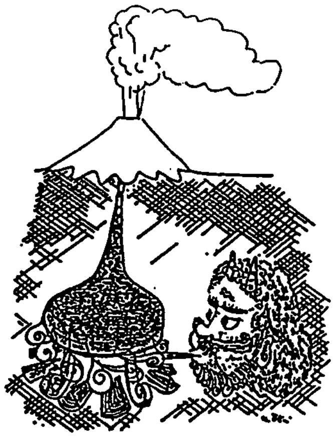


ASH FALL

Newsletter of the Volcanology Division
Geological Association of Canada

ASH FALL #30 JAN 1992

GREECE FIELD TRIP

The trip to examine Fore- and Back-Arc stratigraphy in the Greek Islands, as well as volcanic stratigraphy near Athens is proceeding. A small group of determined scientists from Canada will depart for "Homer's Wine-dark Sea" on May 9 and return May 23 in time for the annual GAC/MAC meeting in Wolfville.

LEOPOLD GELINAS MEDAL

At the 1991 annual meeting the attending members voted to investigate having a Leopold Gelinas Medal struck with which to award author's of the year's best M.Sc., and Ph.D. theses in volcanology. The cost of the die for a 2-inch medal has been generously donated by member Jerry Remick of Quebec City. Portrait medals will be awarded in gold and silver finish annually.

MEETINGS

Geological Survey of Canada, Jan. 20-24, 1992, Ottawa. Current Activities and Minerals Colloquium. This celebrates the 125th year of the G.S.C.

Ocean Sciences Meeting, Jan. 27-31, 1992, New Orleans, La.

AGU Chapman Conference, March 23-27, 1992, Hilo, Hawaii. "Climate, Volcanism and Global Change".

AGU-CGU-Min. Soc. Amer., May 12-15, 1992, Montreal, Quebec.

Western Pacific Geophysics Meeting, Aug. 17-21, 1992, Hong Kong.

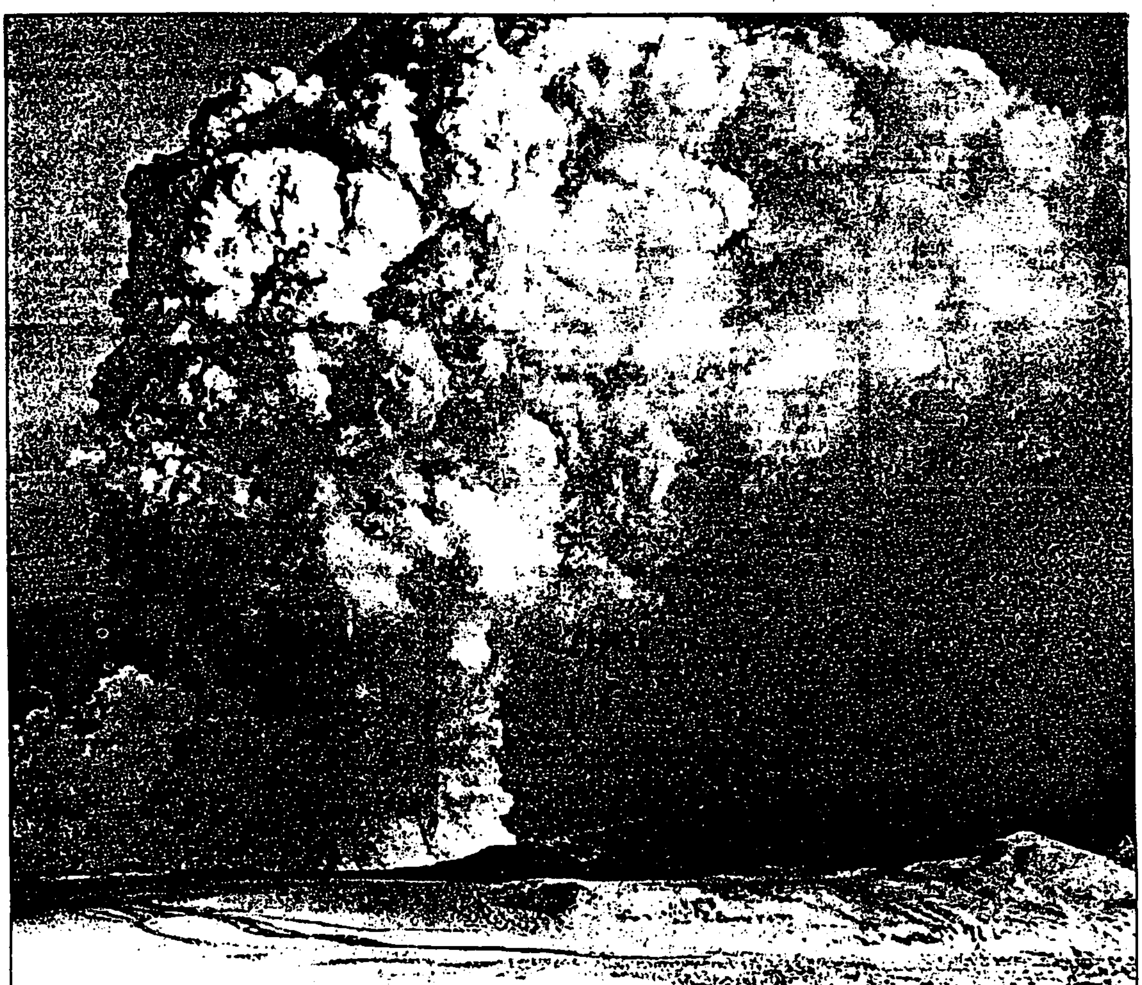
RECENT MEETINGS

AGU Pacific Northwest and Regional Meeting, Sept. 18, 1991. Papers included regional geology, tectonics, magmatism and volcanology.

AGU 1991 Fall Meeting, Dec. 9-13, 1991, San Francisco. Over 330 papers and posters were presented on volcanology, geochemistry and related petrology. A special session was also held on Mt. Pinatubo.

COSTA RICA

The Cordilleran of Costa Rica includes at least 112 Recent and modern volcanoes. Of these Poas and Irazu are within a few hours drive from San Jose. Mt. Arenal, a Strombolian-type which currently erupts on an almost hourly basis is only somewhat more remote. Because of almost year round tourism, costs for food and accommodation have increased significantly. The April 22, 1990 Valle de la Estrella earthquake which rocked the west coast of Costa Rica occurred within the North Panama Thrust Belt with an focus at about 17 km depth. The shoreline at Limon was uplifted about 4 meters enlarging the beach area considerably.



