Figure 19.6. Map showing volcanic rift zones and faults on the island of Hawaii. (Submarine slumps after Normark et al., 1978.)
Geologic Hazards Briefing Sheet

General

- Potential geologic hazards include lava flows, ash fallout, ground swelling and subsidence, earthquakes, ground cracking and faulting, and tsunami.

- Since lava flows are usually slow and follow somewhat predictable paths (i.e. downslope), they pose little danger to people. However lava can cause significant damage to property in its path.

- Geothermal developers are expected to assume all risks of loss from geologic hazards; thus providing them a clear economic incentive to utilize the available mitigation measures.

- Available hazard mitigation measures include:
  * strategic power plant siting, eg. keeping the power plant north of the Kilauea upper east rift zone axis-- on relatively high ground. If a hill is not available and earth and rock platform can be constructed, possibly complemented by a lava diversion wall or berm.
  * Comprehensive evacuation plans should be designed to: assure worker safety and secondarily, to protect equipment.
  * Trip wires, placed in the expected path of a flow (i.e. between the project site and the rift zone axis) can alert development personnel as to the speed and distance of an impending flow.
  * If a lava flow is impending during well drilling, the well can be fitted with a temperature and pressure resistant "bridge plug" to safely isolate the lower resource-bearing portion of the well. These plugs can be installed in one hour.
  * Available well control techniques and blow-out prevention equip. can reduce risk of blowout.
  * Other possible measures include well-head cellars, portable modular equipment and decentralization of power plants (to lessen chance that one flow would wipeout a large megawatt capacity plant).

SPECIFIC PROPOSED SUBZONES

Kilauea Upper East Rift Zone

- The Kilauea upper east rift zone in general has had frequent historic eruptions (21 since 1750). However the area within the proposed subzone has had eruptions only in 1963, 1965, 1969, 1977, and 1983-84; the largest being the current Puu O eruption (24 phases so far).

- These eruptions within the subzone have covered only about 17% of the subzone land area. (See flow sheets attached)

- A fortunate and unusual situation exists in this proposed subzone area: as you move away from the rift zone axis (to the northwest) elevation increases. The southeast corner is about 2100 feet and elevation increases to about 3000 feet in the northwest corner, offering considerable protection to powerplants that may be located in this area of the subzone. Historic lava flows, with the exception of the current Puu O flow, have originated on the rift zone axis and then proceeded to flow south. Some flows from Puu O have proceeded northeasterly.

- 1969 flows flowed posterly - started outside subzone at 3000'
Kilauea Upper East Rift Subzone Continued--

- significant area earthquakes: 1868- South Point- magnitude 7.5 (largest historic)
  1975- Kalapana, near - magnitude 7.2

Kilauea Lower East Rift Subzone

Kamaili section
- Flows from eruptions in 1790, 1840, and 1955 have covered parts of this
  subzone. All the above flows have covered 47% of the area within this subzone.
  If you consider only the 1955 flow, it is 24% of this subzone area.

- the slope of this area decreases from about 1300 feet in the eastern part
  to about 700 feet in the south and southeastern parts. The slope is steep
  in the south and southeastern areas and relatively gentle in the northern
  areas.

- closest area earthquake: near Kalapana in 1975 (7.2 mag.)

Kapoho section
- Flows from eruptions in 1790, 1840, 1955, and 1960 have covered parts of
  this subzone. All of the above flows have covered 42% of the area within this
  subzone. If you consider only the 1955 and 1960 flow, it is 38% of this
  subzone area.

- Slope in this area gently decreases from about 600 feet in the western
  part to about 50 feet in the eastern part. In between, there are several
  cinder cones with elevations of about 500 feet which might be considered
  for power plant siting.

- May be some danger from tsunami near the coastal area.

Comments
- The present lava flow maps for presentation do not include the 1790 and
  1840 flows. It is suggested that they might since they are part of the
  available information and could be considered geologically significant.

- Although the upper east rift subzone appears to be the most hazardous, it
  may not be when you consider two facts:

  * Of the three Kilauea east rift subzone areas, the upper subzone
    has the least land covered by historic lava flows: 17% compared
    to 47% in the Kamaili section and 42% in the Kapoho section.

  * Because the land elevation increases to the northwest in the
    upper east rift subzone, it is unlikely that a flow originating
    on the rift zone axis would flow into the higher area. This
    higher area may be safer (and consequently to be used for power plants)
    than the Kamaili and Kapoho sections because of this topography.

(over)
• Although the Kilauea Upper East Rift subzone may ultimately designated as a subzone by the Board, it should not be given a development permit until the current Puu O eruption has finally ended. Otherwise, it would be near impossible to predict the ultimate extent of this eruptive activity.

