SOME OBSERVATIONS OF HAWAIIAN PIT CRATERS AND RELATIONS WITH LAVA TUBES

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During a two-month expedition in Hawaii in November and December, 1981, it was possible to collect information during descents into pit craters in Hawaii Volcanoes National Park. Although the main aim of the expedition was a 16 mm movie film about speleology in lava, we had some free time to explore new lava tubes and pit craters in the Kau Desert, with the help of geologists of the volcanological observatory. In this paper, we describe the morphology of some pit craters in relation to their genesis and terminology (crater, pit crater, cone crater) and we consider whether there are relationships between known lava tubes near the surface and lava tubes or "pseudo lava tubes" inside magmatic chambers developed under or near "pit craters" along fault zones or dikes. In comparison, a standard lava tube (John Martin's lava tube) of 6.4 km, partly explored and surveyed during the expedition, also is described.

INTRODUCTION

The well-known Hawaiian Islands are situated in the northern Pacific Ocean. This area provides good examples of lava tubes because of the existence of large, low-angle shield volcanoes such as Mauna Loa and Kilauea. Our investigations took place on the island of Hawaii near Kilauea Caldera in the Puna District and in the Kau Desert.

During November and December 1981, five members of the Speleological Society of Geneva (Switzerland) stayed on the "Big Island" of Hawaii for speleological explorations and the production of a 16 mm documentary film about lava tubes and pit craters. On this occasion, it also was possible to collect information and make observations in relation to the pit craters' genesis and evolution. During the expedition, almost 8 km of new galleries were explored and mapped. Pit craters were explored to a depth of 90 meters. Our interest was not limited to the extent of the lava tubes or pit craters, but included the relations of the genesis, the morphology, the evolution and the mineralogy of these structures.

First, we shall describe some discoveries of lava tubes and pit craters during our trip and relate some observations in relation with these subjects.

LAVA TUBES

Our main work was to explore and map 6,263 meters of John Martin's Lava Tube. Previously, members of the Cascade Grotto of the National Speleological Society had explored 2,200 meters of this cave (Wood 1980). This is a very interesting lava tube, with many different features. From observations in this cave and on the surface, we have tried to develop an outline of the formation of lava tubes.

During an eruption, the lava effusion can move among dikes or fissures without necessarily coming to the surface. On the other hand, when it emerges as lava fountains or flows, fluid lava quickly begins to descend along sloping channels and a current begins, following the steepest gradient, and forming a river which is the quickest path to the fore of the flow. There it finds an outlet.

Fed incessantly by the river upstream, this lava torrent gradually "erodes" the former underlying flows, and bit-by-bit, creates an ever-deepening channel. As proof of this, we observed at Apua Cave how a small tube, which had formed before the last flow, was crossed by the new lava tube (on the left bank). We take this to be proof of a major flow with wide-scale lava emission, because in more minor flows, tubes can only develop in the subsequent flow without affecting earlier deposits. Active trenches between 3 to 20 meters wide can reach a depth of 5 to 10 meters.

As the most active current tends to flow along the bottom and center of the canal, the speed of flow tends to lessen at the surface, and when it comes in contact with the air, a crust forms on top. This solidification also occurs in the case of overhangs which tend to form on upper levels of the trench. And so the "lava tube" comes into being, with the surface crust hardening in contact with the air. With new flows from the same eruption, new layers build up on the outside, which may be unable to use the original tube with limitation of the rate of flow, and overflow in successive layers. Thus, several meters of lava may separate the tube from the surface at the end of the eruption, as is the case of Apua Cave.

The rate of flow in the tube can vary in the course of an eruption and thus internal flow can be "phreatic" or "vadose." Massive basalt banks form bulges or shelves. Taking into

