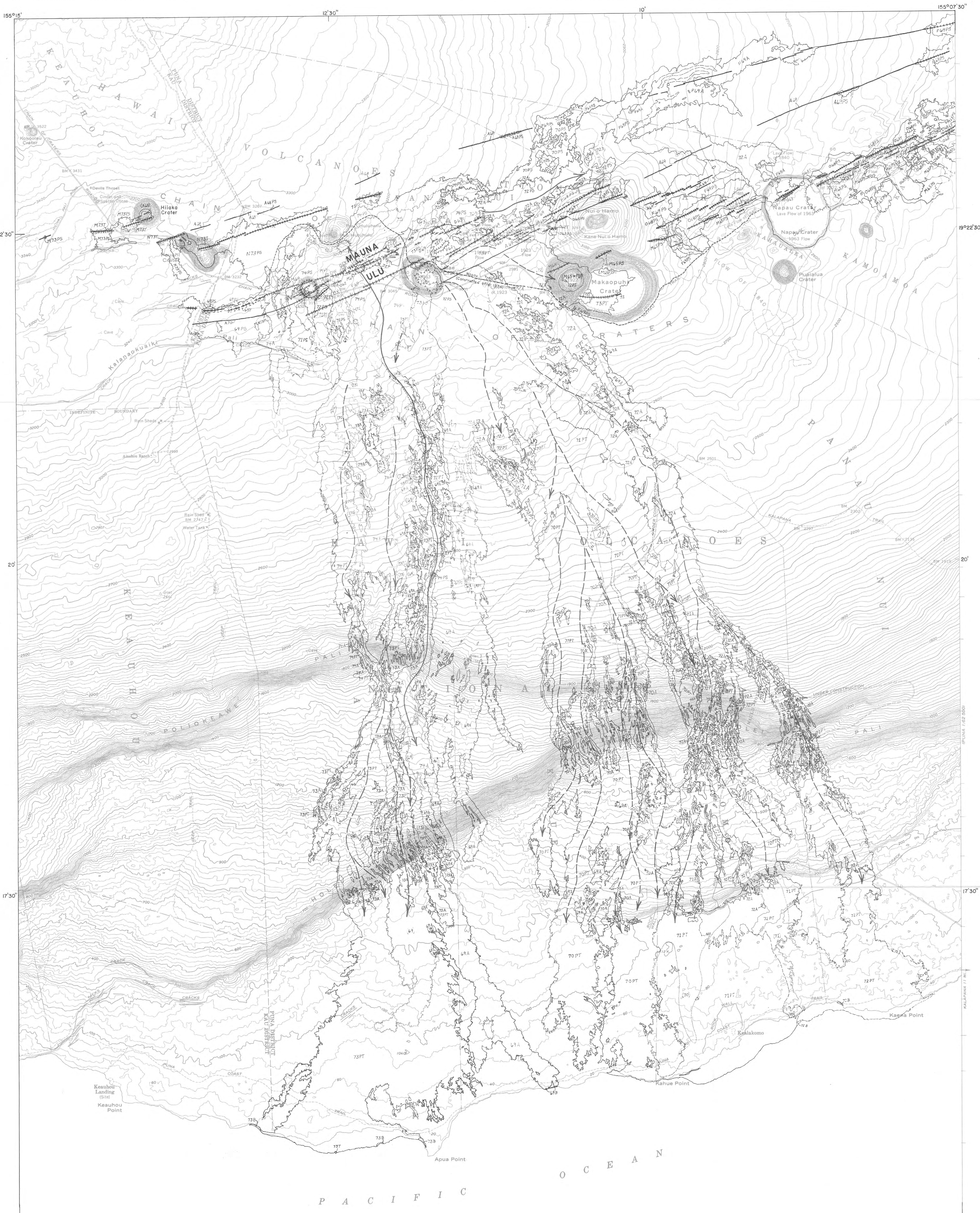
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED WITH THE COOPERATION OF THE
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MISCELLANEOUS FIELD STUDIES
MAP MF-811
KILAUEA VOLCANO, HAWAII