That's smokin' Nov. 30 '91

The Westdahl volcano, which erupted on Unimak Island, spews smoke and ash 7,010 metres into the air over the weekend. No injuries were reported. The island is about 1,126 km southwest of Anchorage, Alaska.

Transport of Cerro Hudson SO_2 Clouds

EOS V72 #45 11/5/91

Scott D. Doiron, Gregg J. S. Bluth, Charles C. Schnetzler, Arlin J. Krueger, and Louis S. Walter

The Cerro Hudson volcano in southern Chile (45.92°S, 73.0°W) emitted large ash and sulfur dioxide clouds on August 12–15, following several days of minor activity [*Global Volcanism Network Bulletin*, 1991]. The SO_2 clouds were observed using (preliminary) near real-time data from the Total Ozone Mapping Spectrometer (TOMS) as they encircled the south polar region. The injection of SO_2 into the stratosphere has essentially created a gigantic chemical tracer that could provide new insights into the wind patterns and seasonal circulation around the Antarctic region.

The TOMS instrument, on board the National Aeronautic and Space Administration's Nimbus 7 satellite, measures the ratio of backscattered Earth radiance to incoming solar irradiance in the ultraviolet spectrum. Although originally designed to measure ozone, it was later discovered that the TOMS instrument could also detect and quantify SO_2 [*Krueger*, 1985]. After this discovery, measurements from TOMS were examined for SO_2 emissions for all recorded volcanic eruptions since Nimbus-7 was launched in October 1978, and current data are analyzed as new eruptions occur. The satellite is in a polar, Sun-synchronous orbit so that it crosses the equator at local noon and observes the whole sunlit Earth in approximately 14 orbits each day. Total column amounts of SO_2 are determined that represent the amount of gas affecting the reflection of ultraviolet light through a column of the atmosphere from the satellite to the reflecting surface, Earth, given in terms of milli atmospheres centimeter (1000 milli atm cm = a gas layer 1-cm thick at STP). The mass of SO_2 is calculated by integrating over the cloud area to obtain a volume, then converting to tons.

Although increased seismic activity, ash emission, and pyroclastic eruptions occurred intermittently from August 12 to 15, there were only two episodes of significant explosive output of SO_2. Table 1 presents a chronology of the SO_2 cloud observations from August 13, when the first cloud was detected, to August 21, when the second, larger cloud completed a circuit around the pole. Preliminary measurements of the August 13 cloud totaled 250 kton (1 kton = 10^6 kg) SO_2, and covered an area of 270,000 km^2. The cloud had drifted ESE 1400 km from the eruption site and lacked an extended trailing edge, which indicated that the SO_2 was emitted during a single burst of activity. This cloud was also observed on August 14, but could not be positively identified on any subsequent days.

A new, large SO_2 cloud was observed on August 15, but untimely data dropout prevented a full image reconstruction. Again, the cloud geometry indicated that the SO_2 was emitted in a relatively short-lived episode. Figure 1 shows the progression of the SO_2 cloud as it encircled the Earth between 50°S and 65°S latitude from August 15 to August 21. At this latitude range the TOMS data in the images were taken at approximately 11:00 A.M. local time. For comparison, speeds were calculated for the drift of the eastern edge of the clouds, but portions of the total cloud clearly move at different speeds and directions depending on the southern winds.

The SO_2 cloud on August 16 crossed 0° longitude and covered an area of 850,000 km^2. Calculations of the cloud mass using TOMS data for August 16 yield approximately 1500 kton SO_2. The cloud on August 17 continued to drift eastward, with the leading edge moving at a rate of approximately 40 m/s. By August 18 the cloud had elongated along a latitudinal axis, with some smaller portions of the cloud breaking away. The speed of the cloud between 45° and 100°W also unexpectedly increased at this time, to 60 m/s. The TOMS observation image from August 19 shows the cloud rotating clockwise and drifting sideways as it approached Australia, effectively slowing its eastern progression. The cloud also began to drift in a more southerly direction, crossing 55°S.

On August 20 the SO_2 cloud continued its southward path to 65°S before resuming its primarily eastern movement. The cloud crossed the international dateline, so it was observed twice on August 20 (only the first cloud observation is shown in Figure 1). By August 21 the leading edge of the cloud had traversed the globe and passed over its place of origin in the southern Andes. The cloud was remarkably cohesive and contained 1000 kton SO_2, approximately two-thirds the SO_2 measured nearly 5 days earlier. The cloud length consistently increased with time, but did shorten somewhat during the 2 days that the cloud passed south of Australia. The horizontal cloud area more than doubled to over 2,000,000 km^2. The cloud shapes in Figure 1 may be misleading in this sense, because the stereographic projection used to display the clouds is not equal area (surface areas are operation. Hudson produced roughly twice the amount of SO_2 outgassed by the explosive Mount St. Helens eruptions in 1980 (which totaled 750 kton). However, the June eruptions of Mount Pinatubo emitted an order of magnitude greater SO_2: in an upcoming paper we report our measurements, which totaled approximately 20,000 kton SO_2 (G. Bluth et al., unpublished manuscript, 1991).

Cerro Hudson is unique in that SO_2 from Andean volcanos, and for that matter from volcanos in southern latitudes, has rarely been observed in the data record from the TOMS instrument. For example, eruptions of Lascar at 23°S in Chile in August 1986, and March 1988, produced no detectable SO_2. Another unusual feature is the persistence and cohesiveness of the cloud. This eruption can be compared with another explosive eruption that occurred in a high latitude—the Alaid (Kurile Islands) eruption in April 1981. The Alaid SO_2 cloud was of a similar tonnage as Cerro Hudson and also formed a serpentine shape as it drifted in an easterly direction, but was torn apart after only 1 week. Cerro Hudson's cloud was sheared into a 3000-km long, 300-km wide stringer 4 days after the eruption. This stringer distorted like a wet noodle as it moved around the Earth during the next 2 weeks. The Alaid eruption cloud started as a stringer, but was torn apart after only 1 week. The difference in transport between the two erupted SO_2 clouds is in part seasonal, but is primarily due to differences in circulation in the two hemispheres.

