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OBSERVATIONS OF ACTIVELY FORMING LAVA TUBES AND
ASSOCIATED STRUCTURES, HAWAII. PART II.

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Volcanic landforms have recently become of increasing interest through the interpretation of these structures as terrestrial analogs to lunar and planetary surface features. Several independent studies show a correlation between lava tubes and channels and certain lunar sinuous rilles. An earlier report (Greeley, 1971a) describes several mechanisms for the formation and modification of lava tubes and channels associated with the eruption of Mauna Ulu on the east rift zone of Kilauea. This account is based primarily on aerial observations made during August 1970. By August 1971 the eruption had subsided considerably so the tubes and channels could be examined on the ground.

Extensive changes have occurred in surface morphology during the year interval. Figure 1 illustrates the main vent-area structures (orientation of figure is same as Figure 2a-e (Greeley, 1971a) with north to the right). Individual vents apparently acted somewhat independently earlier, but they have merged by collapse of intervening sections to form a trench several hundred meters long (Figure 2). The trench has widened by collapse of large lateral slump blocks. Fractures

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delineating potential slump blocks are visible in Figure 2, and, where slumping has been extensive, some sections of the trench have pronounced "V"-shaped cross sections (Figure 3).

In August 1971, eruptive activity consisted of circulation of lava within the summit vent at the west end of the trench. Figure 4 shows part of the trench along which lava earlier flowed from the higher, west end to the lower, east end where it evidently drained through lava tubes into Alae lava lake (Peterson, personal commun.). These tubes are in about the same location as the ones observed forming from the lower vents in the previous year. It was earlier suggested (Greeley, 1971a) that Alae lava lake is sporadically drained through a fracture to the east, thus maintaining the lake level near the elevation of the former crater rim. Although such drainage did occur once [in 1969 (Jackson and Swanson, 1970)], extensive ground observations (Swanson *et al.*, in press; Swanson and Peterson, in press) indicate that in August 1970 it took place entirely through lava tube outlets. Subsidence of more than 10 m of the lava lake crust occurred. However, prior overflow of the crater rim by surface flows resulted in accretion of about 24 m of lava above the former low point of the crater rim (Swanson and Peterson, in press). After the August 1970 subsidence, lava continued to flow into the lake through lava tube networks and surface flows. In February 1971 another subsidence occurred, leaving an ovoid bowl (Figure 5) similar to the earlier structure.

Collapse depressions and subsidence craters are common surface features in pahoehoe basalt flows. Figure 1 shows an irregular depression about 100 m wide by 200 m long, 0.5 km west of the summit vent. This structure appears to have

formed (at least in part) by collapse of crust covering a small lava lake or ponded lava flow. The lake resulted from ponding of lava over the January-February 1971 fissure-flows, fed directly from lava fountains. Drainage occurred when the fissure eruption ceased and pooled lava drained back down the fissure and through ramparts damming the lake (Swanson, personal commun.). Similar appearing craters and depressions have been described in association with lava tubes near Bend, Oregon (Greeley, 1971b).

A different kind of surface collapse (Figure 6) has occurred on the flow down-slope from Alae Crater. It appears that the crust of the flow foundered over the semicooled, plastic body of the flow, resulting in a groove-shaped depression 40-60 m wide.

Many tubes and channels observed in stages of formation in 1970 are buried or modified by subsequent flows, which often follow existing lava tubes and channels. Some of the more obvious surface tubes and channels, which are in about the same location as tubes observed earlier, may be vertical extensions of the 1970 structures.

Molten lava was not seen in any of the tubes examined on the ground, but the flows had not cooled sufficiently to allow subsurface exploration and survey of the tubes. Some of the main tube systems can, however, be traced by partial roof collapse (Figure 1). Undoubtedly, there are many buried lava tubes that have no surface expression. Figure 7 shows the entrance to a tube about 4 m in diameter in the wall of the summit vent. It has been partly buried by more recent surface flows. Cruikshank and Wood (in press), in their description of parts of the Mauna Ulu eruption, discuss the burial and modification of lava tubes.