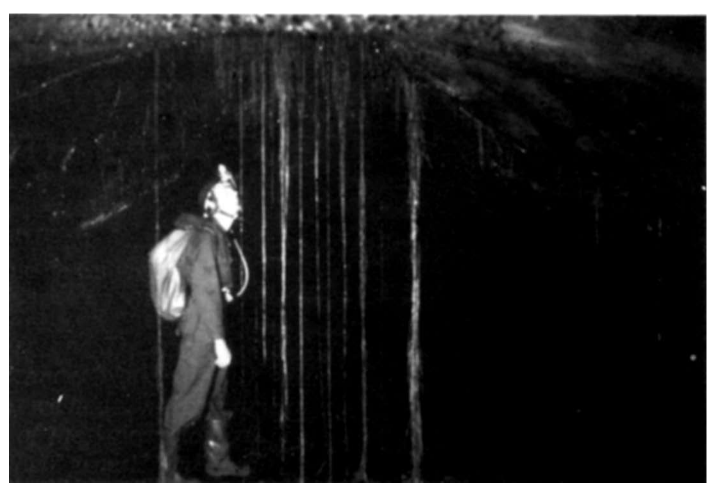
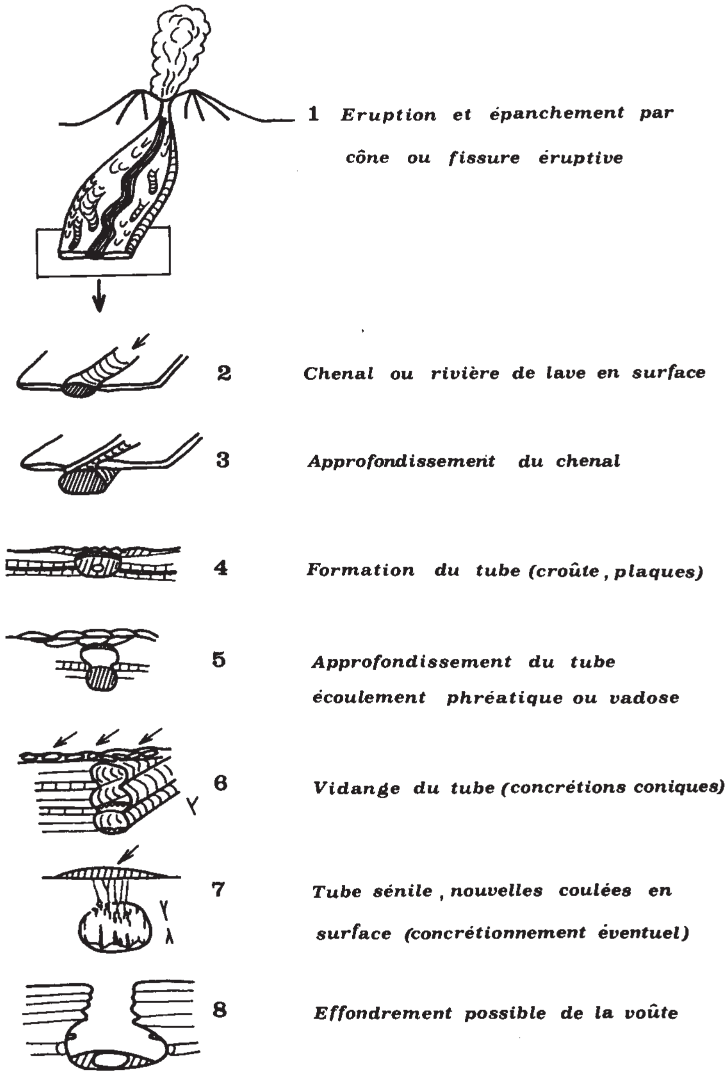


Photo 1. *Roots penetrating the roof of John Martins Cave, Puna, Hawaii.*



account the fluidity of the lava, these findings are quite feasible with hydraulics, and our observations coincide with theory.

In the course of its movements underground, the lava loses only a little of its thermal energy and when it appears several meters down slope ahead of the flow, the lava often appears as a radial or deltaic system, from ramifications of the main tube. During variations of the rate of flow (either during the initial outpouring or later), the lava stream flows freely in the tube. In certain cases, lava tubes form, and in others, small residual streams congeal later. In still other cases, rough lava streams ("aa") use tubes formed in "pahoehoe." When flow slackens, lava sumps hinder its progression.

At the end of an eruption, lava in a tube fan drains off down slope because basalt retains its mobile characteristics in the tube being sealed off from surface air. Once it has drained, the tube may undergo a process of concretion, forming lava stalactites and stalagmites by lava coming from new flows, filtering through fractures and dripping into the tube, like drops of melted wax. Then, in the old-age period of the tube in which the roof may collapse, being thin or broken, if "skylights" or longer unroofed segments do not exist, the tube may be protected from subsequent filling by later flows.

