RECENT VULCANOSPELEOLOGICAL PROGRESS IN HAWAII

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ABSTRACT

In 1993 and 1994 the length of Kazumura Cave was extended to a total of 46.7 km, with a vertical extent of about 850 m. Using single rope techniques, an unnamed volcanic pit on Hualalai volcano was bottomed at -263 m. Exploration and study have been extensive elsewhere on Kilauea, Mauna Loa and Hualalai volcanoes of Hawaii Island and elsewhere in Hawaii. Another cave in the Kazumura System has about 20 km of passages. If it is possible to connect the two, the vertical extent will be about 1090 m, but vertical extent of lava tube caves should not be compared to depths of limestone caves. Other apparent vent caves at the head of the Kaupulehu xenolith nodule beds are described.

The three years between the 6th and 7th International Symposia of Vulcanospeleology (1991-1994) have constituted a time of notable progress in Hawaii speleology. Members, Joint Venturers, and local cooperators of the Hawaii Speleological Survey have intensified field and bibliographic research throughout the islands. An extensive bibliography of Hawaii speleology is in progress, with more than 1000 index cards in process. More than 800 caves, groups of caves, and cave-related place names are listed in H.S.S. files. Not all the caves are in volcanic rock. Not all are large caves. Not all the caves in volcanic rock are lava tube caves. Yet Hawaii clearly has emerged as the world's leading area for the study of lava tube and related caves.

And of all Hawaii, the northern part of Puna District -- between Mauna Loa volcano and the East Rift Zone of Kilauea volcano on «the Big Island» of Hawaii -- has become pre-eminent.

In this part of Puna District, in January and February 1994 Hawaii Speleological Survey teams led by Kevin Allred more than doubled the unsegmented length of Kazumura Cave, to 31.66 km. The end-to-end length was 21 km. This length was the greatest known for any lava tube cave in the world. Beyond two plugs of black pahoehoe lava were two more caves in the same system, known to have at least 15 km of additional length: Sexton's Cave and Olaa Cave.

The vertical extent of Kazumura Cave was calculated at 644 m., more than that of any limestone cave in the United States.

Its average inclination was found to be 1.75 degrees, less in its lower section and considerably more in the upper sections. Passage cross-sections also were found to be different in the different areas. While considerable local variation exists, its lower end tends to be wide and comparatively low while the upper section tends to be high and narrow. Locally, slip slopes and cut banks were found at sharp bends. Lavafalls up to about 15 m are numerous, especially in the upper sections. Multiple stacked levels also were commoner in the upper sections. Tongues and coatings of lavas of different colors were more uniformly distributed.

In late September 1994 a local cooperator of the Hawaii Speleological Survey connected Sexton's Cave to Kazumura Cave. Under the direction of Kevin Allred, an especially intensive period of mapping occurred in October 1994. By October 24, 1994 mapping of the Sexton's Cave section was complete, and an additional 245 m also had been found and mapped in Kazumura Cave proper. With data still being processed, as of the date of this symposium the total length of passages of Kazumura Cave is about 46.7 km (29 miles). Its vertical extent is about 850 m (2800 feet) but the cave never is more than about 20 m below the surface and it has many entrances. Therefore this figure is not properly compared to the depth of limestone caves.

No connection has been made between Olaa Cave and the Sexton's Cave section of Kazumura Cave. Intervening is an apparently short area of breakdown partly covered with intrusive black lava. While seeking a connection in October 1994 more than 3.6 km of passage was mapped in a linear distance of about 1.6 km.This suggests an eventual total length of 15 to 25 km for Olaa Cave. Its vertical extent is known to be about 240 m. Thus the total vertical extent for the system is about 1090 m with only a single short

Olaa Cave and the Sexton's Cave section of Kazumura Cave tend to have especially notable ceiling heights, high lavafalls, and extensive multilevel development. Olaa Cave has especially notable plunge pools and also has an underground hornito or driblet spire above a sheer 10 m pit believed caused by headward erosion.

On both sides of Kazumura Cave are several other major lava tube caves and systems. All these appear to be in the flow field of Ailaau shield, located on the rim of Kilauea Iki crater. On the map, the largest nearby caves and systems appear to be disconnected effluents and/or re-entrants of Kazumura Cave. The pattern of the group is beginning to look like that of 1987-88 Kupaianaha tubes mapped by multispectral thermal infrared techniques (Realmuto et al, 1992). In October 1994, voice and sight connection was made between Kazumura Cave and Doc Bellou Cave, the upper end of a system about 1 km long. Intervening is a distance of about 10 m, in which three very low lava constrictions can be seen, each perhaps 10 cm high. The length of this system is not included in the length figure for Kazumura Cave.