The timing of this eruption coincides with the appearance of the Antarctic ozone hole in the austral late winter/early spring, when the air within the polar vortex is isolated from lower-latitude air. This lack of meridional transport is clearly shown by the circumpolar motion of the SO_2 cloud in Figure 1, which approaches the Antarctic continent but never drifts across the pole. Although the polar circulation has been well studied, it is a complex process and not completely understood. Some of these complexities became apparent during our tracking of the SO_2 cloud, notably the increased cloud velocities between 45° and 90°W (August 17–18), and the southward movement as the cloud passed Australia (August 19–20). The TOMS observation of the SO_2 cloud transport is extremely valuable as a chemical tracer experiment, to assist in development of models of circumpolar transport, and to increase our understanding of stratospheric circulation patterns.

References

Global Volcanism Network Bulletin, vol. 16, no. 7, pp. 2–4, Smithsonian Institution, Washington, D.C., 1991.

Krueger, A. J., Detection of volcanic eruptions from space by their sulfur dioxide clouds, paper presented at the 23rd Aerospace Sciences Meeting, Am. Inst. Aero. Astron., Reno, Nev., Jan. 14–17, 1985.

Table 1. TOMS Chronology of the Cerro Hudson SO_2 Clouds

Date	Time[1], GMT	TOMS SO_2, kton	Area, km^2	Length, km	Drift Speed[2], m/s	Comments
August 13	1530	250	270,000			cloud observed 1400 km ESE of Cerro Hudson
August 14	1400					Aug. 13 cloud dispersing rapidly
August 15	1606			1800		Aug. 13 cloud no longer discernable; new cloud detected
August 16	1254	1500	850,000	1600	40	new cloud observed with full data set
August 17	0945		950,000	2100	40	cloud elongated along a longitudinal axis
August 18	0450		1,000,000	3300	60	cloud moving very rapidly along 50°S
August 19	0323		2,000,000	4200	30	cloud began to rotate as it approached Australia
August 20	0155		2,100,000	3800	25	cloud drifting south above 60°S
August 20	2100			3600	50	cloud observed twice as it crossed the dateline
August 21	1751	1000	2,200,000	5400	30	cloud elongates in a sinusoidal distortion

The Pu'u 'O'o-Kupaianaha Eruption of Kilauea

EOS V72 #47 19/11/91

Christina Heliker and Thomas L. Wright

Kilauea is nearing the 10th year of its most voluminous rift zone eruption in the last 2 centuries. Lava flows have covered 75 km^2 to depths as great as 25 m and have added almost 1.2 km^2 of new land to the island. These flows have devastated downslope communities and have provided a painful tutorial for local government in planning for and living with volcanic hazards [*Heliker and Wright*, 1991]. At the same time, the accessibility and longevity of this eruption have provided a unique opportunity for quantitative studies requiring long-term observations. This article briefly summarizes these studies, which are directed at a better understanding of eruption mechanics, lava-flow field emplacement, and the plumbing system of Kilauea.

Eruption Chronology

Each eruption of Kilauea is influenced by preceding volcanic and seismic events. The site of the current eruption was host to several short-lived eruptions from 1963–1969. Pockets of magma that remained within the rift zone after each of these eruptions may have contributed to lavas that erupted in 1983. Additional magma storage space was created by the magnitude 7.2 earthquake in November 1975, and subsequent activity was dominated by intrusions. Ten intrusions and a single eruption occurred along the middle east rift zone between 1977 and 1980 [*Klein et al.*, 1987]. Leveling and geoelectrical measurements from 1979–1980 identified an intrusive body within 100 m of the eventual site of Pu'u 'O'o [*Jackson*, 1988].

On January 2, 1983, a dike propagated down the east rift zone, heralded by an intense earthquake swarm [*Koyanagi et al.*, 1988]. Twenty-three hours later, lava reached the surface. Over the next 6 months, intermittent activity occurred along several fissures. By June 1983, the eruption had localized at the Pu'u 'O'o vent and the activity settled into an increasingly regular pattern of brief (less than 24-hr) eruptive episodes, separated by repose periods averaging 25 days [*Ulrich et al.*, 1987]. Over the next three years, 44 episodes of high fountaining built a cinder-and-spatter cone 255 m high and covered 42 km^2 with a'a lava (Figure 2).

The volcano was primed for the 48th episode of high fountaining in July 1986, when the vertical conduit of Pu'u 'O'o ruptured and magma erupted through new fissures at the base of the cone. Two days later, another fissure opened 3 km downrift to form the Kupaianaha vent, which has been active ever since. This marked the end of episodic high fountaining and the beginning of continuous eruption. A lava pond developed over the new vent and overflows from the pond built a shield (Figure 3), which reached a height of 55 m in less than a year. By November 1986, a lava tube had formed between the pond and the ocean, 12 km away.

From 1987 through 1988, periodic intrusions occurred within the Kupaianaha shield, accompanied by uplift and faulting and followed by extrusion of a'a flows from the base of the fault scarps. In April 1988, the eruption paused for 1 week—the first period of repose since July 1986. The lava pond drained to a depth of about 40 m below the rim, then quietly refilled at the end of the week.

A series of 12 eruptive pauses began in February 1990, all preceded by sharp deflation at the summit and an increase in summit tremor [*Okubo et al.*, 1990]. During the better defined pauses, magma supply to Kupaianaha stopped roughly 45 hours after the summit began to subside (J. Kauahikaua and T. Moulds, unpublished data, 1990). The end of each pause was marked by rapid summit inflation, a decrease in tremor, and an increase in microearthquakes beneath the summit. About 10–12 hours after the summit began to reinflate, the output from Kupaianaha returned to normal.

The eruption pauses showed a strong tidal influence; 8 of 12 pauses occurred at 4- or 6-week intervals within 3 days of a fortnightly Earth tidal minimum (J. Kauahikaua, unpublished data, 1990). The pauses may have resulted from depletion of the summit reservoir, which has shown net deflation throughout this eruption. The last pause was in November 1990. A month later, a seismic swarm announced a shallow (1–3 km) intrusion that extended from the summit into the upper east rift zone. This event initiated a period of summit reservoir replenishment [*Okubo et al.*, 1991]. Two more intrusions occurred in the same area during March and August 1991. Only the December intrusion had any immediate effect on the ongoing eruption, causing a brief surge in supply to the lava pond in the Pu'u 'O'o crater.

