U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

PRELIMINARY GEOLOGIC MAP OF THE PUU ANAHULU QUADRANGLE, HAWAII

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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GEOLOGIC SUMMARY

Vent deposits and lava flows from Hualalai Volcano and lava flows from Mauna Loa and Mauna Kea Volcanoes cover the Puu Anahulu 7 1/2-minute quadrangle. Hualalai's diffuse north-trending rift zone, marked by the large trachyte cone of Puu Waawaa and several basaltic spatter cones, is located mainly in the southwestern part of the quadrangle. Several Hualalai flows originated in the Hualalai quadrangle (Moore and others, 1986), crossed the Puu Anahulu quadrangle, and terminated in the Kiholo quadrangle (Clague and Bohrson, 1986). Hualalai flows cover most of the western half and are interlayered with Mauna Loa lavas along a 2-kilometer-wide strip from southeast to northwest across the middle of the Puu Anahulu quadrangle. Mauna Loa flows cover most of the eastern half. Mauna Kea flows are restricted to the northeastern corner, where they underlie Hualalai and Mauna Loa lavas. A few extensive, relatively young flows from Hualalai and Mauna Loa cover most of the quadrangle; thus, older units are generally small in area. Climate ranges from tropical rain forest (50-100 inches of annual rainfall) in the southwestern part to semi-arid (15 inches) in the northern part of the quadrangle; one result of this variation is that long lava flows vary considerably in their degree of weathering and amount of vegetative cover.

The oldest units in the quadrangle are the trachyte cone of Puu Waawaa and its flow, which includes Puu Anahulu; they cover about 7 percent of the quadrangle. The cone shows a pronounced radial drainage pattern. Their age is 106,000 $\pm$ 6,000 ka (Clague, 1987). The great height (350 m) of the cone and thickness (250 m) of the flow

probably account for their lack of burial by subsequent basalt flows.

Basaltic lavas of Hualalai in this quadrangle range in age from latest Pleistocene to less than 2,000 years old. Pleistocene lavas cover about 5 percent of the quadrangle. Their vents are buried beneath Holocene deposits but probably were located just east of Hualalai's summit (Moore and others, 1986). Pleistocene lavas are identified chiefly by stratigraphic relations, the virtual absence of surficial glass, the presence of relatively thick (>0.2 m) soils, and radiocarbon ages (Rubin and others, 1987).

Hualalai lavas 5,000-10,000 years old cover about 5 percent of the quadrangle. Their assignment to this age class is based on stratigraphic relations, absence of delicate flow structures (except in arid areas), extensive weathering, local development of soil 0.1-0.2 m thick, rare preservation of surficial glass, and one radiocarbon age.

Hualalai lavas 3,000-5,000 years old cover about 3 percent of the quadrangle. Vent deposits and flows generally are weathered brown, with little or no soil cover, except in the rain forest. Delicate spatter and flow structures generally are present, as is local surficial glass. Stratigraphic relations and one radiocarbon age are further aids in assignment of volcanic units to this age classification.

Three extensive Hualalai lava flows 1,500-3,000 years old, two of them dated by radiocarbon, cover about 25 percent of the quadrangle. They are generally dark gray to black, lack soil (except in the rain forest), and commonly have surficial glass and delicate flow structures.

The oldest Mauna Loa flows in the quadrangle cover about 2 percent

of the area and probably are 5,000-10,000 years old. They occur in small kipukas and commonly are weathered brown, lack surficial glass and delicate flow structures, and are partly covered by thin soil.

Mauna Loa flows 3,000-5,000 years old cover about 18 percent of the quadrangle. They commonly are dark brown to gray, lack significant soil, and have local surficial glass and delicate flow structures. One has been dated by radiocarbon.

Six extensive Mauna Loa flows are 1,500-3,000 years old and cover about 23 percent of the quadrangle. They commonly are gray, lack soil, and have local surficial glass and delicate flow structures.

The A.D. 1859 Mauna Loa flow (Stearns and Macdonald, 1946) is the youngest volcanic unit in the quadrangle and covers about 10 percent of its area. It bisects the quadrangle from southeast to northwest and consists of black glassy pahoehoe and aa with delicate flow structures and no soil.