Sequential observations of active lava flows provide data that enable interpretation of the modes of origin for some volcanic structures. However, from field studies and discussions with members of the Hawaiian Volcano Observatory, it is apparent that continuous, round-the-clock monitoring of active flows would provide a great deal more information on the intricate behavior of flowing lava and the resulting structures.

Acknowledgements. I wish to thank D. W. Peterson, Director, Hawaiian Volcano Observatory (U. S. Geol. Survey) for fruitful discussions and field trips to the eruption site; thanks are also due D. A. Swanson and D. W. Peterson for their helpful comments and suggestions on the manuscript.

Errata. (Greeley, 1971a)

p. 209, column 1, line 5-6 "northwest-southeast" to read "northeast-southwest"

p. 222, column 1, line 25 "less than 1m" to read "at least 4m"

Figure 2, diagram is oriented with north to the right

REFERENCES

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- Swanson, D. A., Duffield, W. A., Jackson, D. B., and Peterson, D. W., in press. The complex filling of Alae Crater, Kilauea Volcano, Hawaii, Bull. Volcanologique.
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FIGURE CAPTIONS

- Fig. 1. Diagram of the Mauna Ulu summit vent area and Alae Crater lava lake.
Shaded parts indicate depressions.
- Fig. 2. Near-vertical aerial view of summit vent and associated collapse-trench.
Partly collapsed lava tubes and a channel are visible extending from the west rim; arrow indicates one of the more prominent lateral fractures.
Maximum width of trench is about 100 m.
- Fig. 3. View along the floor of the trench from the lower, east end; "V"-shaped cross section results from talus blocks produced by lateral slumping.
Rim to rim width about 50 m.
- Fig. 4. Section of the collapse trench where lava oozed upward from the floor and flowed downslope; parts of the flow have been covered with talus.
- Fig. 5. Oblique aerial view of the subsidence bowl formed in Alae Crater lava lake; summit vent collapse trench is to the right; arrow marks partly collapsed lava tubes that fed lava to the lake from the vent area. Length of subsidence bowl approximately 0.5 km.
- Fig. 6. Oblique aerial view of collapse structure down-flow from Alae Crater lava lake.
- Fig. 7. Entrance to partly buried lava tube in the rim of the summit vent. Tube is about 4 m in diameter.