Ongoing Research

Eruption Mechanics: A Self-regulating System

The Pu'u 'O'o phase of the eruption provided us with the most complete set of geophysical data ever obtained on lava fountain dynamics. Tiltmeters recorded increasingly predictable cycles of gradual inflation of Kilauea's summit between eruptive episodes and rapid deflation during each episode. As the summit inflated, slow leakage from the summit reservoir filled the local storage area beneath Pu'u 'O'o, producing extension and uplift across the rift zone near the vent [*Hoffmann et al.*, 1990] (unpublished HVO data, 1985–1986). Fluid dynamic models of the fountaining episodes show that the geometry of the local reservoir beneath Pu'u 'O'o is roughly planar, with dimensions of a few meters in width, 100 m in length, and 1 km in height [*Wilson and Head*, 1988].

Each eruptive episode followed a similar pattern. A plug of degassed magma left from the previous episode acted as a reservoir cap that was gradually pushed upward in the conduit during the 3–4 week repose period [*Greenland et al.*, 1988]. Once the plug was extruded, the release of volatiles rapidly accelerated, causing high lava fountains. The eruptive episode ended, usually abruptly, because of reduced driving pressure from the summit, combined with blockages of cool magma forming within narrow sections of the dike [*Parfitt and Wilson*, 1988].

Petrology: Tracking a Magma Batch

This eruption is the first in Kilauea's history for which we can trace a mantle-derived magma batch from its arrival at the summit reservoir to its eruption at the surface. Hybrid lavas that erupted early in 1983 were a mixture of fractionated and more mafic magmas that had been stored in the rift zone [*Garcia et al.*, 1989]. Mass balance calculations have identified a parent magma for the fractionated component, which was emplaced in the rift zone as early as 1963 [*Wright and Heliker*, 1987]. Since mid-1984, the composition of the lava has been uniform and unfractionated, consistent with its origin as a homogenous batch formed during the 7 years of intrusive activity following the 1975 earthquake. At the currently estimated magma supply rate of about 0.1 km^3/yr [*Wolfe et al.*, 1988], over 0.7 km^3 of magma may have accumulated, more than in any previously defined magma batch from Kilauea [*Wright and Tilling*, 1980]. This volume is comparable to that of the magma erupted since 1983.

Lava chemistry also provides information on changing conditions in the magmatic plumbing. Lava temperatures were obtained from analysis of MgO and CaO in rapidly quenched glass, using a new geothermometer [*Helz et al.*, 1987] developed during this eruption. Lava erupted from Kupaianaha is about 6°C cooler, and plagioclase crystallizes at temperatures 2° higher, than in samples erupted from Pu'u 'O'o. These differences reflect cooling and degassing through the Pu'u 'O'o vent, particularly of H_2O, before lava reaches the surface at Kupaianaha [*Helz et al.*, 1991]. Glass geothermometry has also shown that the temperature of the lava stream insulated within a lava tube cools less than 10°C en route from Kupaianaha to the ocean, 12 km away.

Surface Processes: Quantifying Flow-field Emplacement

Continuous effusion from Kupaianaha has advanced our understanding of how large flow-fields develop and has improved our ability to predict hazards during long-lived eruptions. Since the Kupaianaha lava pond formed in 1986, the eruption has produced mainly tube-fed pahoehoe flows. The development of the lava tube system has been studied by making geoelectrical measurements across the tubes to record rates of tube coalescence, downcutting, and changes in magma flux.

The flow field has grown both endogenously (from intrusion beneath a cooled crust) and by addition of surface flows [*Kauahikaua et al.*, 1990]. The pahoehoe front at the distal end of a lava tube cannot keep up with the supply coming from behind, and the flow surface inflates. On the flat coastal plain a closely monitored flow inflated nearly 4 m in 16 days [*Hon and Kauahikaua*, 1991]. These studies demonstrate the danger in attempting to interpret sections of older pahoehoe lava in terms of simple stratigraphic superposition.

Real-time Geomorphology: A Cone Evolves into a Crater

The Pu'u 'O'o cinder-and-spatter cone grew to a height of 255 m in only 3 years. The mouth of the conduit was 20 m wide at the close of activity in 1986 and was located below and northeast of the cone's summit, due to the prevailing winds during tephra deposition. In the 4.5 years since the eruption shifted to Kupaianaha, Pu'u 'O'o has been losing mass as the conduit walls collapse and the material is stoped into the active dike connecting the Pu'u 'O'o magma reservoir and Kupaianaha (K. Hon, unpublished data, 1987). The cone has lost 20 m in height, and the conduit has been transformed to a gaping crater almost 250 m in diameter, with an intermittently active lava pond at its bottom. We now infer that other cones on Kilauea's rift zones may have stood as high when first formed and that they have since collapsed to form low cones with large craters.

The Slow Process of Building New Land

Lava flows from Kupaianaha have entered the ocean intermittently since late 1986. When the flows encounter a gentle submarine slope, they build outward and form a delta of new land. Where the submarine slope is steep, the lava tubes spread parallel to the shore, building a narrow bench downstepped from the original sea cliffs (K. Hon, unpublished data, 1988). An active bench may collapse catastrophically without warning when slumping of the underlying debris fan leaves the bench unsupported [*Kelly et al.*, 1989]. Many collapses precipitate littoral explosions as the tubes are exposed to the surf (Figure 4). The largest collapse events, which took place in 1988 and 1989, were recorded on seismometers over the southern half of the island.

As land builds into the ocean, undersea divers have observed the feeding tubes emptying directly underwater to produce pillow lava. And for the first time, divers have filmed lava flowing in an open channel underwater, analogous to similar features observed on land [*Tribble*, 1991].

Chemical reactions occur when lava enters the sea, giving rise to hydrogen bubbles below the water surface [*Sansone et al.*, 1990] and a steam plume enriched in hydrochloric acid, produced when the seawater is hydrolyzed by the hot lava [*Gerlach et al.*, 1989]. The plume has created discomfort and an unforeseen hazard to downwind communities.

