What Is a Lava Tube?

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Abstract

Variances and imprecision in defining the term LAVA TUBE have led to its application to a wide range of features, some of them far removed from the ordinary meaning of the word TUBE: "a hollow body, usually cylindrical, and long in proportion to its diameter..." The current American Geological Institute definition helpfully limits the term to roofed conduits and requires that they be formed in one of four accepted mechanisms. However it provides little guidance on whether a variety of injection structures traditionally termed LAVA TUBES actually are undrained or refilled examples or are entirely dfferent phenomena.

Ideally, lava tubes and lava tube caves should be defined as discrete structures with definable parameters which differentiate them from all other volcanic features, e.g., aa cores, lava tongues, tumuli, sills and related injection masses. The defining characteristics should be compatible with:

1) the common meanings of TUBE and CAVE;
2) the presence of solid, liquid, and/or gaseous matter within them;
3) observations of all phases of their complex speleogenesis, e.g., crustal and subcrustal accretion and erosion;
4) their tendency to form braided and distributory complexes, and multlevel structures of at least two types;
5) their propensity to combine with or produce other volcanic structures, e.g., lava trenches, rift crevices, tumuli, drained flow lobes, lava rises, dikes, etc.

The ideal may not be achievable at the present state of knowledge and technology. However, new concepts of flow field emplacement and drainage offer a notable opportunity to shape a clearer definition of this elusive term. I propose that the Commission on Volcanic Caves of the IUS develop such a definition, in collaboration with the AGI and other concerned agencies and organizations, for consideration at the 2005 International Congress of Speleology.

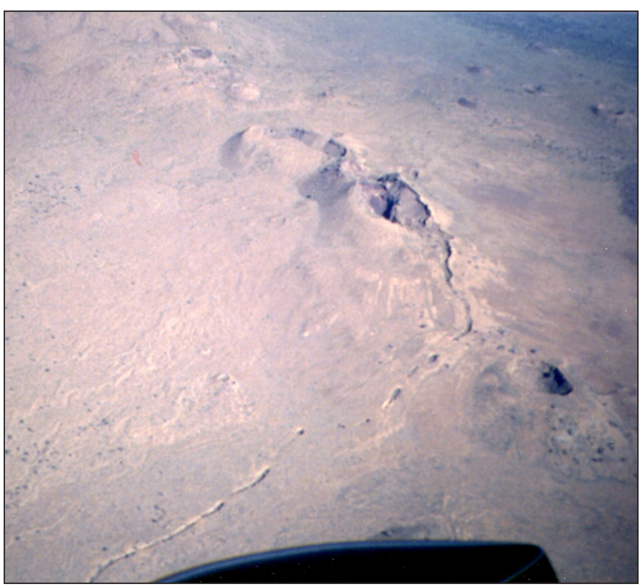

Figure 1. Aerial view of Poikahe Crater and partially collapsed braided lava tube system, Hualalai Volcano, Hawaii Island. Similar patterns have been photographed in several extraterrestrial sites. Photo by the author.

Introduction

Some geologists recently have used the presence or absence of lava tubes or tube-fed lava for important inferences and conclusions. Thus it has become important to have a common understanding of the term. But the term "lava tube" currently is applied to a variety of features which are inconsistent with standard geological and speleological definitions of the term (Jackson, editor, 1997; Larson, 1993), and different observers specify widely different parameters as characteristic of lava tubes.

These inconsistencies are the result of several factors. Uninformed persons commonly confuse tree casts with lava tubes, and vice versa. Indeed, small scale examples lacking bark molds and arborescent branching may be difficult to differentiate; glaze, lava stalactites and accreted linings are sometimes found in tree molds and associated gas cavities (Honda, 2002).

At least in Hawaii, the problem is even more complex. Here and elsewhere, many persons have come to believe that any cave or rockshelter in lava necessarily is a lava tube cave, often simply mistermed a lava tube. Especially misidentified as lava tubes are well-known littoral caves, e.g., Waianapanapa Caves, Maui Island and Kaneana (Makua Cave), Oahu Island (Figure 2). Boatmen on the Na Pali Coast of the island of Kauai commonly refer to spectacular Queen's Bath (Figure 3) as a "vertical lava tube". Actually it is a large littoral cave which has lost most of its roof. Nonlittoral erosional features like Kauai's Fern Grotto are not exempt from this misconception. Such misunderstandings commonly appear in the popular

Figure 2 (top). Entrance of Kaneana (Makua Cave), a littoral cave formed along a dike complex on the northwest tip of the island of Oahu, Hawaii. In the popular literature, it commonly is termed a lava tube. Photo by the author.

