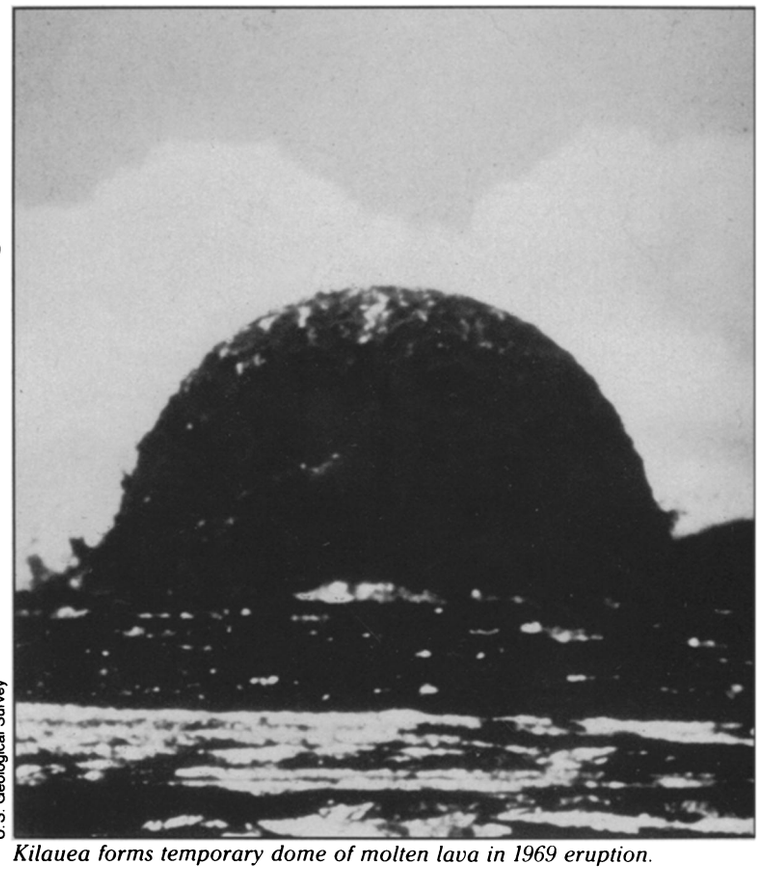
# KILAUEA Window to Nature's Power

One of earth's most active volcanoes is also one of the most accessible to scientific study. Still, its secrets are not easily revealed.

BY KENDRICK FRAZIER



U.S. Geological Survey

*Kilauea forms temporary dome of molten lava in 1969 eruption.*

One day in 1790 an army of Hawaiian warriors was marching along the flanks of Kilauea Volcano on the island of Hawaii to attack the high chief Kamehameha. Suddenly an explosive eruption ripped forth from Kilauea. The warriors were asphyxiated by the gases. A poignant record of the disaster remains today in the form of footprints preserved in the solidified ash flow. The memories of this event were still fresh in the minds of the Hawaiians when the first New England missionaries settled in the islands three decades later.

Kilauea (pronounced Kil'-a-way'-a) is one of the most active volcanoes in the world, with 44 eruptions recorded in the 20th century alone. But what is striking is that for all its action, explosive eruptions like the 1790 blast are uncommonly rare. The only other one known was in 1924. Clouds of dust climbed 20,000 feet into the air, and one man was killed when crushed by a falling rock and burned by hot ash tossed into the air. Kilauea and massive Mauna Loa, the other active volcano on Hawaii, produce especially fluidic lavas of low gas content. Thus, eruptions are relatively gentle. They produce colorful lava fountains and prodigious quantities of lava that change some part of the island's surface every few years. But, with rare exception, the bombastics associated with many other notable volcanoes in the world are absent in Hawaii.