Forecast for the Future

Our ability to predict the onset of Kilauea's eruptions far exceeds our ability to determine how long any eruption might continue. An earthquake of magnitude 7 or greater might be sufficient to disrupt the rift plumbing and close down the current eruption. Such an event is a likely consequence of the strain buildup on Kilauea's south flank due to the pressure of unerupted magma in the east rift zone. It is also possible that the eruption could end less abruptly, either when the magma batch feeding it is used up or as the dike gradually narrows because of cooling and solidification on its walls. Though the current eruption is longer-lived than other historical rift zone eruptions, it is typical of those that have built Kilauea and may well continue for several more years. Regardless of when it ends, this eruption has already given us the most extensive array of data yet on the processes that construct a Hawaiian shield volcano.

The 1991 AGU Fall Meeting will include a special session on the Pu'u 'O'o-Kupaianaha eruption, "The Ongoing Kilauea Eruption: A Dynamic Volcanological Laboratory."

Fig. 4 A littoral explosion hurls spatter offshore (photo credit: J. D. Griggs, USGS).

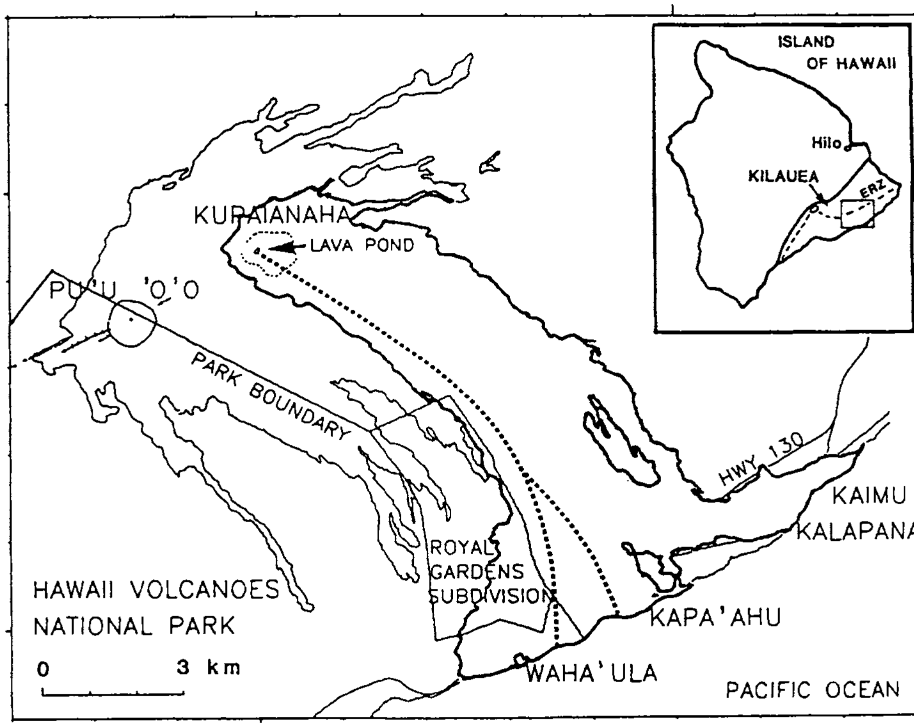


Fig. 2. Lava flows erupted from Pu'u 'O'o (1983–1986) and Kupaianaha (1986–present). Dotted lines indicate the active lava tube system of September 1991.

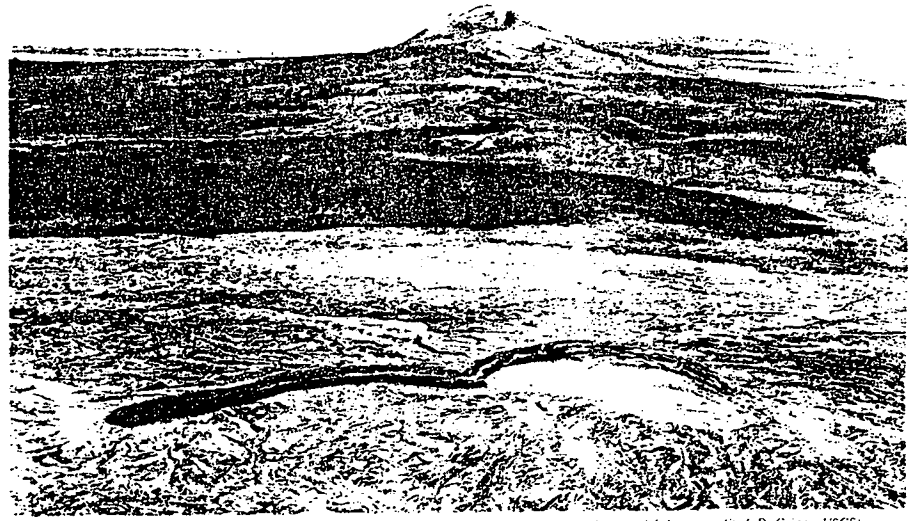


Fig. 3 The Kupaianaha lava pond and shield in early 1987 with Pu'u 'O'o in the background (photo credit: J. D. Griggs, USGS).

Active Eruption Seen on East Pacific Rise

EOS V72#46 11/12/91

Investigators involved in the ADVENTURE program, an *Alvin* dive program on the East Pacific Rise crest at 9°–10°N, have reported evidence suggesting very recent and possibly ongoing eruptive activity along this portion of the mid-ocean ridge. Preliminary age dating of basalt samples from the new flows suggest that the eruption did, in fact, occur during the March–April 1991 dive program.

The East Pacific Rise (EPR) between 9° and 10°N has been the site of much marine geological and geophysical research over the past decade. Research in this region has included a host of interdisciplinary field programs such as numerous high-resolution multibeam and side-looking sonar surveys, multichannel seismic and high-resolution tomographic surveys, a near-bottom refraction survey, *ARGO* optical/acoustical near-bottom mapping, and closely spaced rock sampling along the crest and upper flanks of the EPR in this area.

These programs have defined the morphology, structure, segment boundaries, petrological properties, and shallow seismic velocity structure of the EPR between the Clipperton and Siqueiros transforms. Because a variety of interesting features was revealed at EPR 9°–10°N, this region was recently designated a natural laboratory for study of fast-spreading mid-ocean ridges by the Office of Naval Research [*Tucholke et al.*, 1991]. In addition, the first attempt at bare-rock drilling into zero-age crust on the EPR will be made by the Ocean Drilling Program at 9° 31′N in February 1992.

