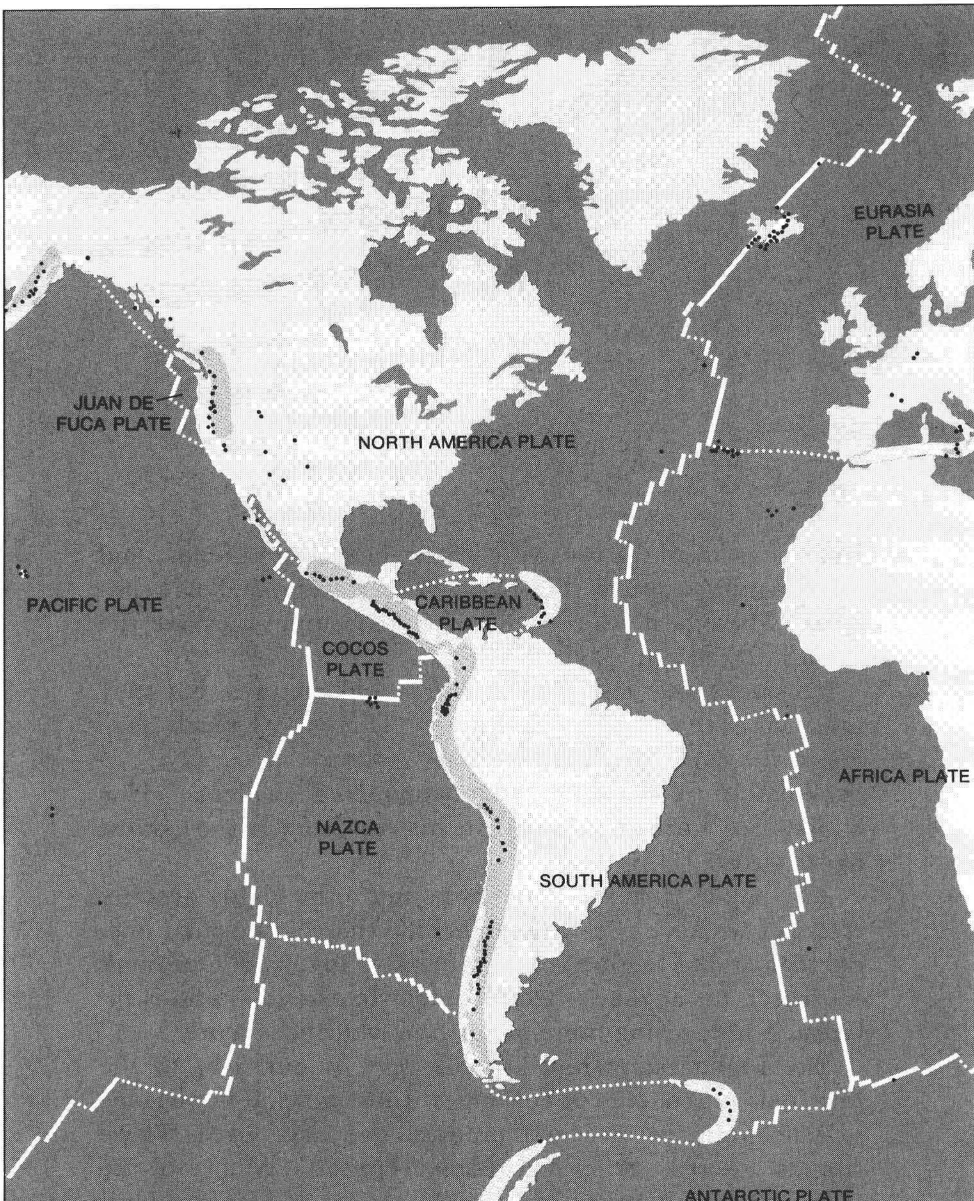
Volcanoes assail the senses. They are beautiful in repose and awesome in eruption; they hiss and roar, they smell of brimstone. Their heat warms, their fires consume; they are the homes of gods and goddesses.

Volcanoes are described in words and pictures, but they must be experienced to be known. Their roots reach deep inside the Earth; their products are scattered in the sky. Understanding volcanoes is an unconquered challenge. This book poses more questions than answers; such is the harvest of curiosity.