The two hawaiite flows from Mauna Kea are late Pleistocene in age (24 $\pm$ 22 and 55 $\pm$ 15 ka; B. Turrin, unpublished data) and cover about 2 percent of the quadrangle. They commonly are unweathered, but lack surficial glass and delicate flow structures, and are covered with up to 10 cm of loess.

Surficial deposits generally have not been mapped but are shown in two small areas. One exposure consists of a thick blanket of alluvium, probably mantling an old Mauna Kea basalt flow, in the northeastern corner of the quadrangle. The other is located at the northwestern base of Puu Waawaa, where alluvium has accumulated during the past 100,000 years above poorly-exposed pyroclastic flow and surge deposits associated with construction of the trachyte cone.

Alkali olivine basalts of Hualalai Volcano in the Puu Anahulu quadrangle contain variable amounts (estimated in the field) of olivine, plagioclase, and pyroxene phenocrysts; a few basaltic rocks are aphyric. MgO contents range from about 4-16 percent; the lowest abundances occur in basalts that are transitional to hawaiite, and the highest values occur in ankaramitic lavas that contain abundant olivine and pyroxene phenocrysts. Scattered xenoliths of gabbro, pyroxenite, and dunite occur in several vent deposits and lava flows.

Puu Waawaa and its flow consist of light gray to light brown pumice, somewhat devitrified black to gray obsidian, and light gray to light brown, devitrified, massive to flow-banded trachyte with rare phenocrysts of altered biotite, plagioclase, and clinopyroxene and rare xenoliths of dunite.

Tholeiitic basalts of Mauna Loa Volcano in the Puu Anahulu quadrangle contain variable amounts of olivine and plagioclase phenocrysts; a few rocks are aphyric. Rare xenoliths of gabbro, troctolite, and dunite occur in a few flows. No new chemical analyses have been obtained.

The two flows from Mauna Kea Volcano in the Puu Anahulu quadrangle consist of aphyric hawaiite.

DESCRIPTION OF MAP UNITS

HUALALAI VOLCANO (h)

UNITS 1,500-3,000 YEARS OLD

Q87S24

f 4 Aa and pahoehoe flow in the southern part of the map. Unit consists of alkali olivine basalt with 1-3 percent olivine and less than 1 percent plagioclase phenocrysts. Source vent is in the Hualalai quadrangle (Moore and others, 1986).

R13S43

v 4 f 4 Spatter deposits, including Hainoa and Puu Papa, and extensive aa and pahoehoe flows, in the southern and western parts of the map. Unit consists of alkali olivine basalt with 2-5 percent olivine, 1-2 percent plagioclase, and less than 1 percent pyroxene phenocrysts. Internal contacts separate flows from different source vents, some of which are in the Hualalai quadrangle. Unit corresponds to Hbf73 in the Kiholo quadrangle (Clague and Bohrson, 1986). ^{14}C age is 2,030 $\pm$ 80 years (Rubin and others, 1987).

Q98S73

f 4 Pahoehoe and aa flow from Luamakami (Hualalai quadrangle; Moore and others, 1986), in the southwestern part of the map. Unit consists of alkali olivine basalt with 1-3 percent olivine phenocrysts. Unit corresponds to Hbf67 in the Kiholo quadrangle. ^{14}C age is 2,350 $\pm$ 80 years (Rubin and others, 1987).

R05R83

f_3 Aa flow in the southeastern part of the map. Unit consists of alkali olivine basalt with 1-3 percent olivine phenocrysts (Moore and others, 1986).

UNITS 3,000-5,000 YEARS OLD

S03S73

f_3 Pahoehoe flow at the western edge of the map. Unit consists of alkali olivine basalt with 2-10 percent plagioclase, 0-2 percent olivine, and 0-2 percent pyroxene phenocrysts. Unit corresponds to Hbf64 in the Kiholo quadrangle.