• There is always a danger that a plant could succumb to a lava flow causing a blackout. However this fear might be allayed by mentioning that HECO has a practice to keep reserve generating capacity equal to at least its largest generating unit. Also, if permitting authorities (development permit) encourage smaller decentralized plants, the risk of blackout would be further lessened.

• Bottom line regarding economic loss; developers are to assume the risk of loss from hazards. In order to ensure that the PUC does not allow such losses to be passed on to the rate-payer, the development permit should stipulate that the developer (including HECO if they build the power plant) will indeed assume all losses and not look to anyone for reimbursement. Note that in 1960 HECO recovered losses due to a tsunami; the same logic could possibly be applied by the PUC to other hazard losses. Of course it all depends upon what policy you want to adopt. If risk of loss is not stipulated in the development permit, then it cannot be said with certainty that the utility (likely builder of the power plant) will assume the risk of loss, since the PUC decides these cases after the fact of loss.

• Note that the percentage of land covered by lava in particular subzone areas appears large, however we're talking about a large period of time (234 years, from 1750 to 1984); likelihood of flows impacting development is MUCH smaller considering that the life expectancy of a power plant is only 30 years.
GEOLOGIC HAZARDS AND MITIGATION

HAZARDS: lava flows, ash fallout, ground swelling and subsidence, earthquakes, ground cracking and faulting, and tsunami.

RISK OF LOSS FROM HAZARDS ON DEVELOPER

AVAILABLE MITIGATION MEASURES INCLUDE:

* constructing power plant outside rift zone
* construct on highest available ground
* construct earthen platforms, diversion walls or berms, if needed.
* comprehensive evacuation planning
  - assure worker safety
  - coordination with H.V.O. and civil defense
  - use of "bridge plugs" and "trip wires"

HAZARDS WITHIN PROPOSED SUBZONES

Kilauea Upper East Rift

* 20% of area within proposed subzone is covered by historic lava flows, including Puu 0 flows.
* Vast majority of historic eruptions in general area have flowed south of proposed subzone. Some Puu 0 flows have flowed northeast into the southern portion of this subzone.
* Rising topography in northwest portion of proposed subzone offers protection from expected future flows.
* area earthquakes: 1868, South Point, 7.5 mag. 1972, Kalapana, 7.2 mag.

Kamaili

* The only flow in past 100 years in 1955 covered 25% of this proposed subzone area.
* recent earthquake: 1972 Kalapana 7.2

Kapoho

* Within the past 100 years, the 1955 and 1960 flows have covered 40% of this proposed subzone area.
* some danger from tsunami coastal areas

Haleakala Southwest Rift

* Only historic flow in 1790. Chance eruption might occur in this area in the future.
Diagram shows the percentage of ground covered by lava flows in the 30 years since 1954, as it varies with distance north and south of the axis of Kilauea's East Rift Zone. (If 30 years is the assumed life of a geothermal power plant, these figures suggest the probability that sites at any given distance may be threatened by burial during their lifetime, as occurred in a 1973 eruption.)
<table>
<thead>
<tr>
<th>Month and Year</th>
<th>Location</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>February 1928</td>
<td>Collected</td>
<td></td>
</tr>
<tr>
<td>February 1929</td>
<td>Collected</td>
<td></td>
</tr>
<tr>
<td>December 1929</td>
<td>North Dakota</td>
<td></td>
</tr>
<tr>
<td>March 1931</td>
<td></td>
<td></td>
</tr>
<tr>
<td>May 1932</td>
<td>Montana and Utah counties</td>
<td></td>
</tr>
<tr>
<td>August 1932</td>
<td></td>
<td></td>
</tr>
<tr>
<td>May 1933</td>
<td>Collected</td>
<td></td>
</tr>
<tr>
<td>July 1934</td>
<td>Nebraska</td>
<td></td>
</tr>
<tr>
<td>July 1937</td>
<td></td>
<td></td>
</tr>
<tr>
<td>February 1938</td>
<td></td>
<td></td>
</tr>
<tr>
<td>July 1939</td>
<td></td>
<td></td>
</tr>
<tr>
<td>November 1939</td>
<td></td>
<td></td>
</tr>
<tr>
<td>December 1939</td>
<td></td>
<td></td>
</tr>
<tr>
<td>September 1940</td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 1944</td>
<td></td>
<td></td>
</tr>
<tr>
<td>May 1946</td>
<td>Nebraska Cities and suburbs</td>
<td></td>
</tr>
<tr>
<td>February 1947</td>
<td>Near white</td>
<td></td>
</tr>
<tr>
<td>November 1947</td>
<td>National City</td>
<td></td>
</tr>
<tr>
<td>January 1948</td>
<td>Near white</td>
<td></td>
</tr>
<tr>
<td>February 1948</td>
<td>Sudan State</td>
<td></td>
</tr>
<tr>
<td>July 1948</td>
<td>Sudan State</td>
<td></td>
</tr>
</tbody>
</table>
## Mauna Loa Volcanic Eruptions