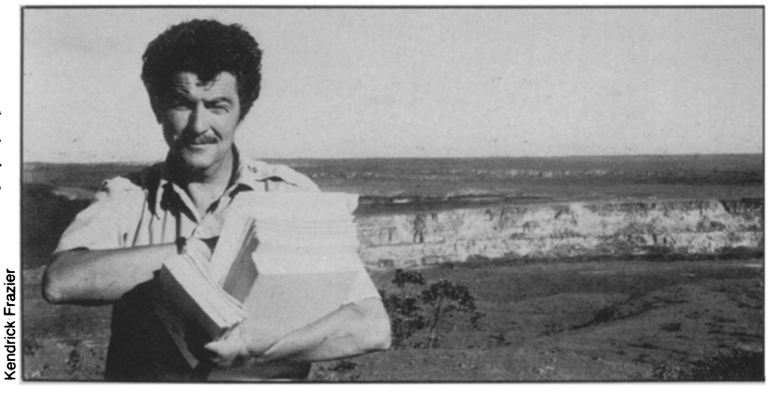
This combination of frequent but gentle eruptions and accessible location makes them an ideal laboratory for the study of volcanism. In July volcanologists from around the world gathered in nearby Hilo, Hawaii, for a series of meetings and field trips. One whole session was devoted to recent research and observations on the active Hawaiian volcanoes.

Robert L. Christiansen of the U.S. Geological Survey in Menlo Park, Calif., has been studying the geologic record of the 1790 explosive eruption. He reported new information at the meeting that the eruption was a steam explosion, much like the one observed earlier this year at La Soufrière on St. Vincent in the Caribbean (SN: 5/12/79, p. 314; 7/28/79, p. 72). And he showed that a previous interpretation of the geologic record seemingly indicating numerous previous explosions of Kilauea in the recent past was wrong.

Bedded deposits 10 meters thick and of a type ejected in volcanic explosions are visible in the area of Kilauea's caldera. It is generally accepted that at least the upper part are from the 1790 explosion. But one geologist, H. A. Powers, found many unconformities in the sequence. He concluded that there had been many explosive eruptions, widely separated in time, and that only the upper few centimeters were due to the 1790 blast.

Christiansen has restudied the deposits. He finds that the entire deposit in question was formed by the 1790 explosion. The unconformities that Powers emphasized are due, says Christiansen, to erosion and deposition of the materials left by the 1790 event. He says the geologic evidence he finds is corroborated by recent carbon-14 dates and paleomagnetic evidence that both the explosion deposits and some of the lava flows beneath them are younger than 250 years old.

A key portion of the deposits consist of fine, blocky shards produced in a phreatomagmatic (steam-caused) volcanic explosion. "So we're looking at the interaction of water and magma," says Chris-



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HVO's *Decker at Kilauea caldera: Probabilistic predictions?*

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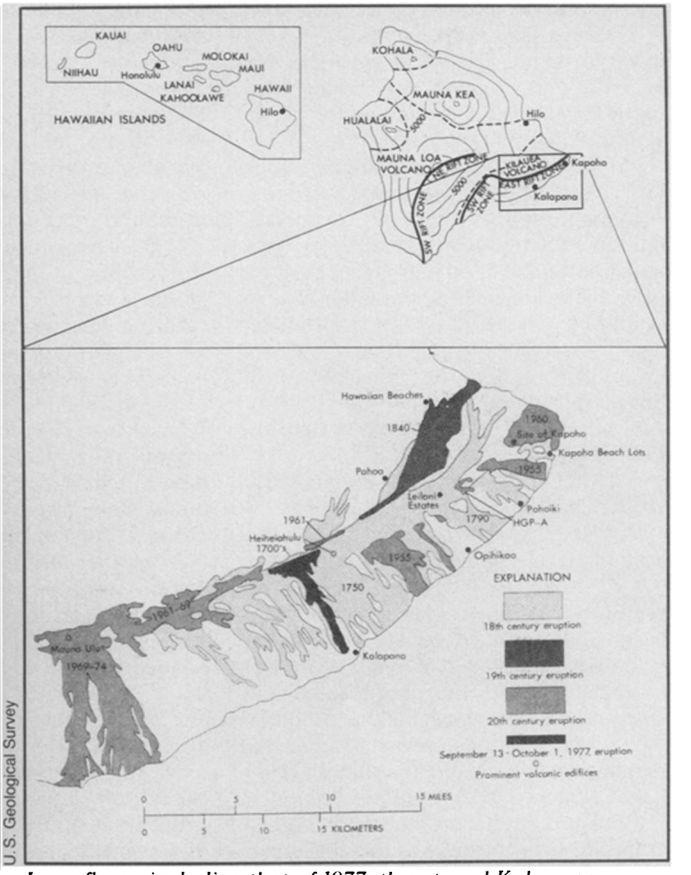
*Lava fountains, fiery flows: Kilauea puts on one of its shows.*