Figure 3 (middle). Interior of Queen's Bath, Na Pali Coast of Kauai Island, Hawaii, a large littoral cave which has lost most of its roof. Boatmen commonly refer to it as a vertical lava tube. Photo by the author.

Figure 4 (bottom). Solid invasive structure on the northwest face of Makapuu Point, Oahu, Hawaii. This structure has been termed a solid lava tube. Photo by the author.

press and in a few compilations which unwisely have relied on the supposed accuracy of press accounts.

In the geological literature, various solid features in volcanic terranes have been identified as lava tubes. Palmer (1929) and Wentworth (1925) described caste of lava tubes exposed by erosion on the islands of Oahu and Lanai. Palmer analyzed and depicted features characteristic of these "fossil lava tubes": near-concentric bands of vesicles and "a very slight tendency toward radial jointing" which is not impressive on the accompanying photographs. The example he reported may be considered the prototype of cores of solid lava tubes.

In contrast, Waters (1960) proposed that the elliptical "war bonnet" structures of Columbia River flood basalts are undrained lava tubes 15 to 35 m in diameter. This was not widely accepted. Greeley (1998) pointed that these features lacked linings typical of lava tubes, nor had they the concentric vesicle patterns which he considered "characteristic of lava tubes". Harper (1915) previously had cited and depicted a rosette pattern of smaller radiating features in at least one of several finger-like littoral ridges of dense Permian basalt in Australia, but did not refer to lava tubes as did two recent reports on this locality (Campbell et al, 2001; Carr and Jones, 2001). Others have applied the term to the entire width of cores of flow lobes and lava rises, to intermittent volcanic ridges, to at least one laccolith and a partially hollow dike, and to a variety of inferred structures.

Solid and inferred structures cited as lava tubes

"Radiating columnar jointing" in digitate littoral ridges of Permian basalt were said to be "indicative of filled lava tubes" (Campbell et al, 2001). Imprecise wording has hindered understanding of features at these and other sites. Carr and Jones (2001) asserted that "the larger, more laterally continuous lava masses (at this Australian site) are interpreted as lava tubes while the smaller, less laterally continuous masses are interpreted as lava lobes". The lava fingers at this site "may contain radially arranged columnar joints and less pronounced concentric joints" 5 to 20 m in diameter. An example which they depict appears somewhat similar to an undescribed light-colored

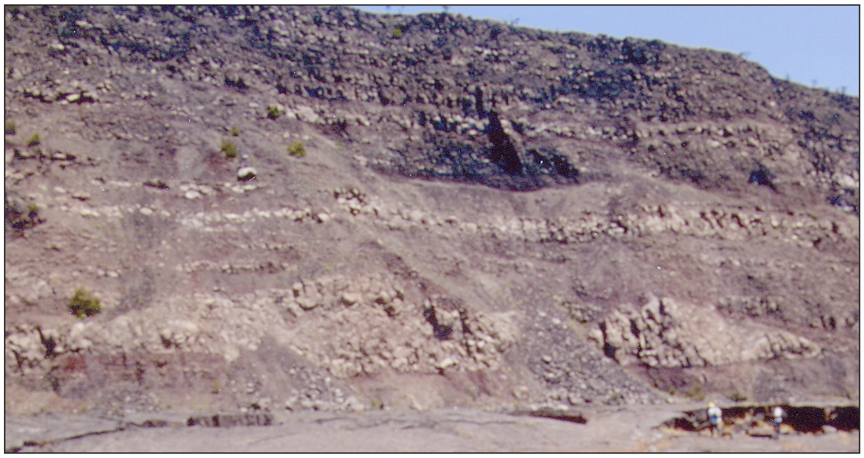

Figure 5 (right). Laccolith exposed in the west wall of Kilauea Caldera. At one time, this was termed a lava tube. Photo by the author.