Also subparallel to Kazumura Cave, at greater distances are Keala Cave and the John Martin-Pukalani Cave System. These have many features in common with Kazumura but are not mere copies of it, and are extensive caves and systems in their own right. The length of Keala Cave is 8.28 km. Most of what originally was called John Martin Cave was remapped in 1993 and 1994; it was found to be segmented. What originally was considered to be its lower end now is recognized as Pukalani Cave, previously thought to have been lost to science because of road construction in a subdivision. It terminates by a lava sump but the Uilani Caves are in line with it and Lower Uilani Cave is about 3 km long. It contains a major distributory complex downslope from a braided entrance section, and its middle branch begins with a drained underground lava pond. The mid-portion of this cave currently is threatened by road construction. Keala Cave and John Martin Cave contain considerably more arborescent lava than does Kazumura Cave and show other qualitative differences.

Farther toward the East Rift Zone the main Pahoa Cave or Caves is/are said to be at least ten miles (16 km) long. Exploration and pacing ended in large «walking passage» (McIlheny and Stone, 1991). These and smaller caves nearby are not under study by the Hawaii Speleological Survey. The published small-scale paced map appears to show segmentation. For current hazard evaluation studies of the U.S. Geological Survey, it will be especially important to determine whether this cave or caves and two neighboring systems arise from vents on the East Rift Zone or from the Ailaau shield.

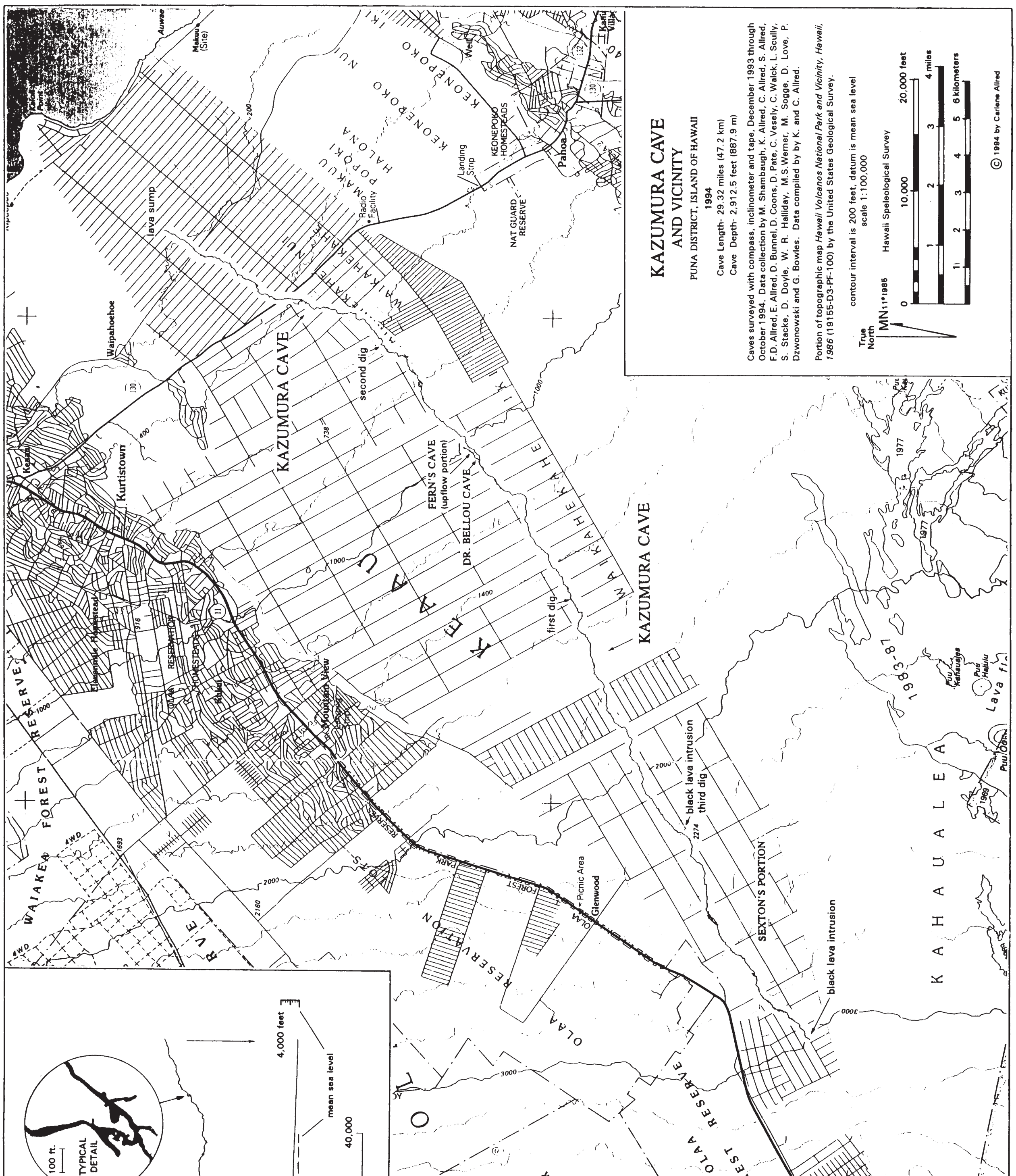
Numerous other lava tube caves have been reported around and up-slope from Kazumura, Keala, and the John Martin-Pukalani System. Few have been investigated, and none is known to approach the lengths of Kazumura, Keala, and John Martin-Pukalani. But empty spaces on the map of the Ailaau flow field suggest that less than half of existing lava tube caves are known.