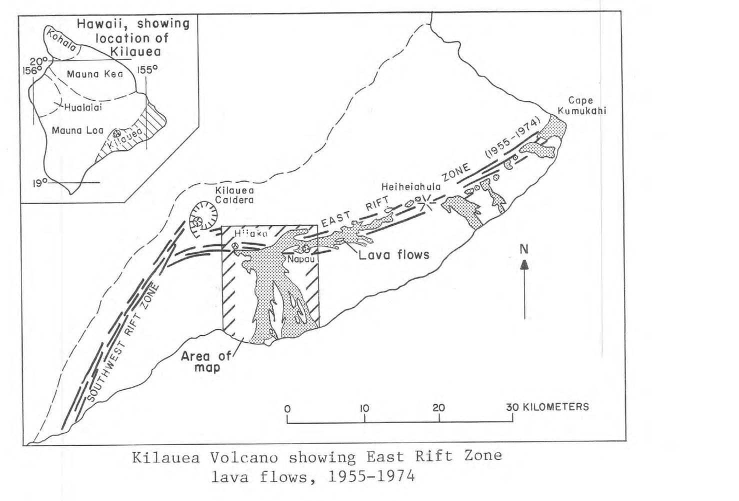

Base from U.S. Geological Survey, Makaopuhi Crater and Volcano, 1963

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

Geology mapped in 1975

INDEX MAP




Kilauea Volcano showing East Rift Zone lava flows, 1955-1974

Table.--*Photographs used in compilation**

| Date Flown | Flight Line No. | Frame Nos. | Approximate Scale | Flight line location and direction |
|---|---|---|---|---|
| 5/28/72√ | 5719 | 1-8 | 1:19,000 | S to N, from Apua Point to Puu Huluhulu |
| | 5736 | 1-9 | 1:11,000 | E to W, from Napau to Hiiaka-Ainahou |
| | 5737 | 1-7 | 1:18,000 | S to N, from Kaena Point to Makaopuhi |
| | 5739 | 6-9 | 1:18,000 | S to N, from Kalapana Trail to Napau |
| | 5740 | 1-10 | 1:22,000 | N to S, from Makaopuhi to Apua Point |
| 10/19/72 | 5809 | 1-12 | 1:16,000 | S to N, from Apua Point to Makaopuhi-Alae |
| | 5810 | 1-13 | 1:21,000 | S to N, from Kahue Point to Makaopuhi-Napau |
| | 5811 | 1-12 | 1:20,000 | S to N, from Kaena Point to Napau |
| | 5812 | 1-12 | 1:16,000 | S to N, from Apua Point-Keauhou to Hiiaka-Mauna Ulu |
| | 5813 | 1-5 | 1:19,000 | S to N, from Poliokeawe Pali to Pauahi |
| | 5814 | 1-8 | 1:21,000 | W to E, from Devils Throat to Puu Kahaualea |
| | 5815 | 1-13 | 1:12,000 | E to W, from Puu Kamoamoa to Pauahi-Ainahou |
| 2/5/73 | 5857 | 1-13 | 1:21,000 | W to E, from Hiiaka to Iilewa-Heiheiahulu |
| | 5858 | 1-12 | 1:9,000 | E to W, from Heiheiahulu to Ainahou-Poliokeawe |
| | 5859 | 1-8 | 1:25,000 | N to S, from Mauna Ulu-Makaopuhi to Kealakomo-Apua Point |
| 7/21/73 | 5926 | 1-7 | 1:12,000 | W to E, from Devils Throat to Makaopuhi |
| 12/13/73 | 6111 | 1-8 | 1:26,000 | S to N, from Apua Point to Puu Huluhulu-Makaopuhi |
| | 6113 | 1-7 | 1:12,000 | W to E, from Devils Throat to Makaopuhi |
| 6/1/74 | 6246 | 1-13 | 1:16,000 | N to S, from Hiiaka-Alae to Kealakomo |
| | 6247 | 1-16 | 1:22,000 | S to N, from Apua Point to Puu Huluhulu |
| 6/3/74 | 6270 | 1-10 | 1:11,000 | W to E, from Pauahi to Napau |
| 7/28/74 | 6356 | 1-9 | 1:19,000 | NW to SE, from Bird Park to Poliokeawe Pali |