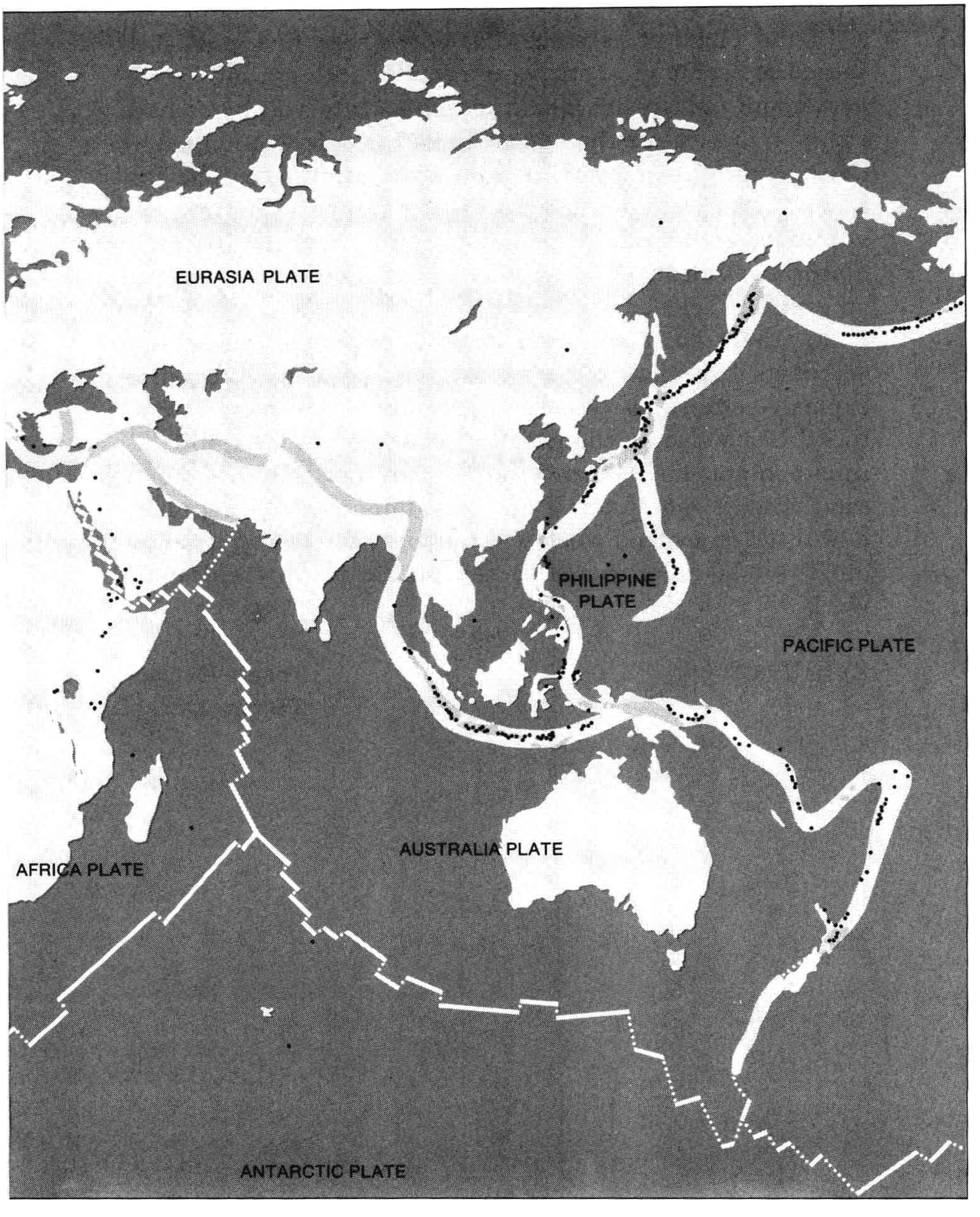
Any book about volcanoes is bound to be highly descriptive, but we have tried to look behind these spectacular phenomena and to emphasize the processes involved. Our book is written for anyone — from student to expert — who is interested in learning more about how volcanoes work.

The Bibliography reflects only part of our debt to the hundreds of students of volcanoes whose general knowledge of volcanic processes and products we have used. Three friends deserve our special thanks: James G. Moore of the U.S. Geological Survey, the late Allan Cox of Stanford University, and the late John Staples of W. H. Freeman and Company. Without their help and encouragement the first edition of this book would not have been written.