Elsewhere on the «Big Island», Hualalai volcano is more noted for pit craters than for lava tube caves, but both are plentiful. At least as 1948, respected staff members of the U.S. Geological Survey termed the pit craters simply «The Bottomless Pits.»

In January 1994 the Hawaii Speleological Survey received permission for a week's investigation of these pits, most of which are on private property. Kevin Allred was chairman of this project also. After preliminary surface reconnaissance, Allred and Don Coons first descended an unnamed pit with benchmark 6083 (feet) on its lip. The main pit crater was found to be about 135 m deep. From a ledge about 15 m above its floor, a vertical magma chamber belled out to an undetermined depth. The general appearance was remarkably like that of a limestone sotano in Mexico with a shaft continuing downward.

Another 200 m of rope was air expressed from the mainland and on January 28 Allred and Coons descended directly to the bottom of the magma chamber from a Tyrolean traverse rope. Mapping showed that the bottom was 263 m (862 feet) below the spillover point of the outer pit.

Subsequently, Hawaiian elders bestowed the name Na One Pit on this remarkable phenomenon. If a partially water-filled volcanic pit on Molokai Island, Hawaii is excluded, Na One is the deepest pit known


KAZUMURA CAVE
AND VICINITY
PUNA DISTRICT, ISLAND OF HAWAII
1994
Cave Length- 29.32 miles (47.2 km)
Cave Depth- 2,912.5 feet (887.9 m)
Caves surveyed with compass, inclinometer and tape, December 1993 through October 1994. Data collection by M. Shambaugh, K. Allred, C. Allred, S. Allred, F.D. Allred, E. Allred, D. Bunnel, D. Coons, D. Pate, C. Vesely, C. Walck, L. Scully, S. Stacke, D. Doyle, W. R. Halliday, M.S.Werner, M. Sogge, D. Love, P. Dzwonowski and G. Bowles. Data compiled by by K. and C. Allred.
Portion of topographic map Hawaii Volcanos National Park and Vicinity, Hawaii, 1986 (19155-D3-PF-100) by the United States Geological Survey.
contour interval is 200 feet, datum is mean sea level
scale 1:100,000
Hawaii Speleological Survey
True North
MN 11° 1985
0
10,000
20,000 feet
4 miles
6 kilometers
© 1994 by Carlene Allred
KAZUMURA CAVE
KAZUMURA CAVE
FERN'S CAVE (upflow portion)
DR. BELLOU CAVE
second dig
first dig
black lava intrusion
third dig
black lava intrusion
SEXTON'S PORTION
lava sump
Waipahoehoe
Kurtistown
Keaau
Pahoa
Mountain View
Glenwood
Picnic Area
Volcano
Thurston Lava Tube
Kilauea Crater
KILAUEA FOREST RESERVE
OLAA FOREST RESERVE
OLAA RESERVATION
WAIAKEA FOREST RESERVE
HAWAII VOLCANOES NATIONAL PARK
KAHAUALEA
1983-87
Lava flow
1977
KEONEPOKO HOMESTEADS
NAT GUARD RESERVE
Landing Strip
Radio Facility
KAZUMURA CAVE
(inset)
N
PLAN
100 ft.
TYPICAL DETAIL
PROFILE
4,000 feet
mean sea level
0
20,000
40,000
feet

in the United States. Depending on definitions, it may be the deepest volcanic pit in the world.