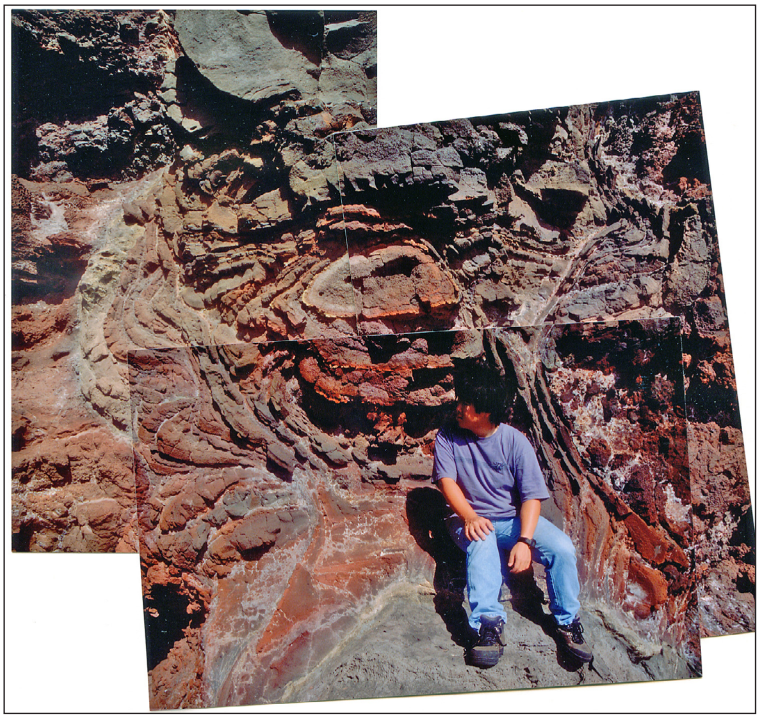

Figure 6 (below). Detail of central part of structure shown in Figure 7. Note complex of filled tubes and laterally displaced lava filling irregular width of buried crevice. Photos by the author.

Figure 7 (below right). Complex structure on the east fact of Makapuu Point, Oahu, Hawaii. This structure has been termed a solid lava tube. Photo by the author.

feature exposed in the northwest side of Makapuu Point, Hawaii which rests on a narrow outcrop of pyroclastic material (Figure 4) and has "baked" adjacent lava. In local geological circles it is said to be a filled lava tube (C. Okubo, written communication, 1999). A light-colored laccolith exposed prominently in the west wall of Kilauea Caldera, Hawaii (Figure 5) also was proposed as a solid lava tube until its actual structure was determined conclusively (Anonymous, cited by Don Swanson, oral communication 1999).

An especially complex feature termed a filled lava tube by Coombs et al (1990) and by Kesthelyi and Self (1998) is located on the northeast side of Oahu's Makapuu Point It is much lower in the stratigraphic column than the feature discussed above and is not aligned with it The two features have little in common. Contrary to the cited reports, the jaggedness of its lateral margins (Figure 6) indicates that it was a tectonic crevice along which lava flowed turbulently and by discrete injections, much as in the case of the Great Crack of Kilauea Volcano (Halliday, this volume). Present are two cores of dense lava (Figure 7) similar to those reported by Palmer (1926) and several solid tubes of less dense lava (Figure 6) which meet criteria published by the American Geological Institute (Jackson, editor, 1998). A few somewhat similar groups of more or less filled tubes (Figure 9) are exposed in roadcuts on Hawaii Island.

Extraterrestrial and sea floor features identified as lava tubes

Several extraterrestrial and sea floor features have been identified as lava tubes. Fornari (1986) considered that segmentation of a sea floor ridge proved that it is a lava tube. Some lunar rills have been termed collapsed lava tubes, but are many orders of magnitude larger than any terrestrial feature which fits the cited standard definitions of this term. On Kalaupapa Peninsula, Molokai Island,

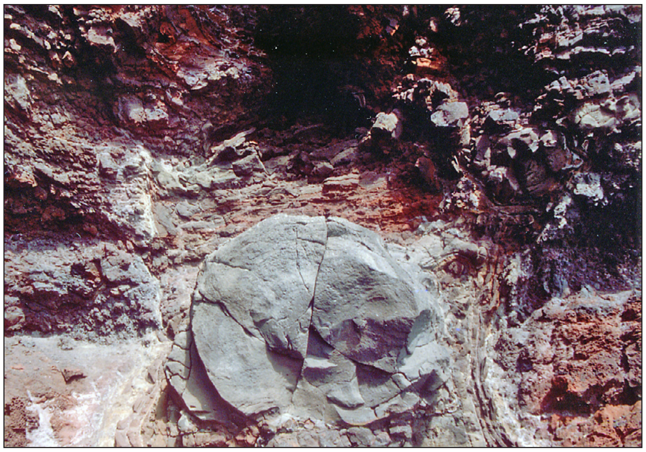

Figure 8. Detail of top of structure shown in Figure 7. Dense solid cylinder with offset concentric vesicle rings is like that reported by Stearns. Above it is horizontally layered lava filling top of buried crevice. Photo by the author.