In the case of fluid lavas, the lava tunnels or tubes thus act as transporting stages for the formation of lava streams which in certain cases (Australia) can be as long as 100 km. Effusions of such scale by purely surface flow, quickly cooled by atmospheric air, are difficult to imagine. This observation shows the essential role played by these tubes, and is important in the understanding of the emplacement of lava fields and of the geomorphology of the Hawaiian volcanoes. Flattened cones would not appear without these volcanic channels and lava tubes, thus emphasizing the importance of listing, exploring and classifying lava tubes, as well as observing their morphology. It is clear that numerous types of lava tube formations exist. From a speleological standpoint, Hawaiian lava tubes represent underground networks with a long horizontal extension.

PIT CRATERS

Pit craters are holes in the volcanic base which have developed by stoping of underlying magmatic chambers. These "volcanic gulfs" have no direct relation with the type of lava tubes just mentioned. Their existence is linked to major masses of molten lava which have built up underground and erupt through fissures or **cone craters**, which are volcanic cones 10 to 50 meters high. When such lava has erupted and its depth has decreased, significant gaps develop about ten meters below the surface. These appear soon, as the roof collapses. The cross section of the cavity therefore is similar to collapse features in limestone, often on a grand scale. In Hawaii Volcanoes National Park beside the highway, Puhimau Pit Crater measures no less than 200 meters in diameter and is 150 meters deep. One hundred meters of rope is needed to reach the talus slope at the bottom. No entrance exists for entry into subterranean magma chambers here. Along the walls, gas emissions hamper ascents and descents, but this is an excellent natural cut for stratigraphic studies.

PIT CRATERS AND CONE CRATERS

With geologists from the Hawaiian Volcano Observatory, we went to the center of the Kau Desert to explore several pit craters and to attempt to explain the relationship between these collapses and lava tubes. Here, three aligned orifices approximately 30 meters in diameter appear punched into the basalt plain. Only the easternmost emitted lava; it is surrounded

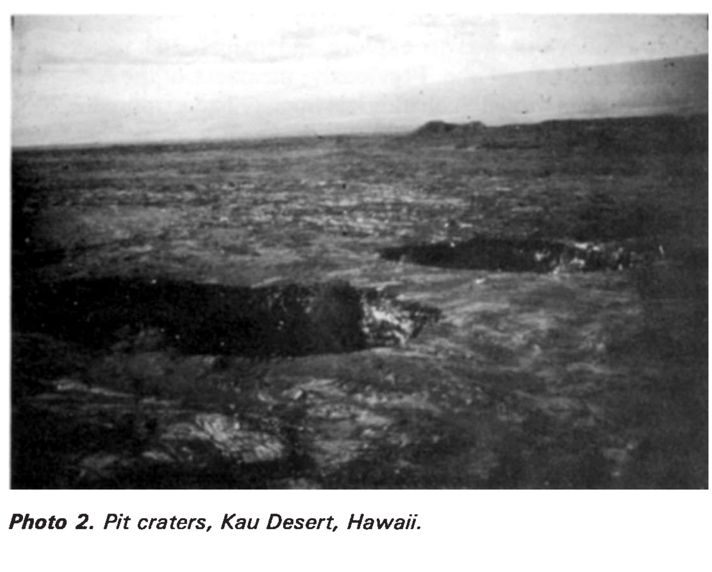
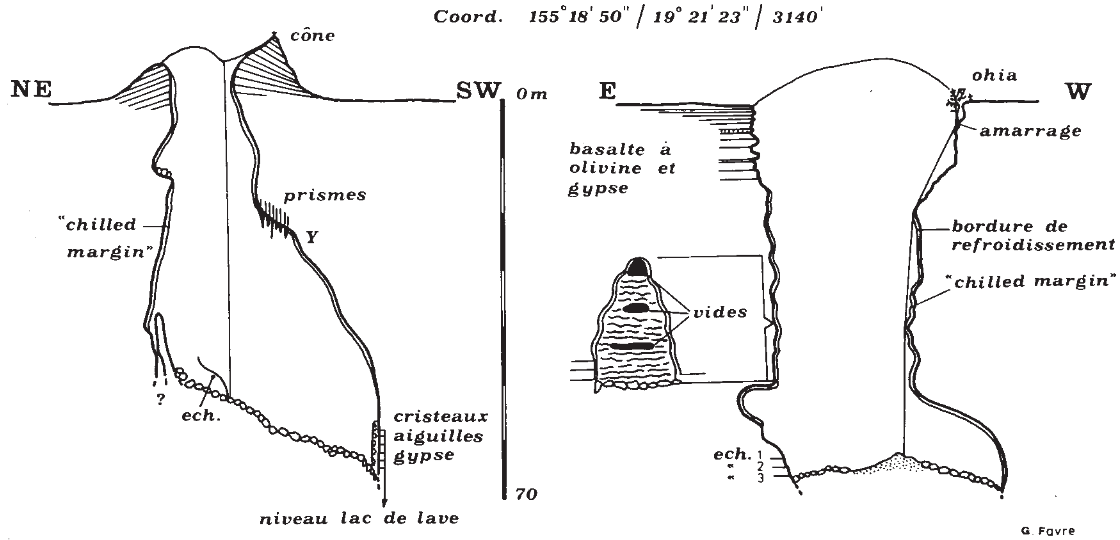