In a different part of Hualalai volcano, Hawaii Speleological Survey teams explored and mapped a new type of vertical volcanic conduits. These are located at the apparent head of the well-known Kaupulehu xenolith nodule beds in 1800-01 flows. These studies were in cooperation with planetary geologists of Arizona State University and the Lunar and Planetary Institute of Houston, Texas. In subterranean field work here, the Hawaii Speleological Survey had the lead role.

In this area are about a dozen vertical volcanic conduits, mostly occurring in distinct lines, up- and down-slope. About half of them are plugged at the bottom, five to ten meters below the surface. The others characteristically continue nearly horizontally as low, narrow passages five to fifteen meters long, expanding into small chambers containing minor evidence of lava flow. The horizontal segments slope gently toward the axis of the main 1800-01 flow channel. Steepwalled septae separate individual vertical conduits, and the appearance is that of «curtain of fire» vents. Some are roofed with thin domes of pahoehoe. No tube structure is present.

The largest of these phenomena differs considerably from its neighbors. It is a complex of three vertical conduits, a spacious sloping chamber about 30 m long, and some minor subterranean extensions. It reaches a depth of 30 m, descending rather uniformly at about 45 degrees. Locally, lava pond strands are present.

The extraordinary feature of this cave is a hanging wall/ceiling of dense lava containing ultramafic xenoliths up to about 20 cm in diameter. Nearly all are at least partially rounded. They occur singly or in clumps, the latter somewhat sorted by size. A considerable variety of ultramafic minerals is represented. The dense lava bed is two to about 20 cm thick. In the upper part of the cave, its slope is about 45 degrees. Near the bottom, it curves toward the horizontal. From its inner surface, small stringers of dark lava enter adjacent rubbly aa or scoria. Locally, xenoliths of this dense lava appear to have settled to its bottom while it still was visco-elastic.

The most uphill of these vertical cavities also is atypical. Its cavernous interior is comparatively wide and shallow, and several faint strand lines are present on its overhanging walls. It has no horizontal component. Its outer surface has the general appearance of a pahoehoe minishield with a clump of xenolith nodules «cemented» on its downhill overflow. At its lower margin is a rudimentary lava tube cave about 10 m long; a xenolith nodule bed is exposed in the cave's pitlike entrance.