*In addition to these recent photographs by Robert M. Towill Corporation (Honolulu), several older photograph series were also consulted. Most useful among these were the 1954 HAI series (1:50,000) by the U.S. Navy and the 1964-5 EKL series (1:20,000) by the U.S. Dept. of Agriculture.
√Flight lines of this date have incomplete stereoscopy

## ACKNOWLEDGMENTS

I thank the staff of the Hawaiian Volcano Observatory for their many and long-continued contributions to this map. I am especially grateful to D. A. Swanson for compiling information on buried eruptive fissures and distributions of lava flows prior to 1972 and to D. W. Peterson for compiling the principal lava tube systems. This work was partly supported by a grant from the U.S. National Aeronautics and Space Administration.

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## EXPLANATION

SYMBOLS FOR ERUPTED MATERIALS--Prefix number indicates year of eruption. A letter before the prefix number indicates month of eruption, for short-duration eruptions only (A69PS means August 1969 surface-fed pahoehoe lava)

- T Tephra
- PS Surface-fed pahoehoe lava
- A Aa lava
- PT Tube-fed pahoehoe lava
- B Hyaloclastite beach deposit
- ( ) Buried lava flow--Number indicates year of eruption. Flow type not indicated

SYMBOLS FOR MORPHOLOGIC FEATURES

- Contact--Dashed where gradational or approximate; dotted where buried
- Fissure, with date of opening--Cross-hatched where lava was emitted
- Buried fissure, with date of opening--Cross-hatched where lava was emitted
- Lava channel, showing flow direction
- Lava tube, showing flow direction
- Crater
- Buried crater
- Perched lava pond
- Buried perched lava pond

## DISCUSSION

Between 1962 and 1974 lava erupted many times from various places on Kilauea's upper east rift zone. The eruptive episodes varied considerably in behavior, duration, and products and are the subjects of ongoing studies. Included among them was the first well-observed long-duration flank eruption (1969-1974) in historic time, an eruption that seems particularly significant in understanding the history of Kilauea.

*Purpose of the map*. This map is intended to serve as a guide to the area of recent eruptions, as a base map for current work, and as a possible model for further mapping of the prehistoric lava flows of Kilauea and volcanic regions elsewhere. The topographic base for this preliminary uncolored version of the map is obsolete. The present map may meet the immediate needs of Hawaii County citizens and planning officials, scientists, and others having interests in the area until a revised base becomes available.

*Location and eruptive history*. Kilauea is an active shield volcano on the Island of Hawaii at the southeastern end of the Hawaiian archipelago (Macdonald and Abbott, 1970). Kilauea has erupted frequently during the 150 years of its historic period and for many centuries earlier. According to Hawaiian oral traditions, eruptions from Kilauea "had taken place during every king's reign, whose name was preserved in tradition, or song, from Akea, first king of the island, down to the present monarch" (Ellis, 1827, p. 194). All known eruptions of Kilauea have occurred from its summit caldera, its southwest rift zone, and its east rift zone.

After at least 150 years of infrequent eruptions and 33 years of dormancy, when most activity was confined to the summit caldera, the subaerial part of Kilauea's east rift zone resumed frequent activity in February-May 1955 with a series of eruptions on the lower segment between Heiheiahulu lava shield and Cape Kumukahi (Macdonald and Eaton, 1964). These were followed by eruptions from the middle (Napau Crater to Heiheiahulu) and lower parts of the rift zone in January-February 1960 and September 1961 (Richter and others, 1970; Richter and others, 1964) Further eruptions from the upper (Kilauea caldera to Napau Crater) and middle parts of the rift zone occurred in December 1962, August 1963, March and December 1965, August and October 1968, and February 1969 (Moore and Krivoy, 1964; Peck and others, 1966; Moore and Koyanagi, 1969; Wright and others, 1968; Fiske and Koyanagi, 1968; Jackson and others, 1975; Swanson and others, 1976). In the first phase of this rift zone sequence (1955-1963), eruptions occurred at points widely distributed along the rift zone, interspersed with eruptions at the summit; as the activity continued, however, it became concentrated primarily along an upper segment of the rift zone between Hiiaka and Napau pit craters. As the locus of eruptions contracted, the frequency of eruptions increased to intervals of a few months in 1968 and 1969.