Figure 9. Cross sections of small lava tubes in aa exposed in road cut along highway between Kailua and Captain Cook, Hawaii County, Hawaii, USA. Maximum height of open tubes is about 10 cm. Photo by the author.

Figure 10. Lava trench on Kalaupapa Peninsula, Molokai Island, Hawaii said to be a collapsed lava tube extending to small volcanic shield beneath lighthouse in background. Photo by the author.

Hawaii (Figure 10), Kauhako Channel is of similar size and also has been termed a collapsed lava tube (e.g., Coombs et al, 1990). Close field examination of this structure, however, revealed that it is a lava channel complex containing eruptive foci (Halliday, 2001) as reflected on a recent geological map of the peninsula (Okubo, 2001). Coombs et al (1990) considered "three land bridges" (channel-wide accumulations of talus) to be proof of collapse of a lava tube, but such "land bridges" also are present in grabens along the Great Crack of the Southwest Rift Zone of Kilauea Volcano (Okubo and Martel, 1998). Four aligned vents are present downslope from the channel (Okubo, 2001). Coombs et al (1990) asserted that the collapsed tube was the feeder for these vents but no evidence is known that these are tube-fed rather than crevice-fed.

Evidence of a huge, deep-lying tube also was said to be evident in Ka Lua o Kahoalii, a pit crater complex opening downward on a level bench within Kauhako Crater (Figure 11). Coombs et al (1990) interpreted it as a collapse skylight of the tube. The vertical shaft of this pit complex opens downward from the surface of a partially destroyed lava pond within Kauhako Crater and is 8 m from the rim of its funnel-shaped inner pit All of its cavernous extension is beneath the talus-covered slope of the inner pit (Figure 11), and slants downward toward it (Halliday, 2001). The total volume of some thinly glazed cavities in the complex (Figure 11, 12) is >> 1% of the volume of Kauhako Channel. Ka Lua o Kahoalii appears to be part of the vertical conduit system of Kauhako Crater and its pond rather than the beginning of some enormous collapsed lava tube.

Extraterrestrial and ocean floor phenomena which are fully congruent with surface expressions of subaerial lava tube caves (e.g., Figure 13) may be considered to indicate the presence of lava tubes with a high degree of certainty (Halliday, 1966). Others are much less conclusive.

Flow lobes and lava rises as lava tubes

Whitehead and Stephenson (1998) conjectured the existence of even larger undiscovered lava tubes in northeastern Australia. Others have written of cores of lava rises, flow lobes and other seemingly amorphous inflation conduits of lava as being lava tubes. Whitehead and Stephenson emphasized "how much larger these wide, flat lava tubes were... in relation to most known lava tubes... the widths of the Toomba inflation conduits were as great as 500 m. . . ." They explained this seeming dichotomy as the product of a new concept which developed in the decade prior to 1998: "any feeder beneath a lava surface" now may be considered a lava tube. Others (e.g., Fornari, 1986) appear to believe that any subcrustal conduit of lava is a lava tube. While nowhere specifically stated, this presumably extends the concept to include crevices, dikes and sills as well as the cores of lava rises and similar structures. No article specifically proposing this concept has been located, however. It may be that it has moved from theory to partial acceptance without adequate scientific testing.

Conduit tubes and drain tubes

Redefinitions of the term lava tube should consider still other tubular structures in lava. Numerous investigators (e.g., Fornari, 1986; Calvari and Pinkerton, 1998) have written as if lava tubes by definition were conduits of flowing lava. On the other hand, some tubular structures in pahoehoe flow fields have features consistent with subcrustal drainage caves (Grimes, 1999, 2002; Grimes and Watson, 1995; Halliday, 1998 a and b). Lack of downcutting, rheogenic abrasion and accretion all show that such caves have carried little or no flowing lava (other than the small volumes drained from the structures themselves). Most of the shallow, thin-roofed "surface tubes" which formed in profusion on some pahoehoe flows (e.g., the Huehue telephone repeater section of the Kaupulehu flows of Hualalai Volcano, Hawaii), also are drain structures rather than conduits.