<table>
<thead>
<tr>
<th>Month and Year</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>December 1962</td>
<td>Hilo Crater</td>
</tr>
<tr>
<td>August 1963</td>
<td>Hualalai Crater</td>
</tr>
<tr>
<td>October 1963</td>
<td>Hualalai Crater</td>
</tr>
<tr>
<td>March 1965</td>
<td>Makapipi Crater</td>
</tr>
</tbody>
</table>

*Known lava extent reserve.*
### Kilauea

**VOLCANIC ERUPTIONS -- Mauna-Kea and Mauna Loa**

<table>
<thead>
<tr>
<th>Month and Year</th>
<th>Eruption</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 1987</td>
<td>Summit</td>
<td>Southeast flank</td>
</tr>
<tr>
<td>November 1914</td>
<td>Summit</td>
<td>Southeast flank</td>
</tr>
<tr>
<td>May 1916</td>
<td>Summit</td>
<td>Southeast flank</td>
</tr>
<tr>
<td>September 1920</td>
<td>Summit</td>
<td>Southeast flank</td>
</tr>
<tr>
<td>April 1933</td>
<td>Summit</td>
<td>South 1933 and South 1934, likewise the village of Honomu.</td>
</tr>
<tr>
<td>December 1933</td>
<td>Summit</td>
<td>Northeast flank</td>
</tr>
<tr>
<td>November 1965</td>
<td>Summit</td>
<td>Northeast flank</td>
</tr>
<tr>
<td>April 1966</td>
<td>Summit</td>
<td>Northeast flank</td>
</tr>
<tr>
<td>April 1968</td>
<td>Summit</td>
<td>Northeast flank</td>
</tr>
<tr>
<td>November 1970</td>
<td>Summit</td>
<td>Northeast flank, large eruption.</td>
</tr>
<tr>
<td>January 1980</td>
<td>Summit</td>
<td>Northeast flank, large eruption.</td>
</tr>
<tr>
<td>June 1980</td>
<td>Outbreak with</td>
<td>Northeast flank, large eruption.</td>
</tr>
</tbody>
</table>
Kilauea Volcano erupted November 16-17, 1979 on its upper east rift zone. Copious emission of steam began east of Pauahi Crater at 0805, November 16, but no lava was erupted from these cracks. At 0821, lava welled up from a fissure in northwestern Pauahi and soon established low fountains (PI, figure 1). Seven minutes later, observers arrived on the eastern side of the crater and found a curtain of fire 5-10 m high and 100 m long west of Escape Road and east of the steaming area. It is unknown when these eastern fountains began activity, but they were observed to migrate eastward and cease activity at 0915. At 1130, two more vents opened in Pauahi Crater west of PI (figure 1), followed shortly by opening of a fourth vent in the crater and cessation of activity of PI. Over the next 1 1/2 hours, five more vents opened progressively west of the crater. Slightly before 1600, activity of the western vents began to wane and, within the next hour, ceased. Lava production in the three still-active vents in Pauahi Crater remained relatively constant until 0100 November 17, followed by gradual waning and cessation of activity at 0630.

The eruption was small (500,000-700,000 m³), with low fountains and fairly viscous, possibly low-temperature lava compared to lava erupted at Mauna Ulu. The lava was initially olivine-poor, and evolved only small amounts of SO₂ from active and dying fountains. However, large amounts of SO₂ were emitted from the steaming area east of the crater and at leading edges of opening vents. Field, petrologic, seismologic, and deformation data suggest that the lava for the eruption came from a shallow magma source that had resided for some time in the rift zone. The right-stepping pattern of vents suggests that a left lateral shear couple was present during the eruption.

HVO released a press statement three weeks prior to the eruption (see October Monthly Report) stating that the likelihood of an eruption on Kilauea had increased significantly, and we provided the SEAN BULLETIN with a substantial report two weeks after the eruption.

Mauna Loa remained quiet throughout the month.

Seismic Notes

Kilauea last erupted September 13 to October 1, 1977. Seismicity between that event and November 1979 was sustained at moderate to high levels, 200-400 microearthquakes a day at the summit and 100-200 on the east rift (figure 2). With the notable exception of the two month period following the September 1977 eruption, there is a good correlation between tilt rate and seismicity suggesting that short-period summit earthquakes accompany keystone-type fault movements related to extension during inflation. Seismicity on the east rift increased slightly in March 1979 to levels averaging 200-300 per day. Earthquake swarms occurred in May, July, August, and September 1979. Two of these swarms (May and August, see figure 2) were accompanied by very small summit deflations and a rapid downrift propagation of earthquakes indicating probable downrift intrusions of magma from the summit reservoir into the rift zone.