Before May 1969, the east rift zone eruptions were short-lived, lasting from a few hours to a few weeks. But this pattern changed when an eruption began and continued for 2½ years from May 1969 until October 1971 (Swanson and others, 1971; Swanson, 1976, written commun.). During the initial stages of this eruption, high lava fountaining alternated with low fountaining and quiet vent overflows of extremely fluid gas-rich lava. After the first six months of eruption the high fountaining ceased, giving way to continuous, relatively quiet activity. After two short summit eruptions and a 3½-month pause late in 1971, eruptions resumed at the same site in February 1972 and continued there with occasional short pauses and brief eruptions farther up the rift zone until mid-1974 (Peterson and others, in press). Renewed eruptions following the pauses generally began with periods of moderate fountaining that occasionally alternated with periods of comparative quiet, reminiscent of the early phase of activity, but never with the vigor of the first six months. Lava from the 1969-1974 eruptions built a new satellitic lava shield 120 meters high named Mauna Ulu between the former pit craters Aloi and Alae, covered 61 $km^2$ of the subaerial south flank of the volcano, and built 0.1 $km^2$ of new land along the southern coast of the island.

*Compilation methods and accuracy of the map*. This map shows the fissures and eruptive products in the area of concentrated and sustained activity during the period of frequent eruptions beginning in 1955. The map area includes the Makaopuhi Crater 7½-minute quadrangle and the southern part of the Volcano 7½-minute quadrangle. The compilation was made from aerial photographs made by R. M. Towill Corporation (see table) and from data and notes collected by the staff of the Hawaiian Volcano Observatory. Although the map area has been thoroughly traversed on foot and is intimately known by the author, field checks were not made following compilation.

Lava flows erupted from 1962 to 1974 are shown on the map. However, the recent eruptive history is exceedingly complex, and because of the great number of overlapping flows, all flows could not be shown. In the rifted vent area along the chain of pit craters, flows buried before 1970 have been omitted, and buried younger flows have been generalized. Elsewhere buried flows are generally omitted if they were covered before aerial photographs recorded their positions. Similarly, lava channels and lava tubes of buried flows have been omitted. Buried eruptive fissures have been simplified, and their indicated positions are only approximate.

On this preliminary map the temporal subdivisions of the Mauna Ulu eruption are in years. This scheme was chosen in order to depict the relative rates of eruption during successive equal increments of time. However, these subdivisions are somewhat artificial with respect to the actual events of the eruption. For example, the sheet of 1973 lava south of Mauna Ulu actually began spreading late in 1972, and the 1972 lava near Alae can be subdivided into distinct units. A different temporal classification could yield a more meaningful picture of the eruption.

The accuracy of this map is limited by temporal and spatial gaps in the photographic coverage. For example, aerial photographs were not made between 1969 and 1972. This has caused uncertainties in the ages of some flows and incomplete delineations of others. Parts of two flows, the 1972 pahoehoe at Kaena Point and the 1974 aa below Holei Pali, still uncovered and mapped, have not been photographed completely since they ceased spreading. Consequently the mapped extents of these flows are incomplete, and their approximate termini are indicated by dashed lines.

The base map does not properly depict present topography because the contour lines show the topography in 1963, before it was covered by new lava. The eruptions have produced drastic changes: Aloi and Alae pit craters have been completely filled, while Hiiaka, Pauahi, and Makaopuhi pit craters have been partially filled. Large lava shields have been built at Mauna Ulu and the site of Alae Crater, and smaller spatter ramparts have been built around other vents. Talus-and-lava cones (Holcomb and others, 1974) have accumulated against palis (cliffs), and lava deltas (Moore and others, 1973) have added new land to the south coast. Ground surface has been modified and generally built up by several meters in areas of new flows.