In the 1919 flow of Kilauea Caldera, Hawaii, numerous elongate flat-floored depressions are present where still-plastic cave roofs slumped when their feeder halted abruptly. A variety of more or less tubular voids are associated with these closed depressions. Some are shallow, relatively featureless corridors locally split by as many as three subparallel slumps. Others are boundary ridge passages on one or both sides of a wide linear or sinuous depresssion. Nearby, caves

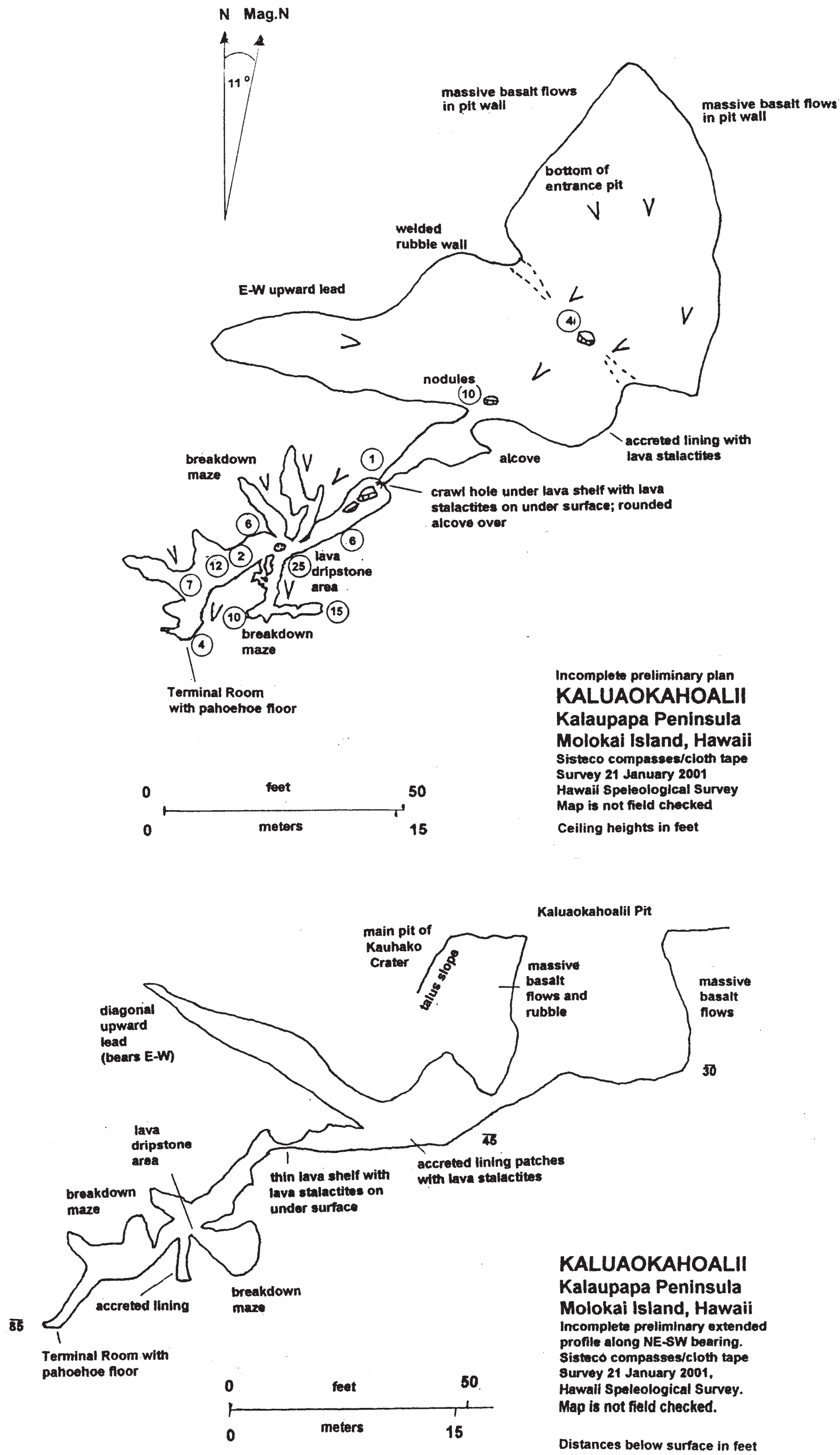

Figure 11. Plan and extended profile of Ka Lua o Kahoalii, Kalaupapa Peninsula, Molokai Island, Hawaii, commonly said to be the start of a lava tube extending from Kauhako Crater to the lighthouse at the tip of the peninsula.

