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SPELEOTHEMIC MINERALS DEPOSITED AS CONDENSATES FROM VAPORS, 1919 LAVA FLOW, KILAUEA CALDERA, HAWAII, USA

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Few publications acknowledge the existence of cave minerals deposited from fumes and/or steam. The 1919 "Postal Rift" lava flow in Kilauea Caldera contains about 200 caves. Included are lava tube caves, hollow tumulus caves, drained flow lobe caves and others. While a single body of magma is believed to underlie the entire caldera, significant differences in the fumes of different areas are readily detected by human senses, on and beneath the surface. A significant minority of its caves is at least intermittently hyperthermal, with varied patterns of steam and fume emissions and varied mineral deposition along hot cracks and in other locations on ceilings, walls, floors, and lava speleothems.

Working conditions include up to 100% relative humidity and temperatures up to 130 degrees F, but as a result of thermostratification, temperatures as high as about 175 degrees F can be measured in speleothemic areas. Sulfates, chlorides and (rarely) elemental sulfur are believed to be present. An initial project of mineral identification foundered with the termination of the position of Cave Specialist at Hawaii Volcanoes National Park. A new project is strongly indicated.

CLIMATE MODELING FOR TWO LAVA TUBE CAVES AT EL MALPAIS NATIONAL MONUMENT, NEW MEXICO, USA

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Reliable data concerning cave microclimate benefits those who manage caves for human visitation, protection, and the conservation and restoration of bat roosts. Both published and unpublished information about cave climates is limited, however. Mathematical models of cave climate are even more limited, and for lava tube caves, these appear to be totally lacking. Because they are simpler than many limestone caves (thus making the task of modelling tractable) we tested the use of lava tube caves as laboratories in which to do climate modeling.

We present the results of investigating temperature and humidity in two lava tube caves at El Malpais National Monument, New Mexico, USA. One cave was a single-entrance cave with an ice sheet, the other a tube with detectable airflow to/from cracks on the surface. In these two tubes, we collected 1.5 years of temperature and humidity data with Onsett Hobo™ dataloggers. Using the data, we investigated how temperature and humidity change with season and distance from the entrance, and we now propose mathematical models to predict future temperatures based on heat flow from the surface as well as advection.

Our models show a good fit to the equation

$$T(t) = a_1 + a_2\cos[(t2\pi)/365.24] + a_3\sin[(t2\pi)/365.24] + a_4\cos(t2\pi) + a_5\sin(t2\pi)$$

This implies that, at least in these lava tube caves, accurate prediction of temperature is possible.