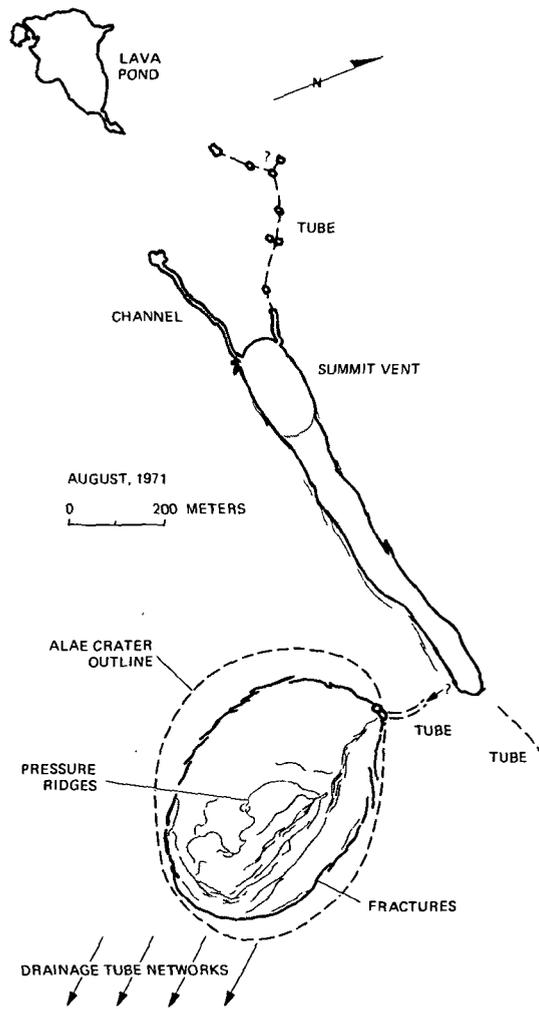


Fig. 1

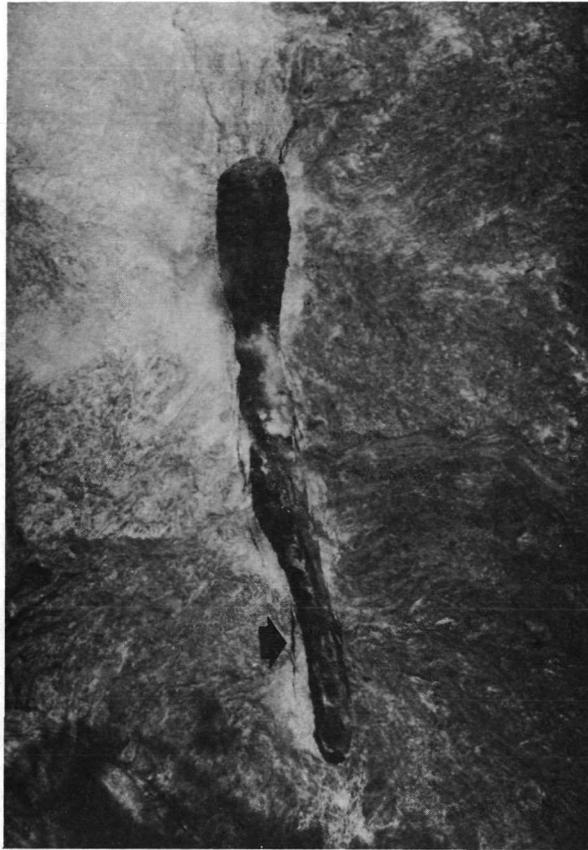


Fig. 2