During the two months preceding the eruption, earthquake counts fluctuated between 200-800 events per day (figure 3). This final period of high seismicity accompanied an increase in inflation rate at the summit (figure 2).

Seismic activity during November (Table 1, figure 4) was dominated by events associated with the eruption. There were no earthquakes larger than magnitude
Figure 1 Preliminary sketch map of the November 16-17 eruption site, Kilauea Volcano.
December 31, 1974 Eruption

Pele, perhaps tiring (momentarily at least) of her tricks at Mauna Loa (see previous report), again turned her full attention to Kilauea and made sure that 1974 went out with a bang. She produced another lava spectacular on New Year's Eve day, beginning at 0255 and ending at 0850, in the area between the upper SW rift zone and Koae Fault zone (Fig. 1). However, for days both before and after the brief (6-hour) display of lava fireworks, seismic activity was intense (see Seismic Notes).

General description.--Throughout the latter part of December, the summit region of Kilauea continued to inflate slowly. A reoccupation of the summit geodimeter monitor on December 23, however, showed that the two lines involving Ahua had expanded considerably, indicating localized inflation which would not have been deduced from the Uwekahuna E-W tilt record (Ideal-Aerosmith tiltmeter). Numerous shallow quakes centered near Outlet were detected the evening of December 30. The frequency and magnitude of these quakes increased throughout the night, and shortly after midnight (0010, December 31) the tremor alarm sounded at HVO residences. Within the next half hour, the E-W component of the Ideal-Aerosmith tiltmeter began to show a significant rate of summit deflation (approximately 3 µrad/hr). By 0205, tremor activity had increased to the extent that it was recorded at the MLO station, and the deflation rate increased to more than 11 µrad/hr.

At 0255, lava fountains were sighted (from HVO) in the general area south of Sand Hill. Field observations around 0310 confirmed that the lava fountains, 35-40 m high by this time, were playing along a 100 m-long fissure approximately 1.5 km south of Sand Hill. The fissure, consisting of several close-spaced en echelon segments, was opening at both ends, and the line of fountains rapidly extended to a length of about 700 m. A number of more widely-spaced en echelon fissures, with general trends of N70-85E, then began to extend to the ENE and to the WSW (Fig. 1). By about 0440, the eastward migration of the active fissure systems ceased, with the easternmost fissure ending within half a kilometer of the September 1971 flow lobe near Outlet. The deflation rate at the summit began to decrease as the activity continued; the average deflation rate was 11.4 µrad-hr during the interval 0200-0400 but decreased to 5.2 µrad/hr during 0400-0600. The westward migration of the activity was apparently slightly more rapid; by 0500, fissure vents had opened within about 1 km north of Cone Crater, lava had cascaded into the westernmost pit crater and had cut the Mauna Iki trail (Fig. 1).

At the peak of eruptive activity, fountain heights on occasion reached a maximum of 100 m but generally averaged about 30-40 m. Shortly after 0500, fountaining waned noticeably at the eastern end of the fissure system, but strong activity persisted, and continued to
Summary of eruptive activity

Well, history repeats itself around Kilauea in a manner distressingly infrequent to those who attempt to predict Pele's antics. But Pele did manage fairly well to follow the tracks she made in the summer of 1971 by repeating this summer the same general script followed during the 1971 summit eruptions.

In the way of background, recall that on August 14, 1971 an eruption occurred on the caldera rim immediately north of Keanakakoi Crater, and on the caldera floor southeast of Halemaumau Crater. This eruption flooded the eastern and southern fifth of Kilauea Caldera. This was followed six and one-half weeks later, on 24-29 September, by an eruption which began on the caldera floor west of Halemaumau and spread into Halemaumau and far down the southwest rift. At this time the Crater Rim Road was cut southwest of Halemaumau at the low point in the caldera wall.

This summer, from 19-22 July, an eruption centered at Keanakakoi Crater and the caldera floor southeast of Halemaumau flooded essentially the same area of the caldera floor that was flooded in 1971 and also flowed southeastward to cut the Chain of Craters Road (HVO Monthly Report, 21 June-20 July). Now, eight weeks after the July eruption, another summit eruption has focused on Halemaumau and the uppermost southwest rift, and a section of the Crater Rim Road has again been inundated. The details of this eruption follow.

Since the July 19th eruption tilt measurements have shown a center of tumescence to be migrating southwestward from the Keanakakoi area to the vicinity of the old Outlet Vault. Very small, shallow, short-period earthquakes centered south of the caldera near Outlet also picked up in frequency, especially after September 16th. Inquisitive newsmen had learned of this activity, and HVO spokesmen were being quoted in the press as predicting an imminent eruption on the southwest rift, largely owing to a comparison with the 1971 eruption sequence. Six and one-half weeks after the July eruption the public was geared up for activity. But the days crept on. Had Pele and the press put egg on HVO's face?