R97S59

f_3 Pahoehoe and aa flow at the western edge of the map. Unit consists of alkali olivine basalt with 2-5 percent olivine and 0-1 percent plagioclase phenocrysts. Unit corresponds to Hbf70 in the Kiholo quadrangle.

S25S69

f_3 Pahoehoe flow at the western edge of the map. Unit consists of alkali olivine basalt with 4-8 percent olivine phenocrysts. Unit corresponds to Hbf74 in the Kiholo quadrangle.

R25S13

f_3 Pahoehoe flow at the southern edge of the map. Unit consists of alkali olivine basalt with 1-2 percent olivine and less than 1 percent plagioclase phenocrysts (Moore and others, 1986).

R61S38

f_3 Aa flow in the southwestern part of the map. Unit consists of alkali olivine basalt with about 3 percent olivine and 2 percent plagioclase phenocrysts.

R53S36

f_3 Pahoehoe and aa flow in the southwestern part of the map. Unit consists of alkali olivine basalt with 8-12 percent olivine, 1-2 percent pyroxene, and 1-2 percent plagioclase phenocrysts.

R61S39

f_3 Pahoehoe flow in the southwestern part of the map. Unit consists of alkali olivine basalt with about 2 percent plagioclase and less than 1 percent olivine phenocrysts. ^{14}C age is 3,610 $\pm$ 200 years (Rubin and others, 1987).

UNITS 5,000-10,000 YEARS OLD

R45S65

f_2 Pahoehoe and aa flow in the southwestern corner of the map. Source is the spatter cone of Poohohoo in the Hualalai quadrangle. Unit consists of alkali olivine basalt with 5-8 percent olivine and less than 1 percent pyroxene phenocrysts.

R40S73

f_2 Aa and pahoehoe flow in the southwestern corner of the map. Unit consists of alkali olivine basalt with 4-8 percent olivine phenocrysts. Unit corresponds to Hbf66 in the Kiholo quadrangle.

R25S67

f_2 Aa and pahoehoe flow in the southwestern corner of the map. Unit consists of alkali olivine basalt with 3-6 percent plagioclase and 1-2 percent olivine phenocrysts (Moore and others, 1986).

R80S70

f_2 Pahoehoe flow at the western edge of the map. Unit consists of alkali olivine basalt with 1-2 percent pyroxene, 0-1 percent olivine,

and 0-1 percent plagioclase phenocrysts. Unit corresponds to Hbf69 in the Kiholo quadrangle.

R57S60

f
2
Pahoehoe and aa flow in the southwestern part of the map. Unit consists of alkali olivine basalt with 3-7 percent plagioclase and 1-3 percent olivine phenocrysts. Unit corresponds to Hbf68 in the Kiholo quadrangle.

S27S58

f
2
Pahoehoe and aa flow in the northwestern part of the map. Unit consists of alkali olivine basalt with 4-8 percent olivine and less than 1 percent plagioclase phenocrysts. Unit corresponds to Hbf75 in the Kiholo quadrangle. ^{14}C age is 9,490 $\pm$ 100 years (Rubin and others, 1987).

R64S50

v f
2 2
Spatter deposits of Puu Iki and a pahoehoe flow, in the southwestern part of the map. Unit consists of alkali olivine basalt with about 5 percent olivine phenocrysts.

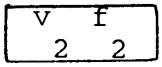
R82S43

v
2
Spatter deposits on the northwestern side of Puu Waawaa, in the southwestern part of the map. Unit consists of alkali olivine basalt with 5-6 percent olivine phenocrysts.

R80S44

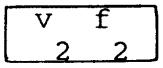
v f
2 2
Spatter deposits and a short pahoehoe and aa flow on the northwestern side of Puu Waawaa, in the southwestern part of the map. Unit consists of alkali olivine basalt with 2-4 percent olivine phenocrysts.

R70S42



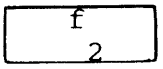
Spatter deposits and an aa flow on the southwestern side of Puu Waawaa, in the southwestern part of the map. Unit consists of alkali olivine basalt with 10-12 percent olivine phenocrysts.