During the adventure dive to the area (Figure 2), divers observed numerous seafloor indicators of eruptive activity while mapping and sampling the hydrothermal vent fields along this portion of the EPR crest. The distribution of hydrothermal vents and animal communities along the EPR axial zone in the region was well-documented in late 1989 by visual imaging of ~80% of the axial summit caldera (Figure 2) using the *ARGO* near-bottom imaging system [*Haymon et al.*, 1991a]. The ADVENTURE dives revealed that the distribution and settings of vents and vent biota from 9°45′N to 9°52′N had been significantly altered by volcanic eruptions occuring in the 15 months between the *ARGO* survey and the ADVENTURE cruise. Within the axial summit caldera at 9°45′N–9°52′N, areas that previously were colonized by dense animal communities now are floored with extremely glassy sheet and ropy lava flows, which are covered with unusual white bacterial mats (not seen in the ARGO images) around hydrothermal vents.

Many biological communities documented in the December 1989 *ARGO* images have evidently been buried by more recent lava flows (Figure 1, top). Near 9°50.6′N, where a dense community of animals in the axial summit caldera had been imaged by *ARGO*, ADVENTURE divers found thousands of newly killed vent organisms, plus a few traumatized survivors, partially buried by a thin flow of new lava. The carnage at the 9°50.6′N "Tubeworm Barbeque" site was so recent that crabs and other scavengers had not yet arrived to consume the tissues of the abundant dead animals, and no bacterial decay was evident.

After the ADVENTURE cruise, basalt samples from the new lava flow at the Tubeworm BBQ site were distributed for age measurement by a $^{210}Po/^{210}Pb$ dating method. Preliminary results of the analyses indicate a March 26–April 6, 1991, time frame for the eruption (Ken Rubin, personal communication). Because the first dives to the BBQ area took place on April 1–14, 1991 it is likely that the eruption was either ongoing or had just ceased when the observations from *Alvin* were made.

To confirm the qualitative biological indicators of extremely recent eruption, two of us (Fornari and Perfit) diverted one dive from our primary survey area in the Siqueiros Transform to the Tubeworm BBQ on May 23, 1 month after the last ADVENTURE dive to this site. The May 23 dive revealed that after 4 weeks a large number of crabs had arrived to feast on the dead animals at the BBQ site (Figure 1, bottom). Significant decay of the dead animals had also occurred by this time. These observations provide further evidence that our dives in April were made very shortly after the community was destroyed by lava flows.

Other observations suggesting that the EPR crest at 9°45′–52′N was in an eruptive phase during the ADVENTURE dive program are discussed by *Haymon et al.* [1991b, 1991 (in press)], *Hildebrand et al.* [1991], *Von Damm et al.* [1991], *Shanks et al.* [1991], *Lutz and Haymon* [1991], and *Nelson et al.* [1991]. These results and those of other field and laboratory studies along the East Pacific Rise will be presented at the AGU Fall Meeting in San Francisco in a special session titled "Studies of the East Pacific Rise Crest at 9°–10°N."

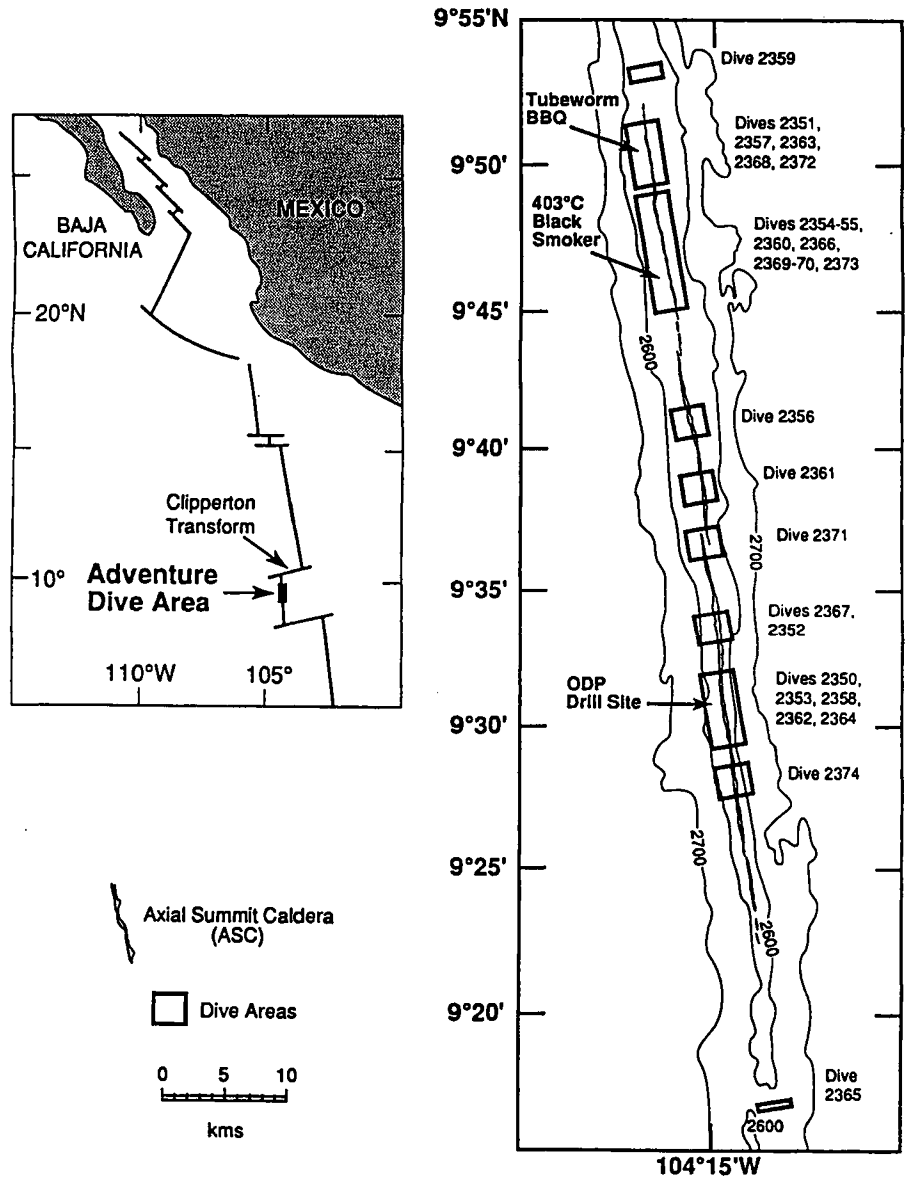


Fig. 2 Boxes show locations on the East Pacific Rise (EPR) crest of the 25 dives in the Adventure Program. Bathymetry is from JOI Synthesis data at University of Rhode Island; outline of axial summit caldera (ASC) is from Haymon et al.[*1991a*], *based on data of D. Fornari et a*