Pele gave little other warning of the reputation-vindicating spectacular soon to be produced. At 0121, 19 September, the tremor alarm sounded at the Park Housing. At 0127, when a view of the caldera could be had during the frantic ride to HVO, glow from Halemaumau indicated an eruption was already in progress. From HVO, at 0132, the tops of fountains 100 m high were seen over Halemaumau's rim, in the northeast corner of the crater. The fountains rapidly migrated southwestward across Halemaumau's floor, and at 0145 climbed the crater's west wall. These fountains, about 20 m high, migrated within one minute to the west rim of the caldera, where they abruptly stopped their southwest advance (Fig. 1). Although the fountains on Halemaumau's floor quickly subsided to about 50 m height, fountaining extended across the crater floor in
Figure 1.—Preliminary, crude, and highly approximate outline of lava flows erupted July 19-22, 1974 (hachured area). Future reports will include more precise maps.
Summary of eruptive activity

The report period began with the Mauna Ulu summit occupied by a large (ca. 50 x 80 m) crater, whose floor was partially covered by sluggishly circulating lava. Several rockfalls occurred in late May, and were well recorded on the Pauahi seismometer.

Quite abruptly, late on the evening of 29 May, Kilauea's summit (as measured by the Ideal-Aerosmith tiltmeter at the Uwekahuna Vault) began to deflate steadily, and tremor at Mauna Ulu increased. On the morning of the 30th, a trip to Mauna Ulu's summit revealed that the summit crater had re-filled to the brim, and was spilling over at two places on the southeast rim. A flow had traveled almost 2 km to the south. Low fountains were active along much of the lake's margin. The surface of the lake, about 60 x 85 m, was covered with a thin, actively circulating crust, and was undulating gently as large waves surged irregularly across the lake. It was a good show, and was in some respects reminiscent of the descriptions of Halemaumau in its active, pre-1924 days. Kilauea's summit continued to deflate, and the rate of Mauna Ulu lava extrusion continued to increase. The night of 30 May provided very spectacular fireworks, as gassy fountains at the summit lake threw spatter about 20 m high and copious overflows began to cascade down all sides of the Mauna Ulu shield. Fountains and overflows continued throughout 31 May.

The morning of 1 June dawned crisp and clear and, fortuitously, aerial photographers were on the Big Island, and chose this morning to fly the bad-weather-plagued and now overdue photo reconnaissance of the Mauna Ulu area. The resultant photographs (three flight lines) were flown at the very peak of the eruptive activity on a cloudless (except for fume) day. These photos show the active vent at Mauna Ulu, with the summit appearing as a bright flower with "petals" of lava pouring down all sides of the shield in deep, brim-full channels. Most of the lava travelled to the south, and these remarkable photos follow the active flow (Figure 1) nearly 9 km to the south and show lava pouring over both Poliokeawe and Holei Palis. The lower part of the flow is aa, and the photos provide clear views of the pahoehoe-aa transition.

About midnight of 1 June Kilauea's summit deflation (10 urad) stopped and inflation resumed; flows from Mauna Ulu ended about 02:00 on 2 June, the episode was over. Lava had crossed Holei Pali for the first time this year, and had reached within ½ km of the sea. Mauna Ulu's summit added about 4 m of new lava to her carapace, and now stands 120 m above the pre-1969 ground level (Figure 2). Mauna Ulu's summit lake drained back, and lava remains sluggishly circulating 20-32 m below the north rim. The summit crater has maintained overhanging, precarious walls since the latest episode, and numerous
Summary of eruptive activity

With some notable exceptions, the eruptive behavior of Mauna Ulu during the report period generally resembled that of the previous period. During the first half of the period (21 March - 5 April) the summit deflated approximately 10 μrad (E-W component of the Ideal-Aerosmith tiltmeter at Uwekahuna)\(^1\), largely related to the 23-24 March eruptive episode that accounted for a little more than 5 μrad. This episode was characterized by sporadic spattering-degassing (“gas-piston”) activity at vent "F" and a copious, continuous overflow to the south from vent "F" (Fig. 1). Summit deflation began 0200 23 March, continued throughout the day, and the flow from vent "F" advanced steadily southward via a channel-tube system that afforded good viewing of lava-tube formation processes.