Photo 2. *Pit craters, Kau Desert, Hawaii.*

by a volcanic cone 10 meters high. This is a cone crater; the other two are pit craters. The westernmost already had been explored by Norman Banks, an American geologist. He descended as far as minus 60 meters. The central crater (#2) has an opening about 30 meters in diameter. Because of the danger of falling rocks, only one of our group reached the bottom, at minus 70 meters. At minus 15 meters was the solidified margin of the magma chamber (its roof). After 40 meters descent, we emerged into an enlarged chamber which continued on into the depths. There, also because of numerous collapsed rocks, we did not continue further back. We collected three samples of the rock surface.

Cône et Pit Craters (KAU DESERT)



At the cone crater, we found difficulties in anchoring, because of the lack of rocks or trees nearby. With the aid of a 40 meter ladder, we encircled a large rock and made a descent. The view was very aesthetic for 50 meters. We landed on a rock cluster at the bottom of a chamber, the sides of which were covered with small gypsum needles.

These three cavities do not open out into a vast underground system. Nevertheless, they form a very interesting trio, significant to our understanding of related phenomena. Very near the surface, magma can be stored for a time in lateral spindle chambers which interconnect along the axis of the break. Since the two pit craters on the western side are the result of stoping of a thin overburden and the cone crater served as an outlet for lava from the system, it may be inferred that other caverns linked with the surface must exist nearby, as seen in the following example.

WOOD VALLEY PIT CRATER

Located on the western edge of the Kau Desert, not far from the main road, this pit crater opens as a circular shaft 30 meters deep and 30 to 40 meters in diameter. Massive surficial basalt forms on overhang to a depth of 10 meters. After a vertical drop past a mass of large fallen rocks (which are the home of wild bees), we reached the first ledge at minus 40 meters. Edging further downward another 10 meters, between stratified lava and breakdown, we reached an underground magma chamber, the floor of which was cluttered with rocks. Only the arch and surface lining of stratified lava are covered by a congealed basalt margin typical of these lava reservoirs.

At the far end of this cavern, we again crawled through scattered rocks and at minus 90 meters, we came out at a totally glazed lava tube which, after 80 meters, led into an underground magma chamber which is entirely intact with no breakdown. The room towers 40 meters and various stalactites hang from the stratum. It is 40 meters long and 10 meters wide. At the far end is a narrower tunnel from which an air current was emerging. After crawling or ducking for about 100 meters in a passage 8 x 5 meters, is a lava sump.