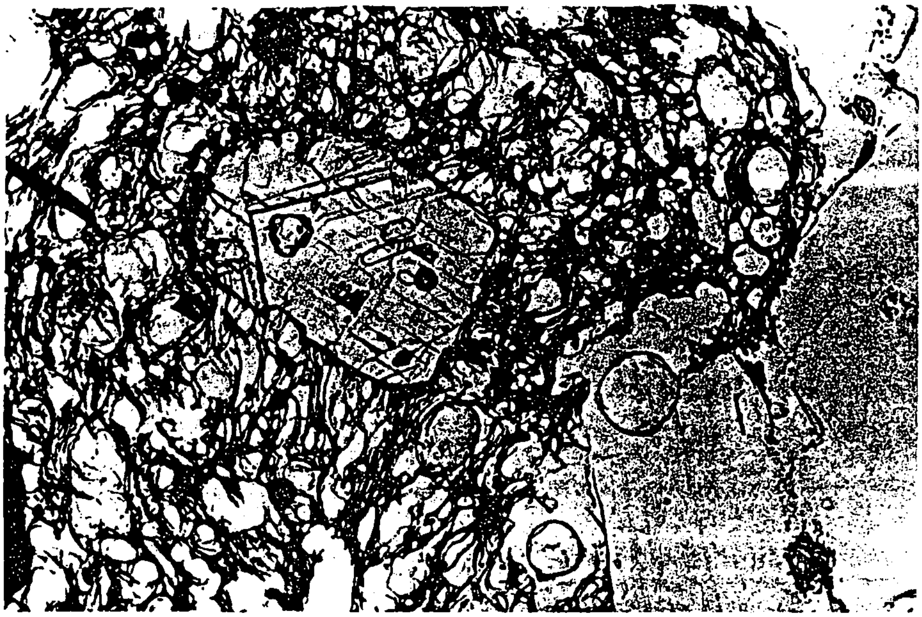


Fig. 1. Euhedral anhydrite crystal in pumice (about 0.22-mm long) containing fluid-inclusions. Most of them contain a gas bubble.

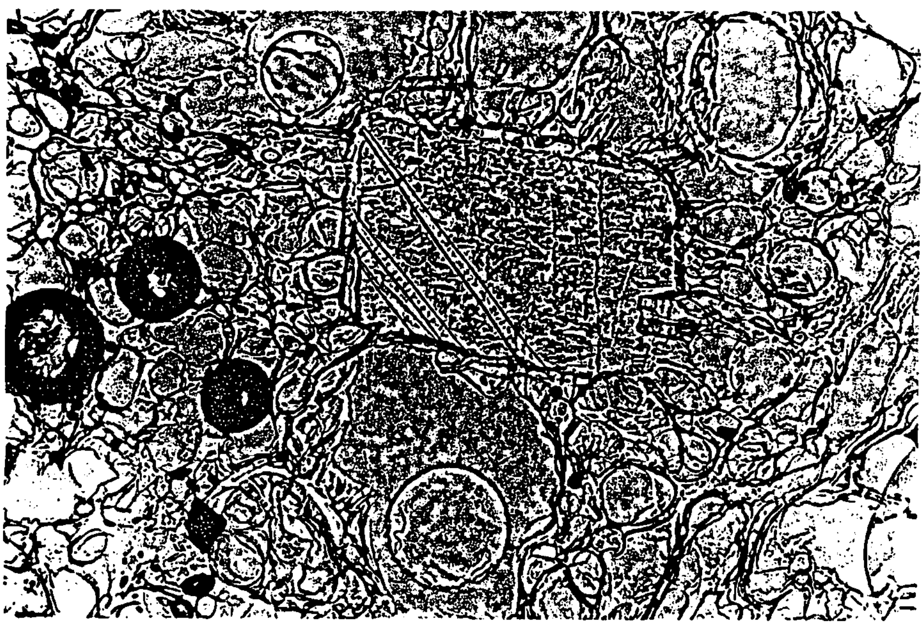


Fig. 2. Euhedral anhydrite crystal with twinning lamellae in pumice. The crystal is about 0.28-mm long.

EOS V72 #47 11/19/91

Pinatubo Pumice Contains Anhydrite

The 1991 eruption of Mount Pinatubo in the Philippines ranks among the largest of this century, surpassed only by the 1902 eruption of volcano Santa Maria in Guatemala, which produced an estimated 10 km^3 of volcanic deposits.

Recently (July 16, 1991, p. 305), *Eos* reported that in terms of SO_2 emission, the aerosol cloud produced by Pinatubo's June 15 eruption may be as large or bigger than the 1982 eruption of El Chichon. While this, in part, may be due to the larger volume of erupted material (about 3 km^3 for Pinatubo as compared to 0.5–0.6 km^3 for El Chichon), it certainly indicates the production of sulfur-rich lava.

Preliminary examination of several pumice samples of the June 12–15 eruptions of Pinatubo has revealed a striking similarity to El Chichon lavas in that most of the examined lavas contain euhedral anhydrite phenocrysts. Anhydrite phenocrysts were considered to be a unique feature of the El Chichon lavas. The crystals are comparatively small, with diameters of 0.10–0.28 mm. Numerous anhydrite crystals contain one- or two-phase (fluid plus gas) fluid-inclusions.

The dominant phenocryst phases in the Pinatubo pumices are plagioclase and brown amphibole. Some samples also contain quartz phenocrysts, while at least one sample contains olivine. This phenocryst assemblage may indicate that prior to the eruption, basaltic (or basaltic andesite) magma rising from greater depths was fed into a reservoir containing differentiated dacitic to rhyolitic magma. This possibility will be investigated by planned, detailed microprobe analyses of the phenocryst phases.