Fig. 3

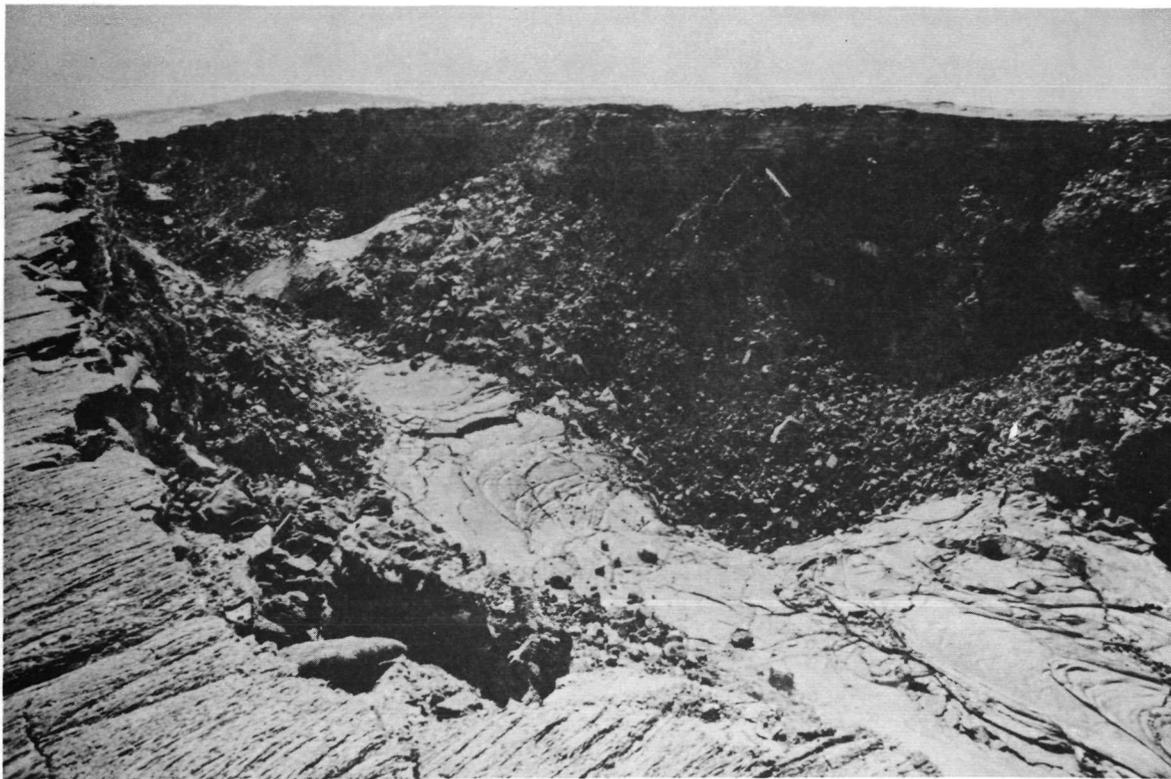


Fig. 4

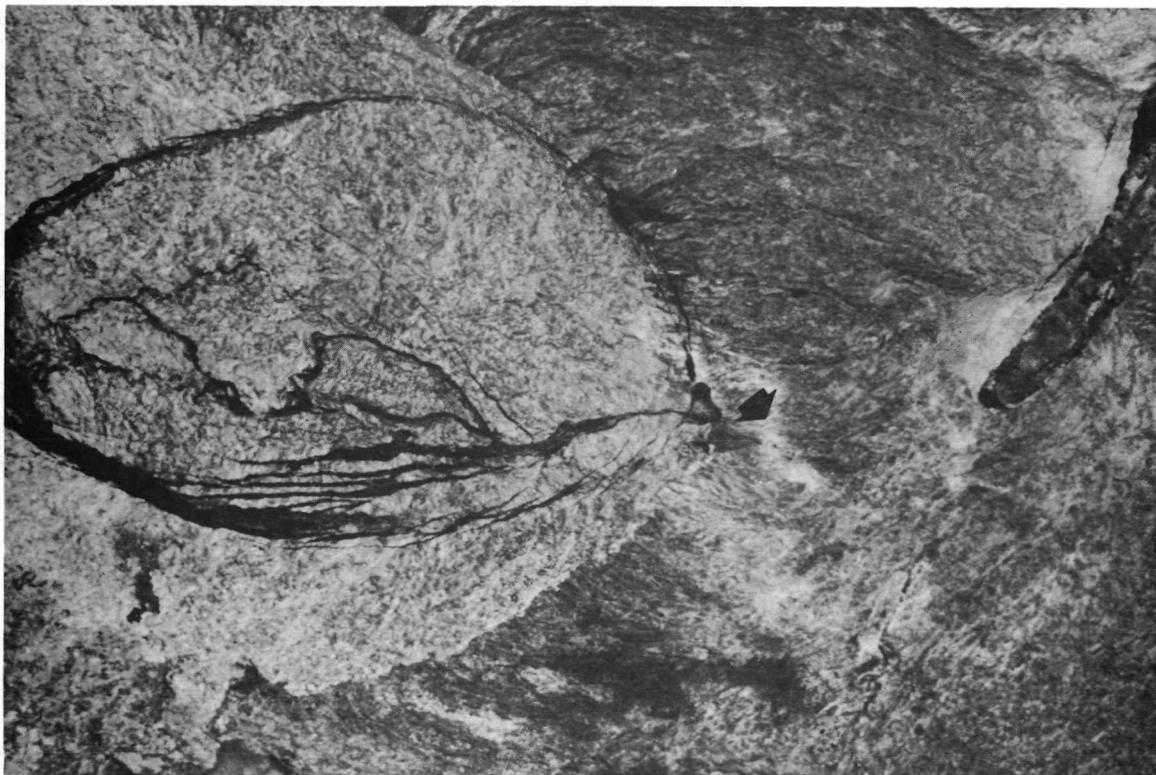