Photo 3. *Cone crater and wall of pit crater, Kau Desert, Hawaii.*

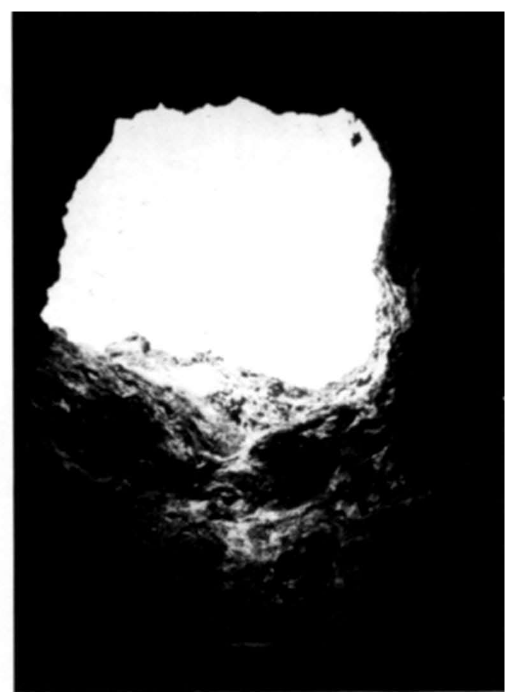


Photo 4. *Looking upward in cone crater, Kau Desert, Hawaii.*

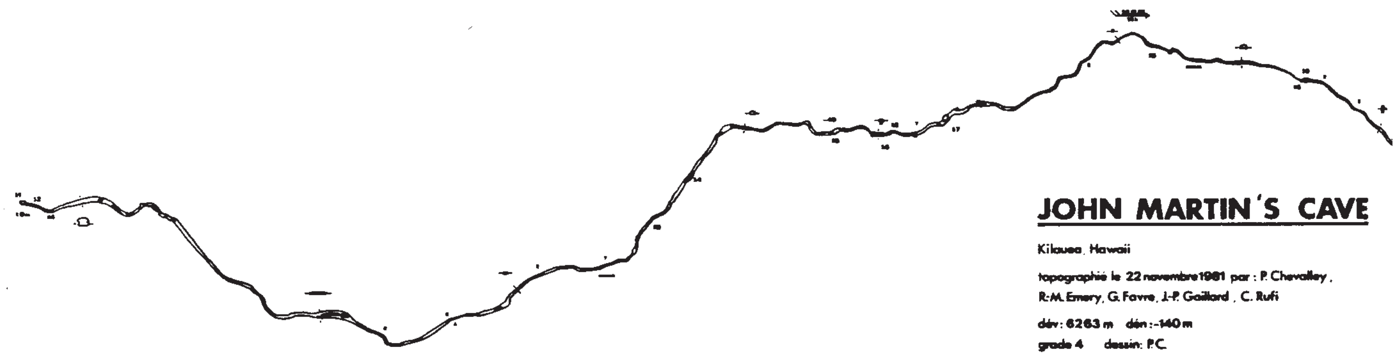


Photo 5. Mauna Ulu, Hawaii.