As the 23 March activity at Mauna Ulu continued, numerous rockfalls occurred at Pauahi Crater, the largest flurry of which was witnessed close hand from the crater's rim by an HVO member. This rockfall generated a strong signal at the PAU seismic station 1 km away. Both the rate of summit deflation and the intensity of tremor increased sharply at 0300 24 March. This set off the alarm at the home of the Scientist-in-Charge, who promptly rousted all the troops. The rockfall activity, high amplitude tremor, and rapid deflation—events which preceded the two previous major outbreaks at Pauahi (5 May and 10 - 11 November, 1973)—were interpreted as possible precursors of another eruptive outbreak at or near Pauahi. The Park officials were notified and the Chain of Craters Road was closed. A few extremely loud degassing blasts at Mauna Ulu, some audible from the observatory, added to the expectancy of the situation. However, the activity at Mauna Ulu remained the same and nothing whatever happened at Pauahi or elsewhere along the rift. When the deflation finally bottomed out at about 0700, still with no unusual eruptive action in sight, and all hands realized they'd been "had" by a false alarm and returned home for Sunday breakfast.

In spite of the "false alarm", the tube-fed flow from Mauna Ulu vent "F" continued its advance southward, and by late afternoon of 3 April it began to cascade in a thin stream over Poliokeawe Pali (Fig. 1), where 15 m of goat-exclosure fence was overrun and destroyed. The southward flow ceased on 5 April, when the deflation trend reversed and Kilauea's summit began to inflate moderately rapidly. Meanwhile, at the Mauna Ulu summit, the upper part of the spectacularly pointed cone of vent "E" (see Fig. 1, last period's report) collapsed sometime during mid-afternoon of 2 April; the collapse event was not evident in the seismic record.

\(^1\)Recent long-base water-tube tilt measurements at Uwekahuna are in better accord with those of the Ideal-Aerosmith tiltmeter than with those of the short-base water-tube tiltmeter. See last period for discussion of the discrepancies in tiltmeter measurements.
Figure 1. Approximate extent of March-April lava flows from vents "E" and "F" of Mauna Ulu as of 20 April 1974. Configurations of Mauna Ulu and Alae shields are as of November 1973.
Summary of Eruptive Activity

Mauna Ulu has remained active throughout this report interval, with red lava always visible at some part of its summit region. In contrast to the last report period, when five distinct eruptive episodes accompanied by abrupt Kilauea summit deflation occurred at intervals of two to six days, this period included only one distinct eruptive episode (17-18 March). Most of the period was characterized by prolonged inflation of Kilauea's summit and low-level activity at Mauna Ulu. During the previous month, eruptive episodes would begin at Mauna Ulu when summit tilt (as measured by the east-west component of the Ideal Aerosmith tiltmeter record at Uwekahuna Vault) reached levels of 170-173 μrad, but this time Kilauea's summit inflated to 181 μrad before the new episode began. This episode lasted about 30 hours, and the summit deflated 5.5 μrad.

The 17-18 March episode was preceded by an interval which can best be divided into two periods for descriptive purposes. From 21 February to 5 March, activity was restricted to a high spatter cone subsequently named vent "E", whereas from 5 March to the 17-18 March eruption activity occurred both at vent "E" and at a new vent (vent "F" - Fig. 1) 140 m east-northeast of vent "E".

The period 21 February to 5 March was characterized by intermittent low activity at vent "E", with eruptive activity occurring at half-hour to two hour intervals and lasting from 10 to 30 minutes. These episodes operated in the fashion of the typical "gas-piston cycle". After a period of quiescence, overflows would begin with gentle surging of lava from one or both of two openings in vent "E", and lava would gradually build up to dome fountains about two meters high. After 10 to 30 minutes
the overflow would end abruptly with a degassing blast, in which gas and spatter, accompanied by a very loud jet roar typically lasting about a minute, would mark the end of the eruptive cycle. A new cycle would begin with another period of quiescence as lava slowly rose again within the vent. Lava from these eruptive events sometimes merely draped fresh lava over the fast-growing cone, usually flowed to the east and/or west to fill up whatever summit depressions existed, and on several occasions fed flows which traveled as far as 100 m from the vent down both the north and south flanks of Mauna Ulu. Early in this period, lava was being extruded from two points on vent "E", but later the lower vent on the north slope of this cone had been blocked, and lava was erupting only from the upper vent. The small dome fountains at the apex of this cone were very spectacular—as a steady hemispherical dome fountain played at the top and as lava cascaded in rivulets down all sides of the tall cone, vent "E" very much gave the appearance of a giant, misshapen strawberry ice cream cone melting in the sun!

During this period the inverse relationship between fuming and extrusive activity was again well displayed. When lava was being erupted from Mauna Ulu, little fume was produced, but between eruptive events, copious amounts of dense, white, crowd-pleasing fume was emitted.

On 5 March a new vent (vent "F") opened east of Mauna Ulu's main spatter cone ("E") and within two days built up an irregular mass of spatter cones and spatter ramparts about 6 m high. Lava welled almost continuously from one to several openings at the base of the vent "F" complex, and flowed both to the northeast and south, down the flanks of Mauna Ulu. The opening of this new vent coincided with a gentle 2 μrad drop in Kilauea's summit tilt and an abrupt drop in the number of shallow caldera microearthquakes. Flows fed from this new vent traveled only about 100 m to the north, but traveled several hundred meters to the south, building up the ground level and ponding between Mauna Ulu and the Alae shield. Eruptive activity at vent "F" showed no close correlation with activity at vent "E", suggesting that any connection between the two vents was complex.