Fig. 5

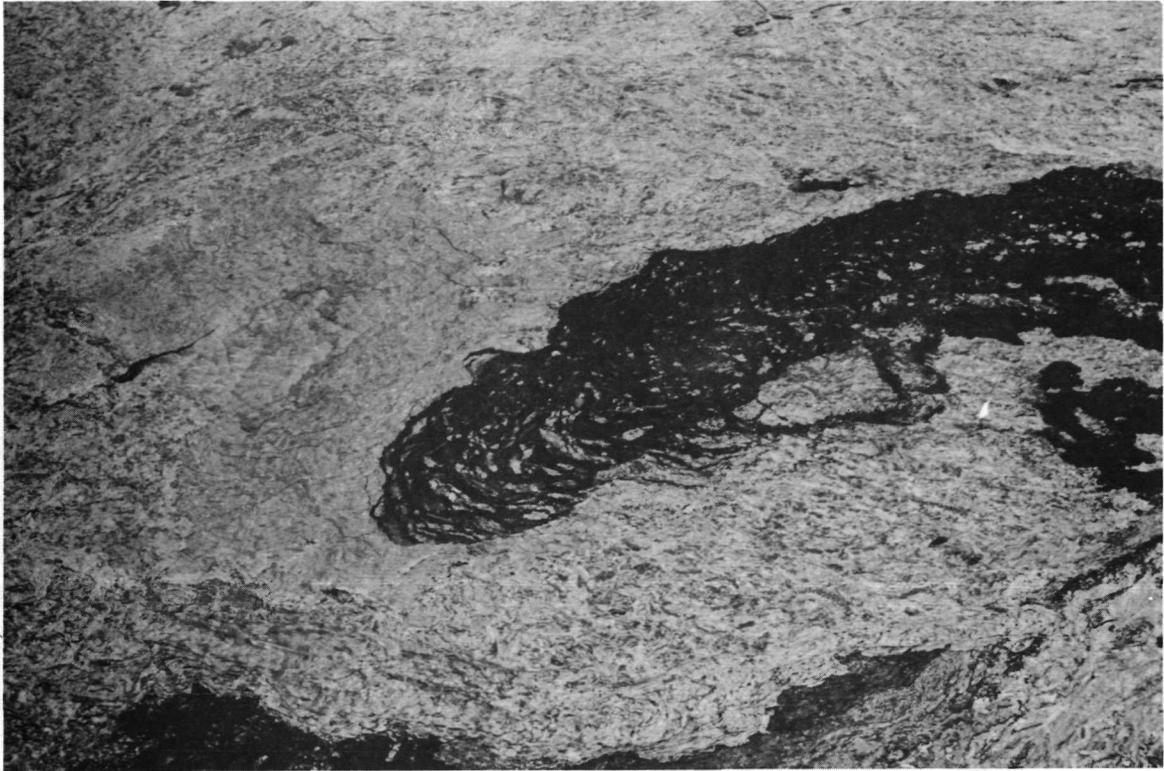


Fig. 6

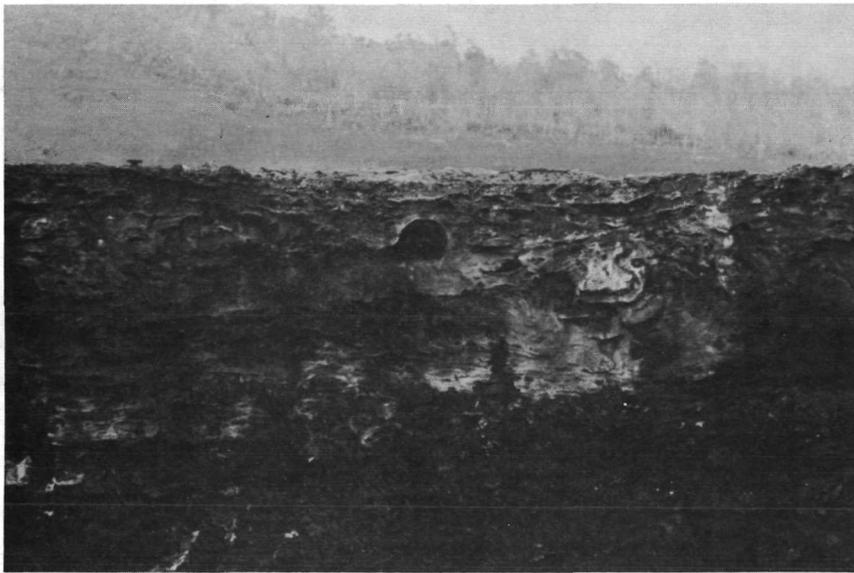


Fig. 7