The presence of primary anhydrite in the Pinatubo lavas is significant for at least two reasons. First, it shows that the presence of anhydrite in the El Chichon lavas is not a unique event. Therefore, anhydrite, which may exist in other lavas or pumice and has been considered a secondary alteration product, may be a primary phase. Second, in contrast to El Chichon, which is underlain by anhydrite-bearing sediments, there is no evidence for the presence of evaporites underlying Mount Pinatubo. Hence, it is very unlikely that the presence of anyhdrite in Pinatubo lava is due to crustal contamination involving sulfate-rich sediments.—*Ulrich Knittel, Dietmar Oles, Hansgeorg Förster, Institut für Mineralogie und Lagerstättenenlehre; and Raymundo Punongbayan, Philippine Institute of Volcanology*

New Volcano Newsletter Planned

In the beginning, there was *Volcano News*, an interdisciplinary forum where volcanophiles of all stripes—professional and amateur, "hard" and "soft" scientists alike—could exchange information. Unfortunately, *Volcano News* became extinct when editor-publisher Chuck Wood became involved in editing *Volcanoes of North America*.

Janet Cullen Tanaka, a former contributing associate editor of *Volcano News* is planning the publication of a new interdisciplinary volcano newsletter to cover all facets of volcano studies, from geophysics to emergency management. Persons interested in contributing articles and/or subscribing should contact Janet as soon as possible at PO Box 405, Issaquah, WA 98027–0405; tel. 206-392-7858. Call between 10 A.M. and 10 P.M. PDT.

Volcano offers rare chance to research climate patterns

G&M, 11/25/91

VOLCANO / *Mount Pinatubo sets off fiery debate about weather*

Disaster's clouds hide silver lining

BY STEPHEN STRAUSS
Science Reporter

WHEN the sleepy Philippine volcano Mount Pinatubo began erupting its way into the natural-history record book five months ago, it set off what looks like a never-ending climatological debate.

In this century's most violent series of volcanic explosions, the mountain shot 20 to 30 million tonnes of hot gas, ash and rocks into the stratosphere.

While tens of thousands of Filipinos fled mud slides, ashy fallout and a hail of pumice, scientists around the world started rubbing their hands together.

"It is like watching a large-scale, semi-controlled experiment. All of a sudden ... you get to see what is happening in the atmosphere," says Allan Carswell, a York University physicist whose laser-beam radar first spotted Pinatubo's cloud over Toronto last summer.

To some scientists, the dusty, acidic ejectus of Pinatubo is a dye in the sky, a marker that lets them monitor swirling, wind-driven weather patterns on a worldwide basis.

To others, this gigantic, unplanned experiment holds promise of resolving a fundamental climatological issue: How big does a volcanic blast have to be to affect world weather patterns seriously?

"There were sad costs associated with destruction and the loss of human life, but from the point of view of getting a handle on this problem, Pinatubo has been a really tremendous thing," says Rolando Garcia, a senior scientist with the U.S. National Centre for Atmospheric Research in Colorado.

It is widely believed that high-floating volcanic plumes with their burden of sunlight-deflecting dust and gases can cool parts of the planet tens of thousands of kilometres away. The explosion of Mount Tambora on Java in 1815 caused the so-called "year without summer" in 1816. Temperatures dropped worldwide; lakes 130 kilometres north of Quebec City remained frozen in July, and grain harvests failed around the world.

More recently paleogeologists have put forward the theory that the dinosaurs were killed off by a multi-year deep freeze after simultaneous eruptions of volcanoes in what is now India.

As Pinatubo's giant cloud of dust and gases spreads north and south — it now nearly covers the globe — the most visible effect is on the sunsets.

"Half an hour after sunset you can look outside and see these deep, red colours. That's the mark of Pinatubo," says Wayne Evans, an atmospheric scientist at Trent University in Peterborough, Ont.

It is less clear whether Pinatubo's cloud will cool the earth to any substantial degree.

Almost from the first eruption, commodities analysts have been besieging clients with predictions of frost and crop failures, but the range of disagreement in the scientific community is almost as colourful as the sunsets.

"I doubt in terms of the public domain that people will notice anything. To the individual on the street, it won't seem particularly colder or hotter," York University's Dr. Carswell says.

Dr. Evans says: "I think there will be some early frosts next fall."

So does James Hansen, of the U.S. National Aeronautics and Space Administration's Goddard Institute for Space Studies in New York. "I think that people will look back in a couple of years and say that the last two years have been really cool."

University of British Columbia atmospheric scientist Gordon McBean says, "I would be very surprised if we will be able to say with very much certainty that there has been an effect from Pinatubo."

One problem is that, although Pinatubo's first major eruption in 600 years released a huge amount of debris, its explosive force was only about 1/900th that of Tambora. Thus its cooling effects probably lie within the capricious bounds of natural weather variability.

Equally confusing for atmospheric physicists is that other physical forces are offsetting the volcano's effect on the weather. What Dr. Hansen, who has been modeling Pinatubo's influence on NASA's computers, means by cooler is cooler than the 10-year sizzler that was the 1980s. In that decade, most years were warmer than the global average since 1950, an effect Dr. Hansen associates with human-induced greenhouse warming.

His models suggest that Pinatubo's cloud cover creates a 30-per-cent chance that the world's weather next year will be colder than average, a 30-per-cent chance it will be warmer than usual, and a 40-per-cent chance that it will be neither.

Finally, there is considerable interest in the possibility that volcanoes deplete the Earth's ozone layer. In 1989, Susan Solomon and David Hofmann of the U.S. National Oceanic and Atmospheric Administration in Boulder, Colo., published a paper pointing out that after the eruption of Mexico's El Chichon volcano in 1982, the lower ozone layer thinned 15 to 20 per cent where the volcanic plume was thickest.

The scientists suggested that a chemical reaction on the surface of volcanic particles destroyed ozone.

Various measurements this winter will try to determine whether Pinatubo's planet-circling cloud is also eating away at Earth's ozone.

Even as they await what should be a rush of data on the Pinatubo cloud, scientists are wondering whether they can apply their still-incomplete understanding of volcanoes' planet-cooling breaths.

Next month, Dr. Evans will present a paper in San Francisco in which he will argue that a yearly injection into the stratosphere of 25 megatonnes of carbonyl sulphide — one of the gases expelled during volcanic eruptions — could cool off the greenhouse effect.

Dr. Evans says making such an artificial cloud is both economically feasible and within the technical capacities of several larger nations.