R56S27



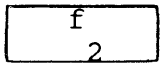
Spatter deposits of Puu Paha and a pahoehoe and aa flow in the southern part of the map. Unit consists of alkali olivine basalt with 6-12 percent olivine and less than 1 percent plagioclase phenocrysts.

R27R78



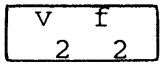
Pahoehoe flow in the southeastern part of the map. Unit consists of alkali olivine basalt with 10-15 percent olivine phenocrysts (Moore and others, 1986).

R97S08



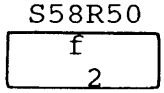
Pahoehoe flow in the south-central part of the map. Unit consists of alkali olivine basalt with about 3 percent olivine phenocrysts.

S35R71



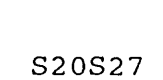
Spatter deposits of Kuainiho and a pahoehoe flow in the northeastern part of the map. Unit consists of alkali olivine basalt with 8-10 percent olivine and less than 1 percent pyroxene phenocrysts.

S58R50



Pahoehoe flow from Puu Iwaiwa (Keamuku quadrangle), in the northeastern corner of the map. Puu Iwaiwa is the northeasternmost vent on Hualalai's north-trending rift zone. Unit consists of alkali olivine basalt with 8-10 percent olivine phenocrysts.

S20S27



Aa flow near the center of the map. Unit consists of alkali

olivine basalt with about 3 percent olivine and less than 1 percent plagioclase phenocrysts and scattered xenoliths of gabbro, pyroxenite, and dunite.

UNITS MORE THAN 10,000 YEARS OLD

S02S23

f_1 Pahoehoe and aa flow overlying the Puu Anahulu trachyte flow in the west-central part of the map. Unit consists of alkali olivine basalt with 4-8 percent olivine phenocrysts. ^{14}C age is 12,230 $\pm$ 150 years (Rubin and others, 1987).

S28S40

f_1 Pahoehoe flow in the northwestern part of the map. Unit consists of alkali olivine basalt with less than 1 percent olivine phenocrysts. A small, unmapped exposure of this flow underlies f_1 S02S23 in a roadcut on the Mamalahoa Highway (Highway 190) near Puuanahulu.

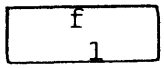
S12S30

f_1 Aa and block flow in the northwestern part of the map. Unit consists of alkali olivine basalt or hawaiite with less than 1 percent plagioclase phenocrysts and scattered xenoliths of dunite, pyroxenite, and gabbro.

S63S67

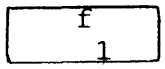
f_1 Pahoehoe flow in the northwestern corner of the map. Unit consists of alkali olivine basalt with 1-3 percent olivine, 1-2 percent plagioclase, and 1-2 percent pyroxene phenocrysts and common xenoliths of gabbro. Unit corresponds to Hbf78 in the Kiholo quadrangle.

R83S68



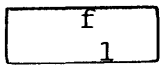
Pahoehoe flow in the southwestern part of the map. Unit consists of alkali olivine basalt with about 5 percent olivine phenocrysts.

R52S52



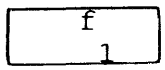
Small aa flow near the southwestern corner of the map. Unit consists of alkali olivine basalt with about 7 percent olivine phenocrysts.

R76S45



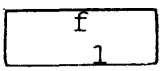
Pahoehoe and aa flow on the northwestern side of Puu Waawaa, in the southwestern part of the map. Unit consists of alkali olivine basalt with less than 1 percent olivine phenocrysts.

R65S35



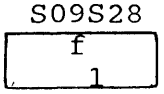
Aa flow on the southern side of Puu Waawaa, in the southwestern part of the map. Unit consists of alkali olivine basalt with 2-4 percent plagioclase, 2-3 percent olivine, and less than 1 percent pyroxene phenocrysts and rare xenoliths of gabbro.

R55S33



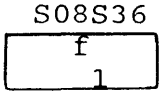
Aa flow south of Puu Waawaa in the southwestern part of the map. Unit consists of alkali olivine basalt with about 3 percent plagioclase and 2 percent olivine phenocrysts.

S09S28



Small pahoehoe flow near the center of the map. Unit consists of alkali olivine basalt with about 1 percent plagioclase phenocrysts.