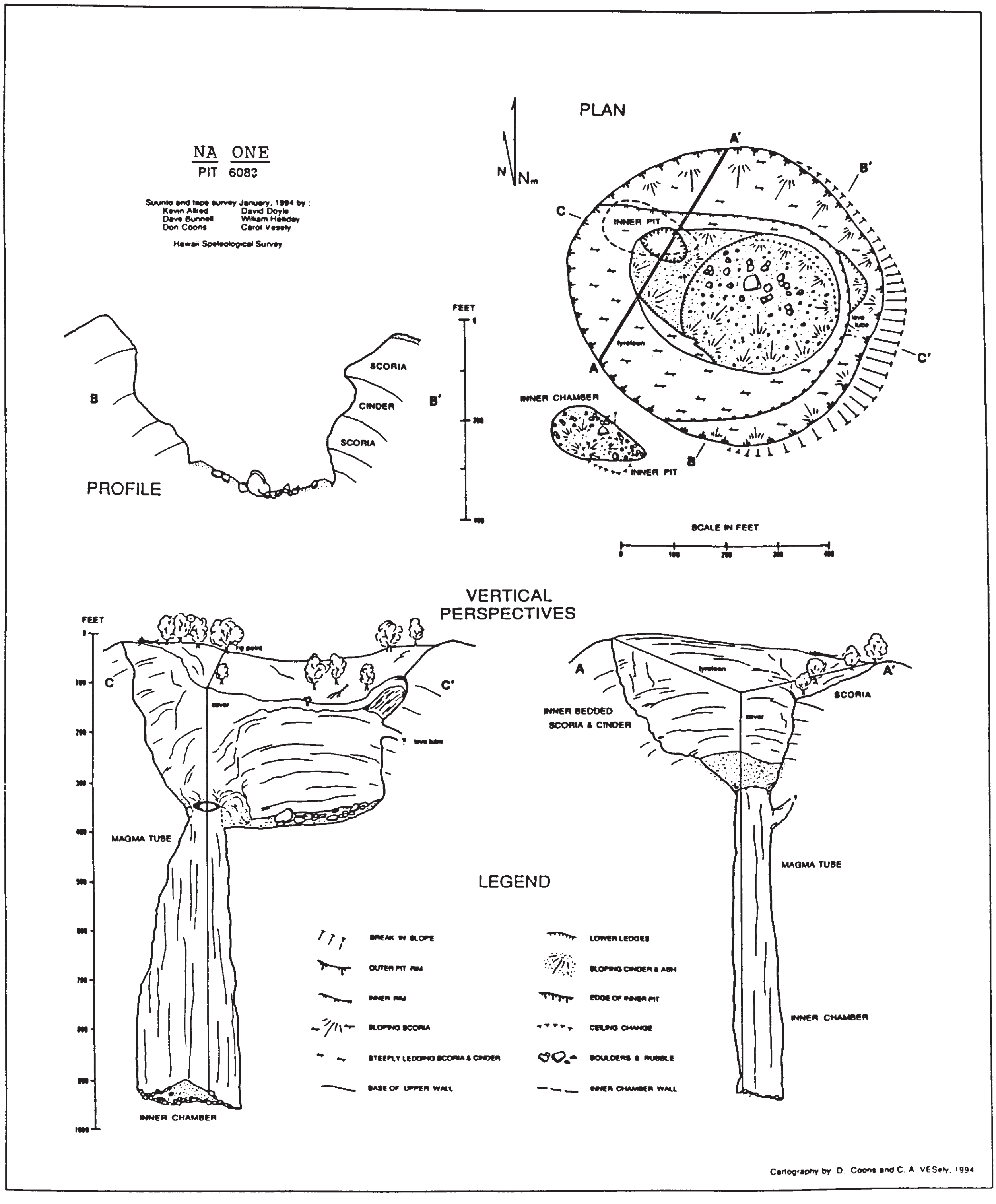
Although the other vertical cavities are quite different in structure from the two atypical forms just described, outflow of pahoehoe lava seems to have been a common denominator. The large cave contains puzzling distributions of small beds and tongues of xenolith nodules as well as the hanging wall previously described. In one of the smaller horizontal caves at the bottom of a vertical conduit, a vertical bed of xenoliths is seen in the rock exposed by lateral breakdown of the crust of the inner chamber. These, however, lack the mineralogical diversity seen in the hanging wall of the large cave nearby. In these complexes, evidence of subsidence or lava reflux is plentiful. But this may only represent a late stage in speleogenesis. Much remains to be learned by on-site study here. While these are all small scale volcanic features, their unique characteristics and their association with the extensive beds of large ultramafic xenoliths are of special interest to planetary geologists.

The Hawaii Speleological Survey also has assisted planetary geologists from Arizona State University in studies of thermal erosion in caves of Hawaii Volcanoes National Park and elsewhere. In addition to simple vertical erosion into nontube forming volcanics, undercutting and development of slip slopes and cut banks have been noted. Some of us have come to believe that some sudden changes in tube diameter, especially where lavafalls are present, are the result of thermal headward erosion.

During these studies we also found fragments of bird bones in deeply buried volcanic ash exposed by lateral breakdown which occurred after downcutting. These still await ornithological study.

Kilauea caldera was found to be an unexpectedly fruitful area for vulcanospeleological study. In addition to a large lava tube system about 1 km long, our teams located several small caves formed by drainage of tumuli, lava ponds, and other small-scale pahoehoe structures. Subsequently we learned from George Walker at the University of Hawaii in Honolulu that he recently had studied and described some of these phenomena (Walker, 1991, 1992). We look forward to future joint studies in this area.