The flows from vent "F" provided an excellent opportunity for HVO personnel to witness lava tubes forming, as tube transport was the dominant means of lava flow to the south. Some surface lava flows fed from vent "F" were very quickly roofed over, many by accretion of pasty blobs of lava to the sides of lava channels. A sketch of the process made on the scene by an HVO scientist bears repeating here (Figure 2):

---

**Fig. 2**

1. DEVELOPMENT OF LAVA TUBES AT MAUNA ULU - MARCH, 1974
   (CROSS-SECTION VIEWS)

- 2 -
The resulting terrain provided rather hazardous walking, because the entire southeast flank of Mauna Ulu became underlain by a complex maze of anastomosing lava tubes, whose roofs in places were fragile and subject to very sudden collapse. Lava flowed through this tube system to the gently sloping terrain south of Mauna Ulu, where lava covered a minimum of 40 hectares of older Mauna Ulu lava. As the flows moved southward, some pahoehoe flows changed to aa. As the tube system lengthened, much of the aa was covered by younger pahoehoe—a repetition of the process described by Swanson (GSA Bull., v. 84, p. 620-621). These flows ultimately reached points at least 1 km from the eruptive vents. The volume of lava being extruded from vent "F" was variable, but estimated to typically be in the range 2-5 m³/sec. Although the rate of flow varied, lava extrusion was nearly continuous, and episodic diminutions of lava production were preceded by loud degassing from vent "F". Occasionally the flows briefly stopped completely.

Following the 5 March opening of vent "F", Kilauea's summit began its slow inflation again and soon reached record high levels as measured by the Ideal-Aerosmith tiltmeter. For the past few months, however, a discrepancy has gradually been developing between the readings of the Ideal-Aerosmith instrument and the east-west component of the short-base water-tube tiltmeter in the Uwekahuna vault. The tilt as measured by the water-tube tiltmeter has not yet reached the level at which it stood prior to the November 1973 eruption. It is important that we determine the cause of the discrepancy between the two tiltmeters, but meanwhile it is not possible to state unequivocally that the inflation reached an all-time high. Summit microearthquakes also increased rapidly in frequency, and from 12 to 16 March exceeded 1,200 per day. Early on the evening of 17 March Pele pulled a few plugs, and Mauna Ulu began to erupt from vents "E" and "F"
Summary of Volcanic Activity

The prevailing conditions of the previous two months--Kilauea's summit region highly inflated but with a very low level of activity at the Mauna Ulu vent--changed abruptly in late January when a 1½ day-long outburst of activity sent lava fountaining as high as 60 m, filled Mauna Ulu crater, fed overflows that reached more than a kilometer from the vent, and built a 15 m-high spatter cone atop the Mauna Ulu shield. Kilauea summit deflated moderately during the activity, but began to reinflate immediately when the episode concluded; low-level activity persisted at the Mauna Ulu vent after the vigorous activity ceased. The crusted Mauna Ulu lake sagged to about 3 m below the rim. Four days later, as Kilauea summit inflated to its previous level, another strong eruptive episode occurred, remarkably similar in character to the first, as lava fountains reached 60-70 m in height, the crater refilled and overflowed; flows were as much as a kilometer long and the spatter cone was built to a height of 20 m. The episode lasted exactly 24 hours. Three additional and similar eruptive episodes have subsequently taken place, all of which define a rather systematic pattern of behavior quite different from the eruptive pattern for Mauna Ulu during 1972-73.

Eruptive episodes have varied from 11 to 35 hours in duration, have produced maximum fountain heights ranging from 35 to 80 m, and have been accompanied by Kilauea summit deflations as measured at Uwekahuna from about 5 to 7 microradians. The perennial bugaboos of estimating eruptive rates and calculating total volume haunts us, and we will defer our estimates to a later report. The strong eruptive episodes are separated by quiet periods that have lasted between 52 hours and 148 hours and have been accompanied by Kilauea summit inflations also of about 5 to 7 microradians. During the quiet periods, lava continues to churn and splash within the Mauna Ulu vent, bursts of spatter reach heights of as much as 20 m, and occasional sluggish overflows descend the flanks of the newly built cone complex and advance a few tens of meters from the vent. Table 1 and Figure 1 summarize the times and durations of the five eruptive episodes and of the intervening quiet periods and indicate the magnitude of the accompanying deflations and inflations, as recorded by the east-west oriented Ideal Aerosmith mercury tiltmeter located in Uwekahuna vault.