Figure 12. Small lava upwelling at start of breakdown area, Ka Lua o Kahoalii, Kalaupapa Peninsula, Molokai, Island, Hawaii. Photo by the author.

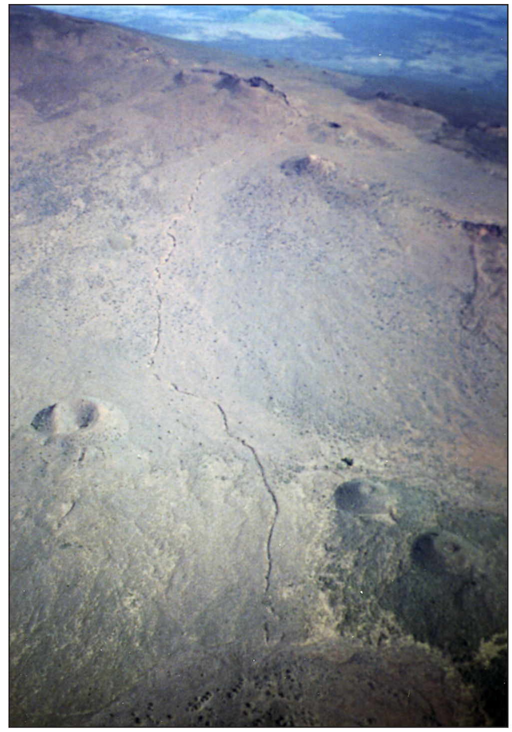

Figure 13. Full length of Poikahe Crater lava tube system, Hualalai Volcano, Hawaii. Poikahe Crater is just below top center. Extraterrestrial and submarine phenomena which are fully congruent with such surface features indicate the presence of lava tubes with a high degree of certainty. Photo by the author.

in sinuous hollow tumuli are essentially featureless but otherwise are much like those of conduit tubes. Cross-sections of donut-shaped boundary ridge caves of lava rises with depressed centers (Figure 14) are similar to those of conduit tubes, and complexes exist combining two or three of these forms. In areas with patent drained flow lobes, some individual cavities are interconnected by essentially featureless drain tubes. Individually, these short tubular segments can easily be accepted as lava tubes, but as a whole, the resulting cave complexes resemble giant ant nests rather than lava tube conduit caves (Figure 16).

At least one basaltic dike (Figure 17) drained and assumed the form of a lava tube cave (Figure 18) where it approached the face of a sea cliff (Socorro and Martin, 1981).

Redefinition of the term "lava tube"

From the above, it is easy to conclude that the term "lava tube" should be redefined in unmistakably specific terms. Ideally, both hollow and solid forms should be included, in terms of specific parameters which differentiate them

Figure 14. Tube-like circumferential boundary ridge passage, Lava Rise C-3 Cave, Kilauea Caldera, Hawaii. Photo by the author.