Under the direction of Douglas Medville, recent H.S.S. exploration and study of caves on the north side of Mauna Loa volcano have produced maps and data on numerous comparatively short lava tube



NA ONE
PIT 6083
Suunto and tape survey January, 1994 by :
Kevin Allred
David Doyle
Dave Bunnell
William Halliday
Don Coons
Carol Vesely
Hawaii Speleological Survey
PLAN
N
Nm
A'
B'
C
INNER PIT
C'
A
B
INNER CHAMBER
INNER PIT
SCALE IN FEET
PROFILE
B
B'
SCORIA
CINDER
SCORIA
FEET
VERTICAL PERSPECTIVES
C
C'
MAGMA TUBE
INNER CHAMBER
A
A'
INNER BEDDED SCORIA & CINDER
SCORIA
MAGMA TUBE
INNER CHAMBER
LEGEND
BREAK IN SLOPE
OUTER PIT RIM
INNER RIM
SLOPING SCORIA
STEEPLY LEDGING SCORIA & CINDER
BASE OF UPPER WALL
LOWER LEDGES
SLOPING CINDER & ASH
EDGE OF INNER PIT
CEILING CHANGE
BOULDERS & RUBBLE
INNER CHAMBER WALL
Cartography by D. Coons and C. A. VESely, 1994

caves. Some of them contain unusual mineralogical deposits including elemental sulfur. Other studies by Australian John Webb found thenardite on the floor plus calcite and gypsum on the walls of one cave here. Detailed followup is in process. On the floors of some of these caves, multicolored lava flows are notable.

On the lower slopes of Hualalai volcano, Medville's teams have found somewhat longer caves, up to about 1½ km in length. Near the summit of Hualalai volcano, other H.S.S. teams found caves with unusual degassing phenomena behind their tube linings.

Investigation of the southern part of Mauna Loa volcano has lagged. but one H.S.S. team assisted a U.S. Geological Survey team in descending 90-meter Hapai Mamo Pit on its Southwest Rift. Nearby, another team found short but evaporite-rich lava tube caves with impressive red lava speleothems.

In the field of resource protection, the Hawaii Speleological Survey has begun community education through illustrated talks in Hawaii Volcanoes National Park and to governing bodies of community associations. These have been well received. Officers of two of these associations now are among our most active members and field cooperators.

Further, the H.S.S. has nominated 110 Hawaiian caves and groups of caves to receive protection under the Federal Cave Resource Protection Act. In 1993 we submitted inventories of 25 caves in Hawaii Volcanoes National Park. Several of them necessarily were incomplete but mapping and inventory of additional caves followed in 1994.

We are working directly with the U.S. Board on Geographic Names to preclude public distribution of locations of Hawaiian caves. We have provided recommendations on cave management to public and private organizations, in one case warning of imminent collapse of a major subdivision road if subjected to heavy vehicles. In that report we recommended several alternative approaches to protection of the cave if that road is to be reconstructed.

These studies have provided a wealth of new scientific data, but also raise many questions. Some are merely definitional; others of real interest in earth science.

Findings from the exploration of Na One Pit («Pit 6083») exemplify the need for clearer definitions in the borderland of fulcanospeleology and volcanology. As described, it contains a vertical magma chamber about 150 m deep extending downward from a ledge of a somewhat atypical pit crater also about 150 m deep. The stated total depth is from the spillover point of the rim of the outer pit crater. We are unaware of any disagreement about this method of calculation. But definitional and procedural problems arise when it is comparated to other volcanic pits and craters of Hualalai volcano.

Consider Kaupulehu crater. Its main portion is a wide, shallow bowl-shaped structure about ½ km in diameter. At the lowest point of this shallow bowl is an arcuate sheer-walled pit estimated to be 15-20 m deep, 10-15 m wide and 30-40 m long. At one end of this inner pit is a narrow vertical shaft of unknown depth, perhaps deeper than Na One Pit (we have not yet received permission to descend it). Should the outer bowl-shaped shaped crater be included in calculating its total depth? What is the line of demarcation between craters and volcanic pits? Perhaps the rules of the International Union of Speleology distinguishing solution dolines from limestone pits can be applied in volcanic terrain. But how widely would they be accepted?

Further, what is a pit crater?