Also shown in Figure 1 are the counts of shallow caldera earthquakes by 6-hour periods. During the quiet periods when Kilauea summit inflates, these quakes gradually increase in frequency in response to increasing stress and reach maximum frequency shortly before the eruptive outbreaks. Their frequency abruptly decreases during the eruptive episodes, and then...
Figure 2. Sketch map showing location of new spatter cone at Mauna Ulu and highly approximate outline of lava flows, January 24-February 15, 1974.
Summary of Volcanic Activity

Kilauea's prolonged inflation was culminated in early November with strongly increased activity in Mauna Ulu, filling the crater in about a day. A week later, a new eruption broke out at Pauahi Crater, up-rift from Mauna Ulu.

Low lava fountaining from the vents in Mauna Ulu fed flows that flooded much of the crater floor on November 3, and by 1600 November 4 began to overflow from the west end. The overflow fed a pahoehoe and aa flow that extends approximately 2.6 km south of the crater, and has an estimated volume of about $2.5 \times 10^6$ cubic meters. The overflow which ceased early on November 8, covers about 90 hectares of land.

A sudden drainback of the brim-full lava lake in Mauna Ulu Crater began about 1730 on November 10, accompanied by a marked increase in harmonic tremor and small earthquake activity, and followed at 1745 by the start of rapid summit deflation, as recorded by the Ideal Arrowsmith tiltmeter at Uwekahuna vault. Immediate discussion between Volcano Observatory scientists and National Park authorities concerning the possibility that the volcanic activity might be entering a new and unpredictable phase led to a quick decision to evacuate the public from the entire upper east rift zone. National Park rangers had cleared nearly 500 visitors from the Puu Huluhulu viewing site and the Chain of Craters road by about 1845. The wisdom of this action was borne out at 2147 when a new eruption broke forth along fissures in the north wall of the eastern pit of Pauahi Crater (fig. 1). Active fissures quickly extended both west and east of Pauahi, and at 2208 the Chain of Craters road, west of Pauahi, was cut by new fountains. Shortly thereafter a curtain of steam rose 20-30 m above a fissure across the escape road east of Pauahi, and at 2245 fountaining began about 100 yards east of the escape road from this fissure. Had visitors remained in the area, it would have been necessary to have led them out via the Ainahou Ranch and Hilina Pali roads.

Fountains along the fissures west of Pauahi fed a small pahoehoe flow, which, in part, cascaded into the western pit crater. Other fountains along a line of fissures extending N70-80E for about 2.5 km eastward, toward and slightly north of Puu Huluhulu, produced pahoehoe flows that cover much of the area between Pauahi and Puu Huluhulu (fig. 1). A narrow extension of the flows southward for nearly a km from the Chain of Craters road, and east of the Mauna Ulu visitor parking area, ends at Kalanackuaiki Bali. Fountaining from the fissures outside Pauahi ceased by about 0600 November 11, and the activity within Pauahi waned progressively. At this writing, eruptive activity is confined to a small spatter cone in the northwest corner of the western pit. Lava continues to issue
Fig. 1: Preliminary map showing locations of lava flows from Mauna Ulu, Nov. 1-8, 1973 and lava erupted Nov. 10-11, 1973 during the Pauahi eruption. All locations are approximate and subject to modification. Scale: 1:24,000.
Figure 3.29. Map showing Kilauea caldera, the upper parts of the east and southwest rift zones of Kilauea Volcano, and lava flows formed since 1968. Aloa and Alae craters, on the east rift zone, have been completely buried by lava flows from Mauna Ulu, a small shield volcano that was active from 1969 to 1974. Lava from that vent entered the ocean at the south coast after cascading down the Poliokeawe and Holii palis, and destroyed the ancient Hawaiian village of Kealakomo. The Hilina, Poliokeawe, and Holei palis are scarps formed by faults, along which the ground to the south has been dropped down more than 600 meters in relation to that farther north Halape, at the south coast, sank about 4 meters during the violent earthquake of November 29, 1975.

1969 to 1974

On February 22, 1969, eruption again occurred in the same general area on the upper east rift as the 1968 eruptions. A line of lava fountains formed between Alae and Napan craters, lava cascaded into the ocean and Mauna Ulu destroyed and built up 5 kilometers of the Chain of Craters Road. Activity came to an end on the night of February 27. The top of Kilauea deflated slightly during the eruption, but tufaescence resumed soon afterward as once more the magma reservoir was refilled in preparation for the next eruption.
south, the coastline had sunk 1 to 2 m during the violent earthquakes of 1868, submerging fishpond walls and other man-made structures.

The fault scarp and cinder cones, and the low ridge on which they were situated, formed a natural barrier along the south side of the Kapoho depression that tended to confine the 1960 lava flows to the depression and prevent them from spilling southward.

The general slope of the land surface in the graben was eastward, but at an angle of only about 5.7 meters.