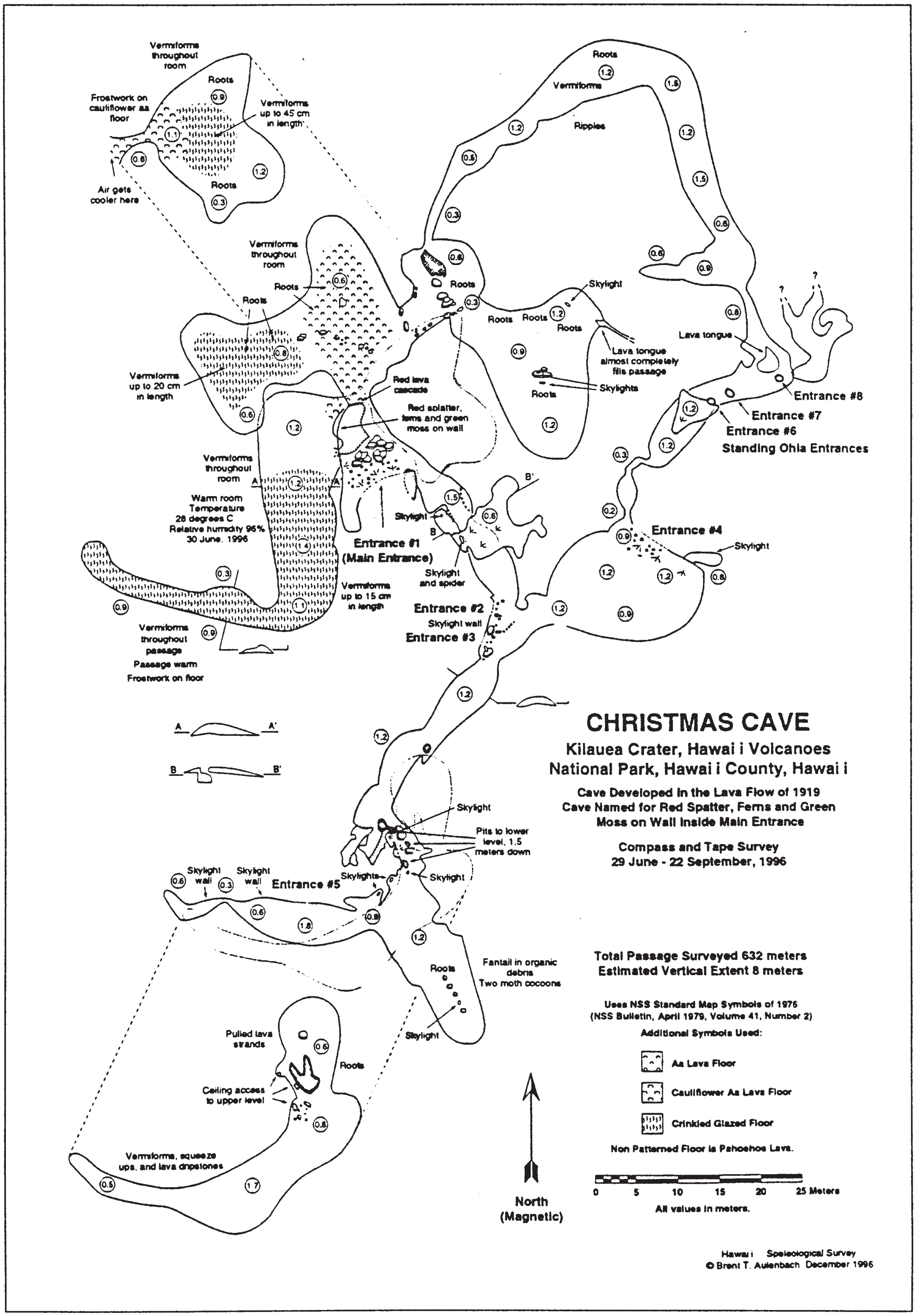

Figure 16. Plan of Christmas Cave, Kilauea Caldera, Hawaii: a nested complex of flow lobe cavities and short tubular connecting passages.

from all other volcanic features (e.g., aa cores, lava tongues, tumuli, sills, self-propagating crevices and related injection masses. But the ideal may not be achievable at the present state of knowledge and technology. However, recent discoveries and new concepts of flow field emplacement and drainage (e.g., Hon et al, 1994) offer a notable opportunity to shape a clearer definition of this elusive term.

In my opinion, the defining characteristics should be compatible with:

1) the common meanings of "tube" and "cave".
2) the presence of solid, gaseous, or liquid matter within them.
3) observations of all phases of their complex speleogenesis, e.g., crustal and subcrustal accretion and erosion.
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I propose that the Commission on Volcanic Caves of the IUS take the lead in developing such a redefinition, in collaboration with the American Geological Institute and other concerned agencies and organizations, for consideration at the 2005 International Congress of Speleology.