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*Lava flows, including that of 1977, threatened Kalapana.*

tiansen. The 1790 explosion was clearly a steam eruption, he concludes, like the one in 1924.

From the evidence, Christiansen believes the explosion was caused when a column of magma especially high up in Kilauea rapidly dropped, perhaps due to an eruption far down on the lower rift zone known to have occurred about the same time. This rapid lowering allowed groundwater to enter the magma conduits beneath the volcano's summit. When the water came into contact with the magma, the result was a series of tremendous steam explosions, scattering ash and debris over the landscape. Many of the warriors opposing Kamehameha's efforts to unite the people of the island soon lay dead, and the symbology of it all advanced his cause of Hawaiian unification.

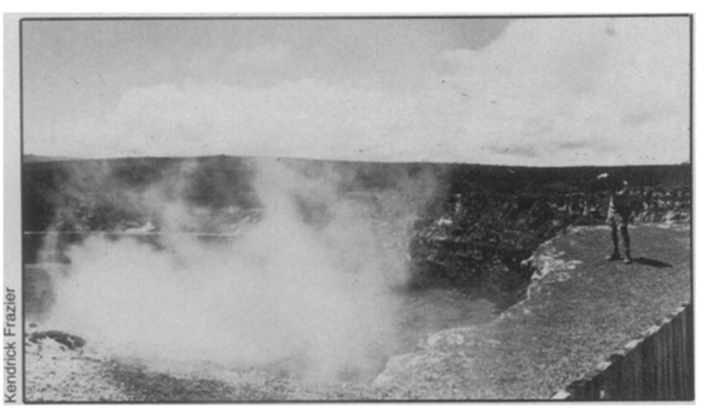
Kilauea's more typical eruptions produce long lava flows, not intense explosions. The most recent eruption was in September 1977.

Richard B. Moore and seven colleagues from the U.S. Geological Survey's Hawaiian Volcano Observatory, which is impressively situated on the caldera rim of Kilauea, described the 1977 eruption to the Hilo meeting. It produced its own brand of threat to human habitation. (The assembled volcanologists were of course hoping for a new eruption during their week-long gathering. They had to be content with visits to past lava flows, color slides of 1977's spectacle, and news that new eruptions had begun on Mt. Etna, on the other side of the world.)

The 1977 events on Kilauea began on September 13, following a 22-month period of quiescence. After nearly a day of intense seismicity on its eastern side and rapid deflation of the summit area, the eruption broke out along a 5-and-a-half-kilometer length of a rift along the east flank of Kilauea, far from the caldera. Over the next two weeks various new vents opened and closed. The nighttime sky was lit up by glowing lava. Cumulonimbus clouds generated by the heat were anchored overhead.

By late evening on September 28, the main lava flow split, and the main arm headed downward toward the coastal village of Kalapana. "We were very worried, because a fault scarp down there could have diverted the flow into Kalapana," says Moore. The authorities quickly evacuated the village, and its destruction was awaited. But the disaster was averted when the lava surprisingly thickened, and the flow stopped. It had traveled 8 kilometers downslope. Its lower end was scarcely 60 meters above sea level and 700 meters from the nearest house in Kalapana.