The obsolescence of the topographic base has caused inaccuracies in the compilation of this preliminary geologic map. A Kail Radial Planimetric Plotter was used to transfer flow boundaries and other features from the photographs to the topographic base. The plotter's position on the base map and its scale could not be accurately established because control points shown on the base map have been obliterated by new lava flows. Moreover, the accuracy of some indicated positions is reduced because of the plotter's inherently poor resolution of high-relief features, such as steep-walled craters and precipitous palis. Though an effort was made to plot positions to within an accuracy of 20 meters, some points may be a hundred meters off, especially near the center of the map where identifiable control points are widely spaced.

*Lava flow types*. The principal purpose of this map is to illustrate changes in character of lava flows erupted on Kalauea's east rift zone during this interval. Flows were classified according to the scheme of Swanson (1973), who recognized three major types of pahoehoe lava produced by the Mauna Ulu eruption: (1) shelly, (2) fountain fed, and (3) tube fed. Although these types grade into one another, the distinctions between them are useful for interpreting eruptive and lava flow histories. Because they are difficult to distinguish on aerial photographs, the shelly and fountain-fed varieties are grouped together on this map as surface-fed pahoehoe, distinguished from two other broad categories designated tube-fed pahoehoe and aa. Swanson's observations have shown that surface-fed flows were relatively short lived or resulted from widely fluctuating rates of lava supply, whereas tube-fed flows reflect fairly constant supplies for at least a few days (Peterson and Swanson, 1974). Under certain conditions pahoehoe changed to aa, and commonly the aa was covered by pahoehoe slightly later in a flow episode. As a result, the different categories are not only intergradational, but their boundaries, when distinct, may be extremely intricate. This map is generalized and depicts merely the broad major trends that characterized successive eruptive stages.

Lava-type designations on the map are based on the morphology and reflectivity of the lava flows evident on aerial photographs. The appearance of a flow varies with the scale at which it is viewed. For simplicity in this report, however, the effects of viewing scale are ignored, and features of the flows are generally described in terms of their absolute dimensions.

Aa flows tend to be long and thick relative to their width, and have relatively high surface relief (more than 2 m), on a dekameter scale (that is, over horizontal distances of tens of meters). They are characterized by such hectometer-scale features (over horizontal distances of hundreds of meters) as longitudinal ridges and large lava channels, commonly anastomosing, in their upper parts, and transverse ridges resembling glacier ogives in their distal parts.

Surface-fed pahoehoe flows are relatively thin and widespread--sheetlike--near the vents, and numerous successive flows may accumulate to build broad lava shields in the vent areas. The flows contain numerous large and small lava channels and longitudinal ribs on dekameter and hectometer scales. Lava ponds are common; their surfaces are nearly flat on an hectometer scale and are composed of a polygonal pattern of dekameter-sized plates bowed slightly upward and separated by cracks, resembling large cobblestones on the photographs. Ponds in older depressions, such as Hiiaka and Pauahi pit craters, generally subside after they form and leave lava-subsidence terraces chilled to their confining walls (Holcomb, 1973). Other ponds are enclosed by contemporaneous lava levees and perched above the surrounding surface (Holcomb and others, 1974). Subsidence of perched ponds commonly produces shallow depressions atop small ventless lava shields.

Tube-fed pahoehoe flows are broad and thin, with broadly dendritic patterns, feathering out from low, broad ridges marking the master lava tube systems. In the upper parts of the flows, large lava tubes that have undergone partial collapse occur and can be recognized by chains of hornitoes, skylights, and small rootless lava flows. In the lower parts of the flows, tumuli and pressure plateaus are abundant on dekameter to kilometer scales.

Fresh aa flows have low albedoes, apparently due to their centimeter-scale surface roughness and their paucity of glass. Fresh pahoehoe flows have generally higher albedoes, apparently due to their glassy skins and comparative centimeter-scale smoothness. However, while the fresh aa flows are uniformly dark, fresh pahoehoe flows exhibit a great range of albedoes depending upon the phase angles through which they are viewed. At different times, the same flow may appear very dark or very light depending upon the relative positions of the sun and viewer above it. Because of this, pahoehoe can be misinterpreted as aa; this problem has been minimized by studying most flows on several photographs made under contrasting illuminations.