PA'AUHAU CIVIL DEFENSE CAVE, MAUNA KEA VOLCANO, HAWAI'I: A LAVA TUNNEL ("PYRODUCT") MODIFIED BY WATER EROSION

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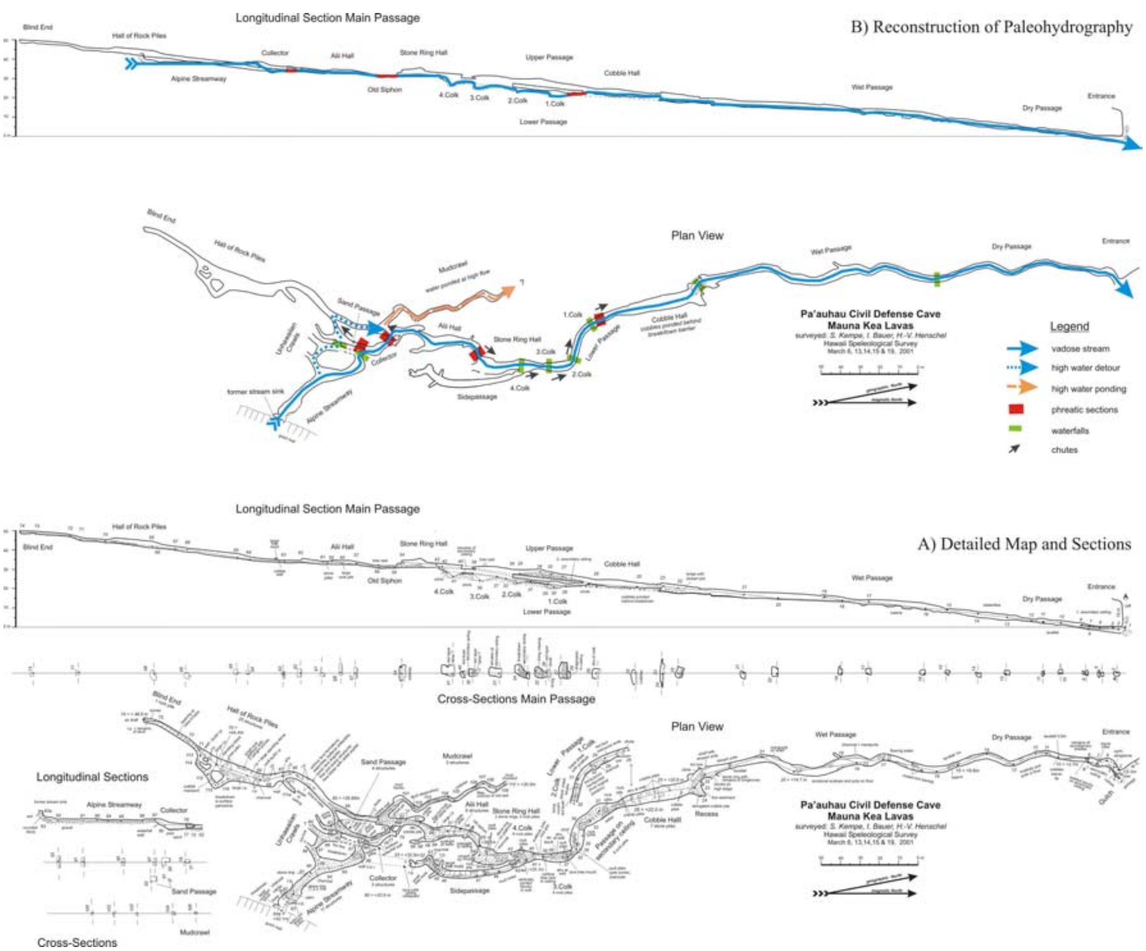
Pa'auhau Civil Defense Cave was surveyed and geologically inspected by the authors in 2001. It is located on the heavily eroded eastern flank of Mauna Kea volcano, in the Hamakua volcanics (200-250 to 65-70 ka). It is the largest lava tunnel ("pyroduct", "lava tube") known on this volcano. Typical morphologic elements of natural lava tunnels are present, including secondary ceilings, linings, base sheets, lava falls, and lava stalactites. The cave has only a moderate width and the cross section of the lava flowing in it did not exceed 1-2 m^2. The cave has a dendritic passage pattern and is only a section of a once longer system (Fig. bottom). The present entrance is situated at the downhill end of the cave. It looks out into a modern canyon (Kahawaili'ili'i Gulch). Upslope, the Alpine Stream Passage of the cave ends in breakdown at the wall of the same gulch. The Main Passage ends at a lava choke, and Mudcrawl and other side passages end in mud and sand chokes. The presence of casts of large trees shows that the cave lava transgressed a forested terrain. Plunge pools expose a diamict which contains large blocks in a fine-grained matrix with a red top layer underlying the cave lava. The Table lists some of the morphometric characteristics of the cave.

Table: Morphometric characteristics of the cave.

		Stations	Measurements m	Horizontal m
Main survey line		1 to 74	579.6	573.4
Side passages sum:			420.9	415.5
	Sum:		1000.5	988.9
End to end (horizontal)				502.6
Sinuosity main passage				1.14
Vertical		1 to 74	48.9	
Slope ($\tan^{-1}$ 48.93/573.3)				4.87°
Slope ($\tan^{-1}$ 48.93/502.62)				5.56°
Main passage/side passage ratio				1.37
Secondary ceiling ratio				0.11

Water of the gulch entered the cave upslope and traversed much but not all of the cave modifying it substantially (see Fig. top). It left polished walls and ceilings, large plunge pools, stream potholes, scallops, flutes, gravel, rounded blocks, sand and mud. At high water it partially ponded, flooding high elevation passages which then fed water back to the main gallery. It excavated four large plunge pools, cutting through the dense base sheet of the lava and exposing underlying strata. Polished ceilings show where the water sumped in several places. When in flood the speed of the water was enough to create potholes and to remove blocks of the lava from the cave's margins and grind them to rounded boulders and gravel. Even though dripwater presently collects in the cave and flows along some sections of the floor, no water has flowed out of the cave for a long time. The presence of charcoal shows that nearly all the cave's passages were visited by ancient Hawaiians. They left numerous piles of stones, cairns, and stone rings, and also placed stones on the walls. The purpose of this is unknown. The presence of caves eroded by flowing water in the lavas of Hawai'i offers a new view of deep-seated watercourses in volcanic edifices.