Meeting participants visited the lower end of this flow. From its base it appears to be only a huge hill of lava, but a climb to its top shows it to be a long, linear downhill flow, its upper reaches disappearing beyond the hills in the distance. This jumble of two-year-old black rock is of the type known as aa (pronounced ah-ah). This is the term borrowed from the Hawaiian language for lava that is broken, jagged and angular, in contrast to the smooth or rope-textured pahoehoe lava. Standing on it, one could see the short distance down the coast to the village of Kalapana, which



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*"Firepit" at Kilauea today: Steaming but not bubbling.*

was spared destruction by the lava flow.

The lava flow is 14 meters thick at its lowermost end. "The thickness of that flow is really very unusual for Hawaii," says Robert Decker, the new director of the Hawaiian Volcano Observatory.

Moore agrees. "It's a remarkable thickness. It's what we believe saved Kalapana."

Overall, the 1977 eruption extruded 35 million cubic meters of lava, covering an area of 8 square kilometers. These are not particularly unusual amounts for Kilauea eruptions. The 1972 eruption produced nearly four times as much lava; the 1969 eruption more than five times as much. But the seven eruptions between 1972 and 1977 all yielded lesser amounts than the 1977 event.

But the 1977 lavas were atypical. The erupted basalt, says Moore, was highly differentiated. Its mineralogy was unlike that seen in lavas erupted from Kilauea's summit. Even the last lava erupted late in the eruption was differentiated. All this suggests to Moore and colleagues that the lava that emerged had been stored as magma in Kilauea's rift zone for some time. It was not the actual magma that produced the eruption. This also seems to mean that the magma responsible for summit deflation has not yet been erupted.

Still another unusual feature of the 1977 eruption, says Moore, was the absence of any increase in seismicity or change in the tilt of Kilauea's summit in the six months prior to the September 1977 events.

The search for an explanation of these oddities focuses on the Hawaiian earthquake of 1975. On November 29, 1975, a magnitude 7.2 earthquake rocked the south flank of Kilauea. Earthquakes are common on Hawaii. The precise locations of 45,600 of them were plotted by the Hawaiian Volcano Observatory from 1960 through 1977. Most are byproducts of volcanism. But this one was the largest in more than a century.

A study of the earthquake by Masataka Ando of the Disaster Prevention Research Institute at Kyoto University in Japan has shown what probably happened. Magma forced itself up into Kilauea's rift zones. This put great southward pressure on Kilauea's south flank. A nearly horizontal fault plane 10 kilometers below the south flank was locked against shear displacement — until a certain threshold was reached. At that time the lock released. The flank at that depth suddenly slipped southward several meters. The result was a large earthquake.

And that earthquake seems to have influenced the 1977 eruption. "We think," says Moore, "that the big earthquake allowed more magma to be delivered and stored in the rift zone, then be forced out in 1977 by newer magma."

What's happened at Kilauea since the 1977 eruption? The overall pattern, report Moore and his Hawaiian Volcano Observatory colleagues, has been inflation of a long length of the east rift zone. (Inflation usually is a sign that magma is being stored in a shallow reservoir.) One seismic swarm this past May probably signals magma movement. But beyond that it's hard to tell. The 1975 earthquake injected many new uncertainties. "It kind of changed our thinking," says Moore.

A new eruption could nevertheless come at any time. Decker says the 2.5 percent odds of an eruption happening during any given week still hold. Seismicity below Kilauea jumped to 1,100 earthquakes on the Tuesday of the volcanologists' meeting. "We thought we might have something for you," said Decker. But the seismic activity quickly subsided without further event.

But what of the longer term? It is clear that over the decades and centuries Kilauea has gone through enormous changes. What made Kilauea famous was the presence throughout the 19th century and the first quarter of the 20th century of an almost continuously active lake of bubbling, molten lava in Halemaumau. This is the "Fire Pit," a depression now 3,200 feet across, on the bottom of the enormous 2-mile-by-2-and-a-half-mile collapsed crater, or caldera, at the summit of Kilauea.