S08S36



Small aa flow in the west-central part of the map. Unit consists of picritic alkali olivine basalt with 15-20 percent olivine and about 1 percent pyroxene phenocrysts.

S69S32

v 1 f 1 Cone of Puu Waawaa, in the southwestern part of the map, and an extensive aa and block flow in the western and northwestern parts of the map. Cone has a pronounced radial drainage pattern. Cone consists of generally unconsolidated fragments of pumice, obsidian, and massive to flow-banded trachyte. Flow is commonly sheared and altered to a light brown color. Trachyte contains less than 1 percent biotite, plagioclase, and pyroxene phenocrysts and rare xenoliths of dunite. K-Ar age is 106,000 $\pm$ 6,000 ka (Clague, 1987).

MAUNA LOA VOLCANO (k)

UNITS LESS THAN 200 YEARS OLD

Q52R50

f 7 Pahoehoe and aa flow extending from southeast to northwest across the center of the map. Unit consists of tholeiitic basalt with 1-3 percent olivine phenocrysts. Flow erupted in A.D. 1859 (Stearns and Macdonald, 1946).

UNITS 1,500-3,000 YEARS OLD

R38R50

f 4 Aa flow extending from the southeastern corner to the northern edge of the map. Unit consists of tholeiitic basalt with 1-4 percent olivine and less than 1 percent plagioclase phenocrysts and rare xenoliths of troctolite and gabbro (Moore and others, 1986).

S57S47

f 4 Aa flow in the northwestern part of the map. Unit consists of tholeiitic basalt with about 2 percent olivine phenocrysts.

Q58R50

f 4 Extensive glassy pahoehoe flow, locally including minor aa, extending from southeast to northwest across the center of the map and mainly exposed in kipukas surrounded by the A.D. 1859 flow. Unit consists of tholeiitic basalt with 2-4 percent olivine phenocrysts (Moore and others, 1986).

S22R50

f 4 Aa and pahoehoe flow in the northeastern part of the map. Unit consists of tholeiitic basalt with about 1 percent olivine phenocrysts.

S38R50

f 4 Pahoehoe flow at the eastern edge of the map. Unit consists of tholeiitic basalt with about 1 percent olivine phenocrysts.

S35R50

f 4 Aa flow at the eastern edge of the map. Unit consists of tholeiitic basalt with about 6 percent olivine phenocrysts.

UNITS 3,000-5,000 YEARS OLD

R60R50

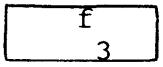
f 3 Extensive aa and pahoehoe flow in the eastern part of the map. Unit consists of locally-picritic tholeiitic basalt with 8-20 percent olivine (often lath-shaped) and less than 1 percent plagioclase phenocrysts. ^{14}C age is 3,360 $\pm$ 200 years (Rubin and others, 1987).

R55R61

f 3 Extensive pahoehoe flow in the eastern and northern parts of

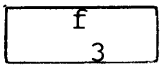
the map. Unit consists of tholeiitic basalt generally with 6-8 percent olivine phenocrysts; locally, olivine abundance ranges up to about 20 percent.

R45R64



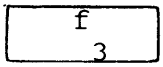
Pahoehoe flow at the southeastern edge of the map. Unit consists of tholeiitic basalt with 4-8 percent olivine and 2-6 percent plagioclase phenocrysts (Moore and others, 1986).

S45S09



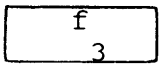
Aa flow at the northern edge of the map. Unit consists of tholeiitic basalt with less than 1 percent olivine phenocrysts.

S56S20



Aa and pahoehoe flow at the northern edge of the map. Unit consists of picritic tholeiitic basalt with 15-20 percent olivine and less than 1 percent plagioclase phenocrysts.

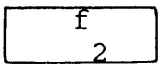
S65S47



Aa flow in the northwestern part of the map. Unit consists of tholeiitic basalt with about 1 percent olivine phenocrysts.