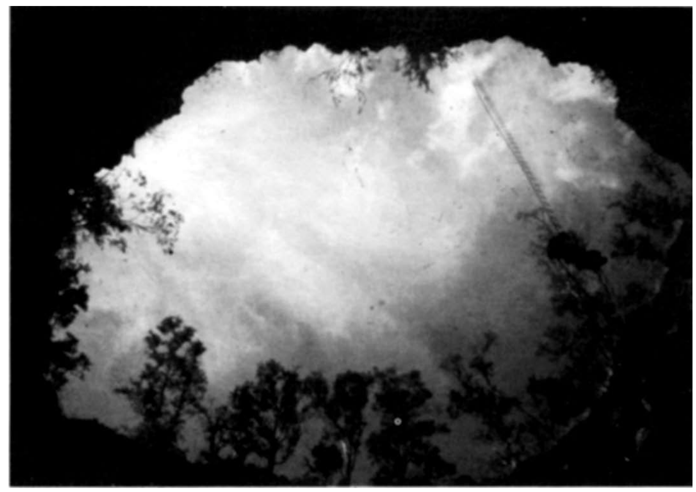
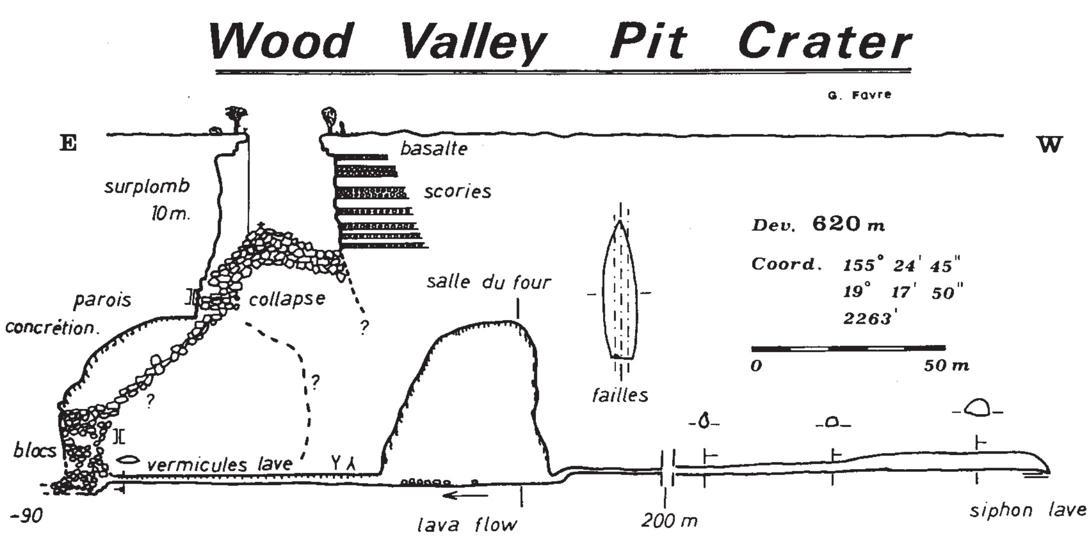
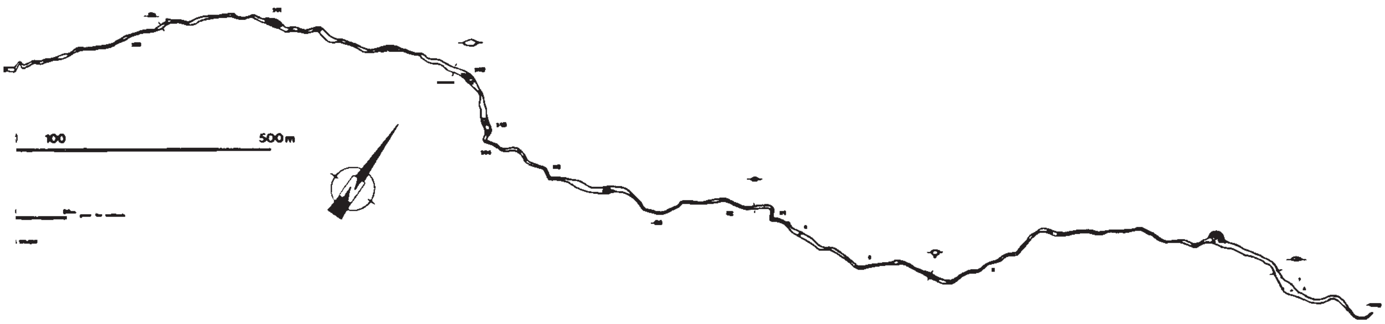
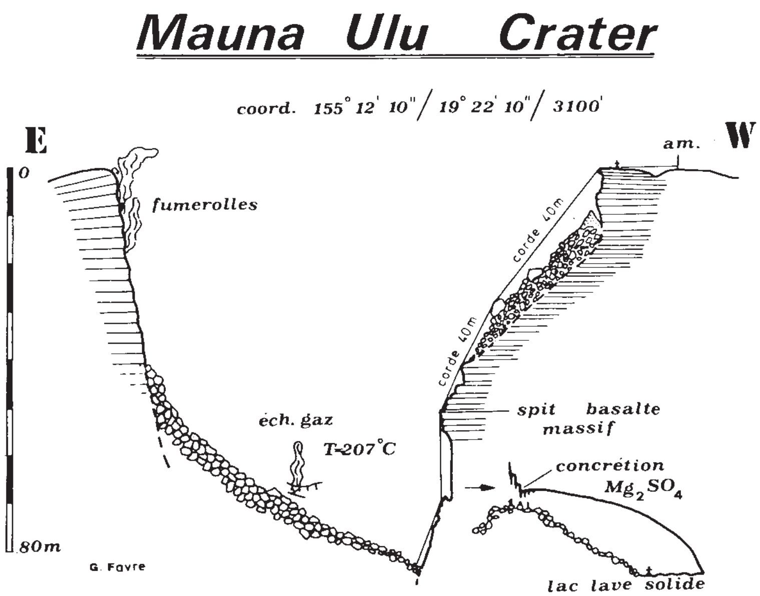


Photo 6. Looking upward in Wood Valley Pit Crater, Hawaii.