Active Volcanoes of the World



After L. D. Morris, NOAA; T. Simkin, Smithsonian Institution; and H. Meyers, NOAA; Volcanoes of the World (map), NOAA, 1979.



Key

Rift zones

Strike-slip (transform) faults

Subduction zones

• Geologically young volcanoes

In the eight years since *Volcanoes* was first published there has been a great increase in public interest and awareness about volcanism. One hundred twenty volcanoes have erupted, most more than once; 28,000 people were killed by those eruptions or by their immediate aftermath. The fact that the most lethal eruptions during this period were from volcanoes not on our original list of "The World's 101 Most Notorious Volcanoes" is another sign that volcanology is still an evolving science.

But there has been good news during these years, too. Scientists have had some notable successes in forecasting explosive eruptions, thus saving thousands of lives. Thanks to Kilauea Volcano, the Island of Hawaii is at least 400,000 square meters larger than it was 8 years ago, with new black sand beaches kilometers long. Most importantly, new ideas, new discoveries, and worldwide cooperation have helped geologists add more pieces to the puzzle of how volcanoes work.

April 1989

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VOLCANOES

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The lava falling back from the high fountains formed aa flows that moved away from the vent to the northeast, east, or southeast for 5 to 8 kilometers. Flows of this type are generally about ¼ to ½ kilometer wide and 3 to 5 meters thick, fed by a central river of incandescent lava about 10 to 20 meters across. The central stream moves quite rapidly— 10 to 20 kilometers per hour—but as it spreads beneath the dark rubbly blocks near the front of the flow, it slows dramatically. The overall advance rates of the Puu Oo aa flows were only a few hundred meters per hour. Although people had plenty of time to evacuate, several homes were crushed and burned as the relentless aa flows covered parts of a rural subdivision 7 kilometers southeast of the vent.

The reason the early eruptions at Puu Oo were episodic and geyserlike is not clear. Two factors seem to have been involved; first, some sort of off-on valve in the conduit between the summit magma reservoir and the vent, which was sensitive to pressure changes. As the summit inflated and the magma pressure increased, new magma would push through the conduit; as the summit deflated and pressure dropped, the magma flow would stop. The second factor was the gas content in the magma. Lava would appear in the vent for several days before the fountaining started, and slow overflow of the vent would precede the high fountaining. Apparently a gas-poor, dense plug of lava had to overflow before the strong boiling of gas that propelled the lava fountains began. As fountaining removed the top of the magma column, pressure was reduced on magma below and it too would flash into boiling effervescence. This discharge continued at a high rate until the available magma and gas were exhausted.

The gases dissolved in magma are mainly water, carbon dioxide, and sulfur dioxide. At Kilauea they amount to only about 1 percent of the magma by weight. However, at high temperatures and low surface pressures, these gases vigorously boil out of the magma, and the gas volume can be many times the molten lava volume.

The high lava fountains produced large amounts of pumice and Pele's hair. Pumice is a quickly cooled volcanic rock that traps the volcanic gases in tiny bubble holes; in a sense it is a solidified lava foam. The ratio of gas bubble holes to glassy volcanic rock is so high that large pumice lumps are as light as Styrofoam and float easily on water. Fine strands of volcanic glass that spin off from molten drops of lava whirling in the turbulent lava fountains are called Pele's hair. Both pumice lumps and Pele's hair were often blown several kilometers downwind from the lava fountains. Heavier lumps of solidified lava called cinders or scoria and still-molten lumps of spatter accumulate near the base of fountains and build the cinder and spatter cone around the vent. The Puu Oo cone grew highest on the southwest rim of the vent because the prevailing northeast trade winds piled most of the fallout from the lava fountains on the downwind side.

Puu Oo's seventeenth eruptive episode brought an answer to a long-standing scientific question. For years volcanologists had speculated on what the underground connections of Kilauea and nearby Mauna Loa volcanoes might be, and whether the activity of one would affect the other. Mauna Loa began a major eruption on March 25, 1984, and by March 30 was pouring a large flow of lava toward the city of Hilo from a vent at 2900 meters elevation (Color Plates 18 and 19). Puu Oo was expected to erupt in late March, and everyone waited to see if Mauna Loa's eruption would affect the Kilauea activity or vice versa. Episode 17 arrived on schedule with 100-meter-high fountains that lasted 23 hours and poured out 10 million cubic meters of lava. It was rare and marvelous to see both volcanoes erupting at the same time.