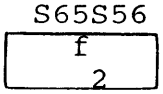
UNITS 5,000-10,000 YEARS OLD

S60S45



Aa flow near the northwestern edge of the map. Unit consists of picritic tholeiitic basalt with 15-20 percent olivine and less than 1 percent plagioclase phenocrysts.

S65S56



Pahoehoe and aa flow near the northwestern corner of the map. Unit consists of tholeiitic basalt with 6-8 percent olivine phenocrysts.

S22R68

f_2 Pahoehoe flow in the northeastern part of the map. Unit consists of tholeiitic basalt with about 1 percent olivine phenocrysts.

S40R53

f_2 Pahoehoe flow in the northeastern part of the map. Unit consists of picritic tholeiitic basalt with 15-20 percent olivine and less than 1 percent plagioclase phenocrysts.

R51R50

f_2 Pahoehoe flow in the southeastern corner of the map. Unit consists of tholeiitic basalt with 1-2 percent olivine phenocrysts.

MAUNA KEA VOLCANO (1)

UNITS MORE THAN 10,000 YEARS OLD

S40R50

f_1 Aa flow in the northeastern part of the map. Source vent is located at Puu Ka Pele (Keamuku quadrangle). Unit consists of aphyric hawaiite. K-Ar age is 24 $\pm$ 22 ka (B. Turrin, unpublished data).

S66R50

f_1 Aa flow in the northeastern corner of the map. Source vent is located at Puu Keekee (Keamuku quadrangle). Unit consists of aphyric hawaiite. K-Ar age is 55 $\pm$ 15 ka (B. Turrin, unpublished data).

SURFICIAL DEPOSITS

Qal Unconsolidated alluvial deposits, mainly consisting of basaltic

and trachytic rock and mineral fragments. Includes poorly-exposed pyroclastic flow and surge deposits at the northwestern base of Puu Waawaa. Not shown where underlying units can be recognized.

REFERENCES

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GEOLOGIC MAP SYMBOLS

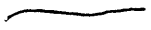
v=vent deposit; f=lava flow

Subscripts (1-7) indicate relative age classification: 7=<200 years old; 6=200-750 years old; 5=750-1,500 years old; 4=1,500-3,000 years old; 3=3,000-5,000 years old; 2=5,000-10,000 years old; 1=>10,000 years old.

A six-character symbol consisting of a letter plus two digits followed by a second letter and two more digits is a unique geographic identifier for each vent deposit and its related flows. The pair of letter-digit-digit combinations represents a pair of coordinates on an island-wide grid based on latitude and longitude (E.W. Wolfe and C.A. Neal, written commun., 1985). The letters represent 6-minute intervals in the grid. In the Puu Anahulu quadrangle, R or S in the first position correspond, respectively, to latitude $19^{o}42'$ and $19^{o}48'$ or 19.7^{o} and 19.8^{o}. Similarly, R or S in the fourth position correspond, respectively, to longitude $155^{o}42'$ and $155^{o}48'$ or 155.7^{o} and 155.8^{o}. The two numbers that follow each letter correspond to hundredths and thousandths of degrees. Thus, the identifier S69S32 (Puu Waawaa) refers to a grid position at latitude 19.869^{o} and longitude 155.832^{o}. The identifier for flows that cannot be traced to vents within the Puu Anahulu or Hualalai quadrangles is chosen arbitrarily to represent the grid position of the part of the flow closest to the axis of Hualalai's major northwest-trending rift zone.

Each volcanic map unit is the product of a brief geologic event. In the absence of ^{14}C ages (there are 6 for the Puu Anahulu quadrangle), there is no certainty about the absolute age of a map unit. The units are included in chronostratigraphic groups on the bases of field stratigraphic relationships, the few ^{14}C ages, amount of soil development, paleomagnetic studies (D.E. Champion, written commun.,

1987), and degree of degradation of surface glass and delicate flow features. A bracket on the correlation chart indicates the possible age range of any unit or sequence of units. Stratigraphic relationships are indicated by the vertical placement on the correlation chart.



Contact, approximately located

X — Location and age of ^{14}C-dated charcoal sample

Geology mapped 1984-1988

O/Y — Relatively older and younger units, at location where relationship is demonstrable