Some tube-fed pahoehoe flows are dark on all photographs, apparently because they are unusually rough on a centimeter scale. These flows may be mistaken for aa, but stereoscopic examination reveals tumuli and other dekameter- to hectometer-scale features characteristic of tube-fed flows. This type of lava appears to be one of the transitional forms between pahoehoe and aa. A good example is the 1972 pahoehoe lying between the sites of Alae and Makaopuhi craters, southwest of Makaopuhi and east-southeast of Alae.

Fresh Mauna Ulu pahoehoe is difficult to distinguish from prehistoric pahoehoe in the same area. The old pahoehoe is uniformly gray, as are the young lavas under some illuminations. Many of the contacts are practically invisible, and the only means of separation are commonly the scattered trees on the older lava. Where vegetation is sparse on the older lava, separation of pahoehoe of different ages is sometimes nearly impossible. This accounts for the dashed contacts shown in the area of coastal flats inland from the site of Kealokomo.

Further complications are caused by transitions between the various flow types. Transitions are of several types and may occur over distances from a few meters to a kilometer. In this map albedo has been used as the sole criterion to distinguish pahoehoe (light) from aa (dark) in their transition zones. Mapping on the ground may yield a different pattern. The transition between surface-fed pahoehoe and tube-fed pahoehoe is much more subtle than the pahoehoe-aa transition and can be defined only on the basis of hectometer-scale flow features such as the presence of a well-developed master tube system and medial ridge. Differences between the two pahoehoe flow types are not apparent on photographs, as least in the transition zones; therefore dashed contacts shown are gradational and somewhat arbitrary.

*Significance of the map*. Broad temporal trends in the morphology of lava flows and landforms are evident on the map; they reflect rather well the eruptive history of the area. The brief but voluminous initial eruptions of the series and early unstable stages of the Mauna Ulu eruption produced surface-fed pahoehoe that generally ponded or underwent transitions to aa. Long fissure vents were generally left gaping when the eruptions ceased, and vent edifices are generally absent or small and consist chiefly of tephra. Later, more continuous eruption at Mauna Ulu produced broad fields of tube-fed pahoehoe that partly covers earlier lavas and eruptive fissures. Fluctuations in lava supply later produced additional surface-fed pahoehoe that accumulated around the vents to form broad lava shields and occasionally underwent transitions to aa. Because changes in lava flow and vent morphology reflect changes in eruption mode, the same mapping techniques used here may be applied to prehistoric lava flows to help characterize eruption modes at various times in the past.

Detailed mapping using Swanson's classification could be useful in elucidating detailed eruption histories, but the preparation of this map has indicated it would be difficult. Initial near-vent products of continuing eruptions become covered, while the surficial pattern of exposed lava flows can be extremely complex. The complexity is caused by (1) changes in lava-flow types with respect to the distance from the vents, and their attendant transitions, and (2) the complexity of eruptive events which produce a spaghetti-like intermingling and overlapping of different flow types of different ages. The preparation of this generalized map has relied upon repeated photography and the detailed and careful observations of the staff of the Hawaiian Volcano Observatory for several years. It would be extremely difficult to work out the detailed history of a prehistoric, unobserved eruption sequence as complicated as this, even if the lava flows remained unconcealed by vegetation and surficial deposits.

Although the details of a complex assemblage of lavas cannot be elucidated, the general assemblage is useful in defining the gross nature of eruptions and the conditions giving rise to them. Geologists investigating the history of an extensive area of recent basaltic volcanism--such as the Hawaiian Islands, Iceland, or the Snake River Plain of Idaho --should concentrate not so much on the individual lava flows but on the assemblages present, because the assemblages could reveal long-term changes in the eruptive history of the region.

# PRELIMINARY MAP SHOWING PRODUCTS OF ERUPTIONS, 1962-1974 FROM THE UPPER EAST RIFT ZONE OF KILAUEA VOLCANO, HAWAII

By
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1976

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