This term is used very loosely in Hawaii and probably elsewhere. At least since discovery of the adjacent Thurston Lava Tube in 1913 everyone except a few vulcanospeleologists has called Kaluaiki a pit crater. Kaluaiki is the slightly sinuous multilevel closed depression between Mauka Thurston Cave and world-famous Thurston Lave Tube. Part of Mauka Thurston extends beneath the shallow upslope end of Kaluaiki, like the unnamed cave in the middle of the Big Trench Cave System in Skamania County, Washington (Halliday, 1963). Kaluaiki thus appears to be an unusually large trench segment rather than a pit crater, and part of a jameo system. During the 6th International Symposium of Vulcanospeleology in 1991, this was pointed out during the field excursion and also in the published Proceedings. But most authorities still speak and write of it as a pit crater. Even if vulcanospeleologists agree among themselves on such matters, how do we bring volcanologists and administrators into the process of definition and redefinition?

In a different frame of reference, the vertical extent of Kazumura Cave currently is greater than the depth of any limestone cave in the United States. But the cave is never more than about 20 m below the surface. It has many entrances, and its challenge simply is not comparable with that of limestone caves of similar vertical extent. In my opinion, Kazumura Cave should NOT be considered the deepest cave in the United States. To list vertical extents of lava tube caves with depths of limestone caves would be very misleading. In my opinion, listing depths or vertical extents separately for caves in different kinds of rock should be the minimum. But some disagree. Can agreement be reached?

Agreement has not been reached among planetary geologists and U.S. Geological Survey volcanologists about the origin of the vertical volcanic conduits at the head of the Kaupulehu xenolith nodule beds, nor about their relation to the nodule beds themselves. Are they vents, subsidence residuals, hollow dikes, or something yet unthought?

My impression -- like that of some planetary geologists -- is that all these cavities were parts of xenolith-bearing vents, with some late secondary subsidence. Only additional study can confirm or refute this.

Much additional exploration and study also remain to be done in the caves on both sides of Kazumura Cave. On the surface, the entire area between Mauna Loa volcano and the immediate vicinity of the East Rift zone has the appearance of a single flow field. But especially in the upper end of this area, the jungle is so dense that direct observation is very limited, and some aerial photos seem to show sizeable flow lobes of the East Rift overlapping part of the Ailaau flow field. Precise mapping of the Pahoa and nearby caves would clarify their relation to the more northerly caves and their origin from the Ailaau shield or the East Rift.

Another question arising underground here is the reddish color of some cooled pahoehoe. Traditionally, this is attributed to oxidation. But characteristically, the outside of cooled pahoehoe flows on the surface in Puna is black, not red from exposurė to atmospheric oxygen. And in the larger caves, red tongues of lava consistently break out from beneath a grey crust at lavafalls. Moreover, in the largest, most extensive caves, the characteristic colors of solidified lava tongues commonly are brown, red, orange, or yellow. A few are black, as on the surface (some have a red interior with a thin black crust). The black tongues tend to be found near entrances, and often plug the tube. Are these black tongues invasive flows which entered the caves after initial cooling of the tube? If redness is a sign of oxidation, lava congealing near entrances should be red, not black. Does a red, yellow, orange, or brown color thus indicate an initially higher temperature rather than oxidation? Or especially slow cooling? Clearly, further investigation of the cause of colors of intratubal lavas may provide new insights into the fiery processes of their developments.

After degassing during injection of lava beneath lava crusts, does cavitation persist? Is there a continuum of cavitation between the finger-sized tubes in a few pahoehoe toes and enormous «boreholes» like Kazumura Cave? Is there a critical minimum diameter of tubes in advancing lava tongues, below which internal cavities cannot be continuous?

Do lavafalls of 10 m or more in Kazumura, Olaa and other Puna caves really result from thermal headward erosion, or do they merely reflect pre-existing surface features overrun by tubeforming lavas? If the latter, why is the cave often much larger below the lavafall than above it? Can stacked multilevel speleogenesis be attributed to thermal erosion?

These are only a few of the question to be answered about the plumbing of volcanoes and lava beds. My own part in these studies soon will be ending. I urge all of you to seek the answers to these -- and to the other questions yet to be formulated -- throughout the lava tube caves and volcanic pits of the world. 45 years of observation of lava tube caves around the world have shown me that their features differ markedly, from area to area. Study on a world-wide basis is essential to fuller comprehension of the processes which they demonstrate.

But when you reach impasses in your own areas of study, consider seeking the answers in Hawaii. The recent breakthroughs here promise much for the future of vulcanospeleology.

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