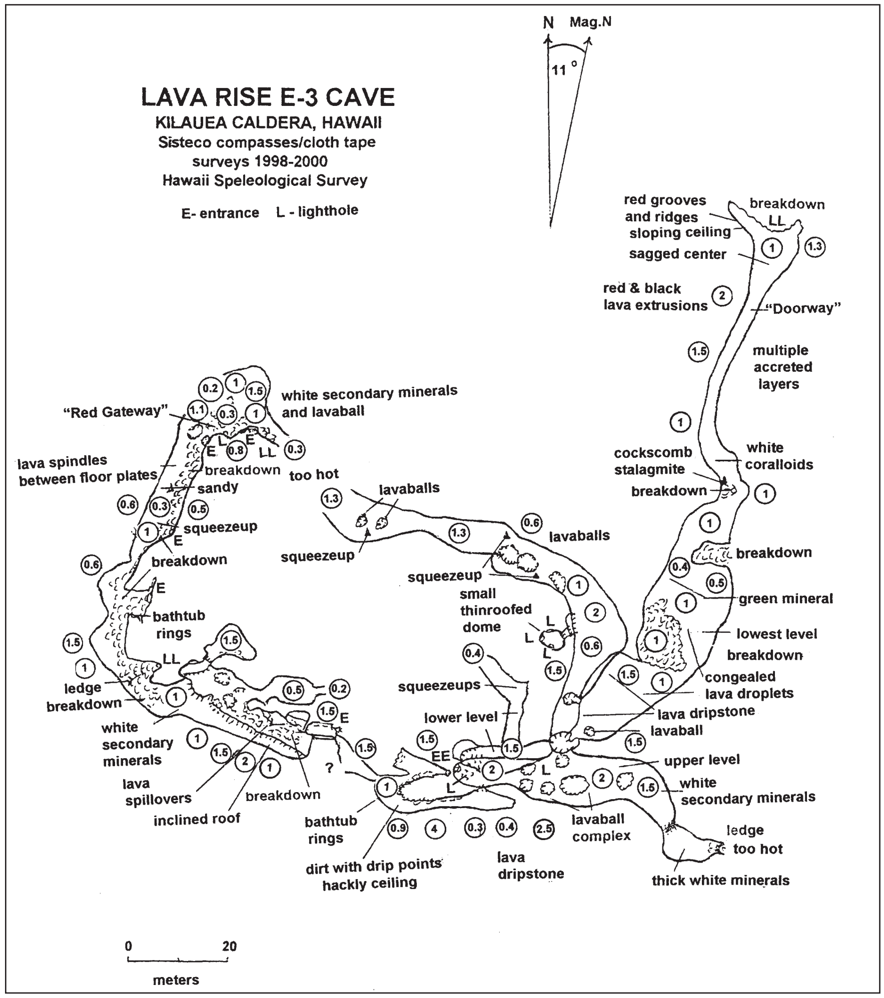

Figure 15. Plan of Lava Rise C-3 Cave, Kilauea Caldera, Hawaii. A typical cross section of the tubular circumferential passsge is depicted in Figure 14.

Figure 17. Dike exposed in ceiling of inner chamber formed in pyroclastics, Cueva de la Fajanita, La Palma Island, Canary Islands. This dike is hollow from a point a few meters behind the photographer to the sea cliff. Photo by the author.

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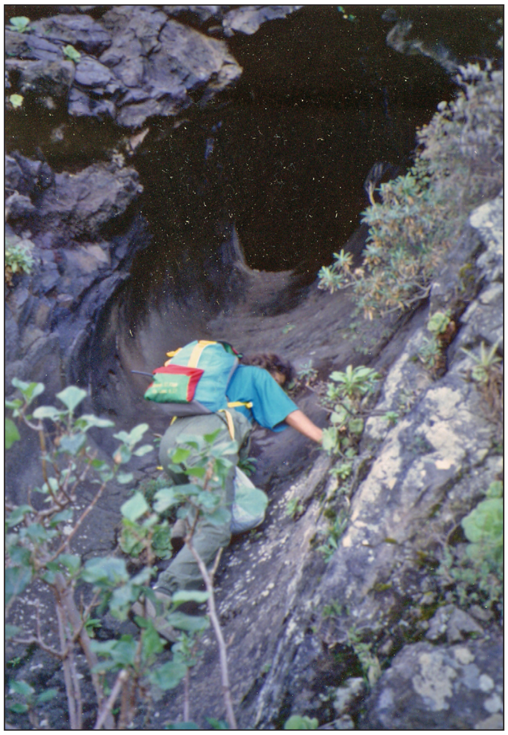

Figure 18. Ascending into the sea cliff entrance of the tubular hollow section of the dike of Cueva de la Fajanita, La Palma Island, Canary Islands. Photo by the author.

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