This unusual discovery raises an interesting question of the relation between pit craters and lava tubes. The final section of this tunnel resembles an ordinary lava tube at surface level. Yet it is clearly a lava tube of different origin, or "pseudo lava tube." It seems very unlikely that an old lava tube would have developed precisely aligned with the vertical fractures which we observed in the chamber. Taking into account the changes in the course of the lateral section, we believe that this is a vertical pipe of tectonic origin with its lava derived from a dike. At magma chambers of the form we observed and in certain other fractured sites, bedrock somehow can be consumed by magma moving along the axes of fracture. Along this tube, a lava stream traveled from west to east. At the base of the mass of fallen rocks, in the continued axis of the system's development, other holes may exist.







MAUNA ULU CRATER

Mauna Ulu is one of the most recent volcanic structures, having been active from 1972 to 1976. Its major flows extended south 12 km to the ocean. Some gas emissions still continue at the edges and in the depths of the crater.

At the head of this crater is an oval "mouth" about 125 by 100 meters in a unsymmetrical cone. Scree-covered slopes on its southwest side cover alternating strata of scoria and basalt. On the opposite wall, thick and thin basalt layers are seen. Some gas-emitting fissures exist on the upper side. At the foot of the southeastern side, their temperature reaches 207° C, but on the southwestern side, they reach only 55° C.

Ten meters above the highest point between the rock mass and the wall is a former magma chamber, recognizable by the congealed layer which lines the walls and covers the original strata. Its lenticular orifice is 15 meters long and 2 meters high. It is wholly covered by an extraordinary forest of peculiar concretionary forms of magnesium sulfate, lemon-yellow, orange, pale green or creamy white in color. The existence of such formations was previously unknown in Hawaii. Some loose samples were recovered for analysis.

The blocky incline falls away sharply and we came to the surface of a lake of solidified lava. Its temperature proved that molten lava was not very far.

REFERENCES

Wood, C. A. 1980. Caves on the Hawaiian volcanoes: addendum. *Caving International Magazine* 6 & 7 (Jan. & Apr.):4-10.

Editor's note: The April, 1980 issue of *Cascade Caver* (19:4) contains several accounts of explorations and studies on the island of Hawaii in November and December, 1980, including John Martin Cave, Kazamura and nearby caves; Kaumana, Makalei, Apua, Blair caves; Cave of Refuge, Joel Cave, and the first descent of Western Cone Crater by Phil Whitfield, Dave Jones and Norman Banks. It also contains vulcanospeleological abstracts and reprints of earlier reports, and accounts of a few caves on Oahu and Maui.

Photo 7. *Spelean chamber, Mauna Ulu Crater, Hawaii.*

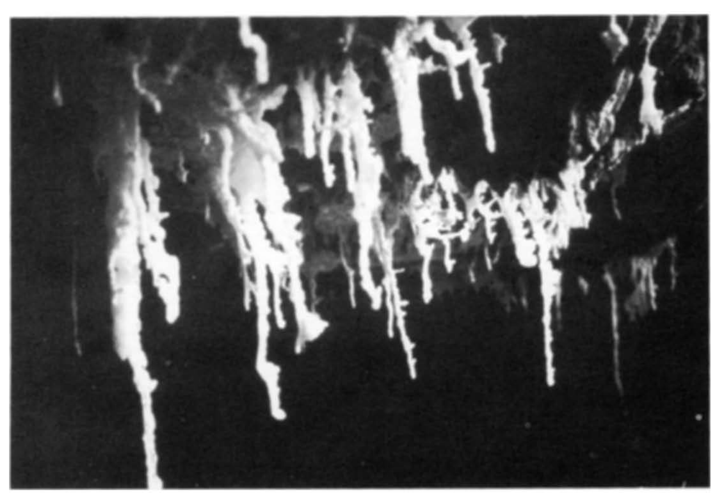


Photo 8. *Magnesium sulphate stalactites and helictites, spelean chamber of Mauna Ulu.*