Even though the vent at Puu Oo was more than 2000 meters below the Mauna Loa vent, neither eruption had any apparent effect on the other. Although both Kilauea and Mauna Loa volcanoes may get their magma from the same general deep source, it is clear that there is no hydraulic connection between the shallow magma reservoirs of the two volcanoes.

Three and a half years after the start of the Puu Oo eruption, episode 48 in July 1986 brought a significant change. Fractures opened both up- and downrift from Puu Oo; a new vent became established about 3 kilometers downrift and activity was now focused there. Smooth-surfaced lava flows called pahoehoe issued slowly and steadily from this new vent, building a broad, low pile of solidified lava around it and ponding the upwelling magma into a 100-meter-wide active lava lake. Lava sometimes overflowed the rim of the pond, but more often it escaped through a tunnel to feed pahoehoe flows that slowly advanced through lava tubes beneath their surfaces.

In contrast to the earlier episodic pulses, the eruption now has been nearly continuous, pouring out lava at a rate of almost ½ million cubic meters per day for more than 2 years. Although the pahoehoe lava flows from this phase of the eruption advance more slowly than the aa flows from the earlier intermittent eruptions, they have slowly but inexorably moved down the southeast flank of the rift to the sea. Flows reached the sea in November 1986, destroying rural homes and covering a highway on the way. More homes were destroyed in December. Lava has been intermittently pouring into the ocean since that time, adding new land to the island.

The molten rock moves in lava tubes beneath the surface of the flows from the lava lake to the sea, a distance of about 11 kilometers. Sometimes the tubes become blocked with chunks of lava crust. When this happens the lava lake rises and overflows, or new flows break out from the lava tubes above the blockage. Often the tubes clear themselves and flows to the sea are reestablished. Small explosions of steam and lava sometimes occur as the red-hot rock slips into the sea, but usually a pillar of steam is all that marks a remarkably docile meeting of fire and water (Figure 61).

As the molten lava is suddenly quenched by the sea, some of it shatters into sand-sized fragments. This new sand is swept along by shoreline currents and has formed large black sand beaches where once the surf pounded on bare rock ledges. These new beaches extend for several kilometers along the coast, well beyond the edges of the flows entering the sea.

The billowing surface of the pahoehoe flows that form most of the land that has been added to the island looks like easy walking, but its appearance is deceptive. Not only is it possible to break through the surface into a lava tube, but recently large sections of the newly added land have started to slump into the sea. This happens without warning and poses a major danger to volcano watchers who seek a close view of molten lava meeting the ocean.

Why did the eruption become slow and steady after the new vent opened downrift? Part of the explanation may be that much of the volcanic gases keep venting from the Puu Oo cone, and not enough remains in the magma that supplies the lava lake to drive high fountains.

The gases also seem to be responsible for another phenomenon, a haze of volcanic fume locally called vog (volcanic smog) that has plagued parts of the Big Island since the lava began entering the ocean in late 1986. The ingredients of this vog come not only from the gases from Puu Oo and the active lava lake, but apparently also from an aerosol of hydrochloric acid droplets formed in the steam plume where the lava meets the sea. The trade winds generally blow the vog out to sea near the eruption, but it usually eddies back on the west side of the island — much to the irritation of residents used to warm, clear breezes and unobscured sunset views.

Although the Puu Oo eruption is the largest rift eruption in recorded history, it is not unprecedented. Summit eruptions of Kilauea were nearly continuous from 1823 to 1924, and one prehistoric east rift eruption appears to have been much more voluminous than the present output. Each new eruption leads to important insights on how volcanoes work. As old questions are answered, new ones arise. How do the lava tubes form, block up, and reopen? Why does some of the new land added to Hawaii in this eruption slump into the sea in sections larger than a football field? How does the hydrochloric-acid vog form in the steam plumes where the lava enters the sea? There is much for the present group of scientists at the Hawaiian Volcano Observatory to learn. There always will be.