A young reporter named Mark Twain visited the caldera in 1866 and described its drama: "Over a mile square of it was ringed and streaked and striped with a thousand branching streams of liquid and gorgeously brilliant fire! ... The place below looked like the infernal regions, and these men [his companions on the rim glowing in the reflected crimson light] like half-cooled devils just come up on a furlough."

The 1924 steam explosion at the summit ended all that. The long-present lava lake was now seen only intermittently. No more was there a continual, bubbling lava lake. Today the caldera and the old Fire Pit are quiet, only a few lazy wisps of steam here and there betraying the volcanic power beneath.

Geologist Robin T. Holcomb of Stanford University has recently defined the history of Kilauea over the past 2,000 years. At the Hilo meeting he reported on century-scale changes in its eruptive behavior. His investigation indicates that the present caldera probably formed by summit collapse in the 18th century. Prior to that, there had been 250 to 500 years of very long eruptions from the summit. After the collapse, activity switched to the flanks of the volcano. The 1790 phreatomagmatic explosion initiated the period of continual lava-lake activity at the summit that continued until the similar explosion in 1924.

Since 1924, the summit has seen only relatively brief and intermittently occurring eruptions. Eruptions on the flanks of Kilauea, in contrast, have become more frequent and more sustained. Kilauea's activity, in other words, has moved away from the summit and down on its flanks.

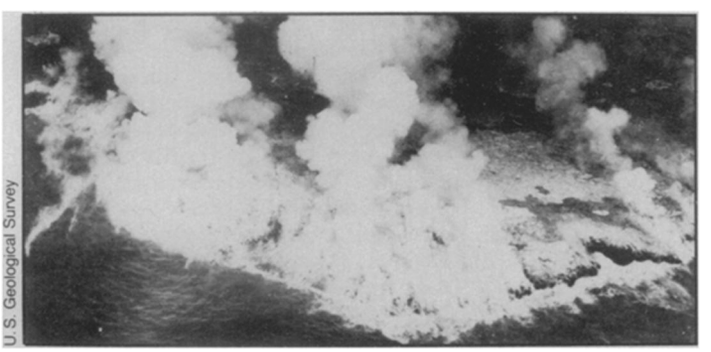
"Geophysical evidence indicates that a well-developed plumbing system now delivers magma laterally from the summit to the upper east rift zone," says Holcomb. This means, he says, "that we can expect frequent eruptions over the next few hundred years on the east rift zone."

This, he notes, is of some concern. The long period in which activity was confined to Kilauea's summit encouraged the location of villages and farms down along the volcano's east flanks, supposedly safe from eruptions. Now it is apparent that the volcano has great lateral subterranean reach, and many of these developed areas are vulnerable.

Fortunately, Hawaii is now crisscrossed by a dense network of monitoring instruments. To the degree that changes in seismicity, land deformation, geoelectricity and gas output are clues to impending eruptions, the next manifestation of Pele, the Fire Goddess, need not be a surprise. "We hope to get into quantitative probabilistic predictions," says HVO's Decker. "And," he says with a smile, emphasizing the uncertainties in volcano forecasting, "I do mean probabilistic."

Volcanoes, like other natural phenomena, both create and destroy. Lava from the 1960 Kilauea eruption, far down on the northeast tip of the island 28 miles from the volcano's summit, destroyed most of the village of Kapoho. It also created new land where it flowed into the ocean, enlarging the state of Hawaii by 500 acres. (The inevitable dispute over who owns this new land is still in the courts.) The 1971 eruption built 97 new acres of coastal land.

Hawaii was created this way, a child of volcanism. So were all the islands of the Hawaii chain. Kilauea is a window to the power of nature in action, creating and continually reshaping the surface of the planet. □



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*Steam towers skyward when lava from 1971 eruption enters ocean, enlarging Hawaii.*