KUKA‘IAU CAVE, MAUNA KEA, HAWAI‘I: A WATER-ERODED CAVE (A NEW TYPE OF LAVA CAVE IN HAWAI’I)

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From 2000 to 2002, Kuka‘iau Cave (alias ThatCave/ThisCave) was explored, traversed from end to end for the first time, surveyed and inspected geologically. It is located on the heavily eroded eastern flank of Mauna Kea, Hawai‘i in the Hamakua volcanics (200-250 to 65-70 ka). Together with Pa‘auhau Civil Defense Cave (a natural lava tunnel) it is one of the first substantial caves described in detail in lavas of Mauna Kea volcano. Furthermore, we assert that it is the first cave known in Hawai‘i which owes its existence entirely to stream erosion.

Kuka‘iau Cave is ca. 1,000 m long. It is used by an episodic river that enters the cave by a series of waterfall pits. The resurgence of the stream is 108 m lower than its insurgence: thus the average slope is 9.8° (Fig. 1). 200 m before the exit the intermittent stream passes through a sump where it flows upward over a series of gravel chutes into a vadose passage which follows the dip of the strata (Fig. 2 a-d).

The cave is essentially erosional in origin. We concluded this from the geology of the strata exposed in the cave, from its morphology and from the lack of typical lava tunnel features (such as pahoehoe sheets of the primary roof, secondary ceilings, lava falls, glazing, etc.). At the upper entrance the cave is located in a thick series of ‘aa. The lower section was created by removing ‘aa and diamict layers, thus excluding the possibility that the cave developed from a precursor lava tunnel (“pyroduct”; “lava tube”). Also, in its phreatic sump section, the cave makes several right angle turns and moves upward through a series of pahoehoe sheets, unlike any lava tunnel. Furthermore, the major section of the upper cave has developed along a red paleosoil which forms a base layer. Allophane and halloysite (minerals produced by weathering) helped in sealing the primary porosity of this base layer causing a locally perched water table. Water moved along this base layer on a steep hydraulic gradient through the interstices in ‘aa and through small pahoehoe tubes. This exerted a high pressure on the porous diamict of the lower cave, causing its removal by erosion. These observations of water-eroded caves in lavas in Hawai‘i offer a new perspective on deep-seated water courses in volcanic edifices.

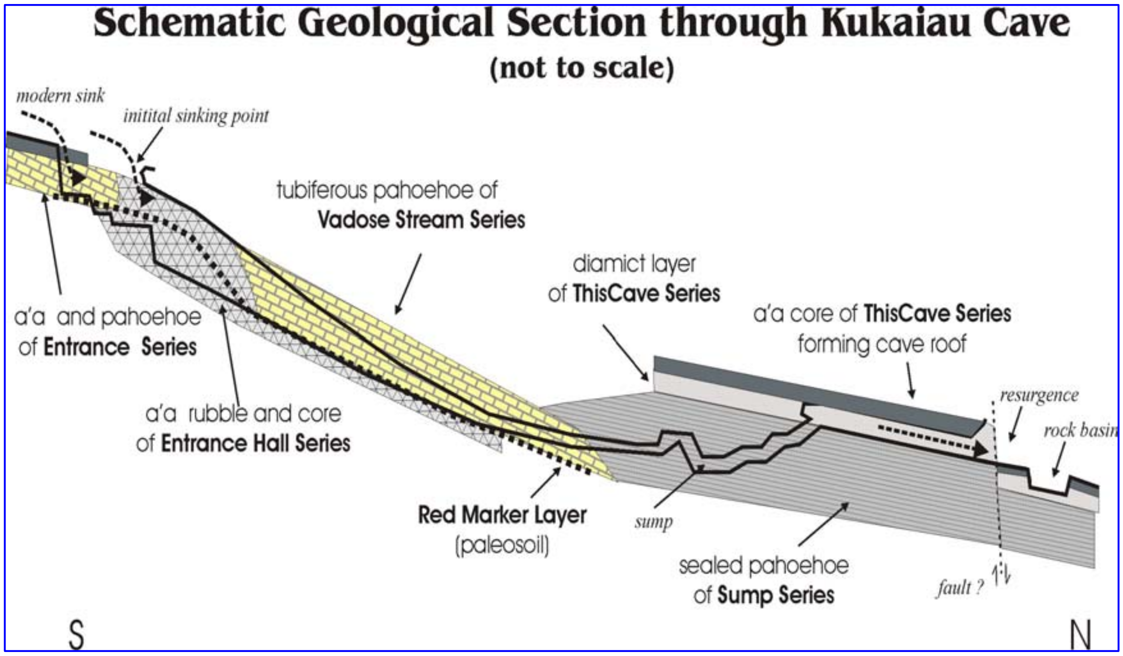

Fig. 1: Schematic geological section through Kuka'iau Cave, showing its complex course through a variety of different rock layers and illustrating the upward movement of water in the sump-section.

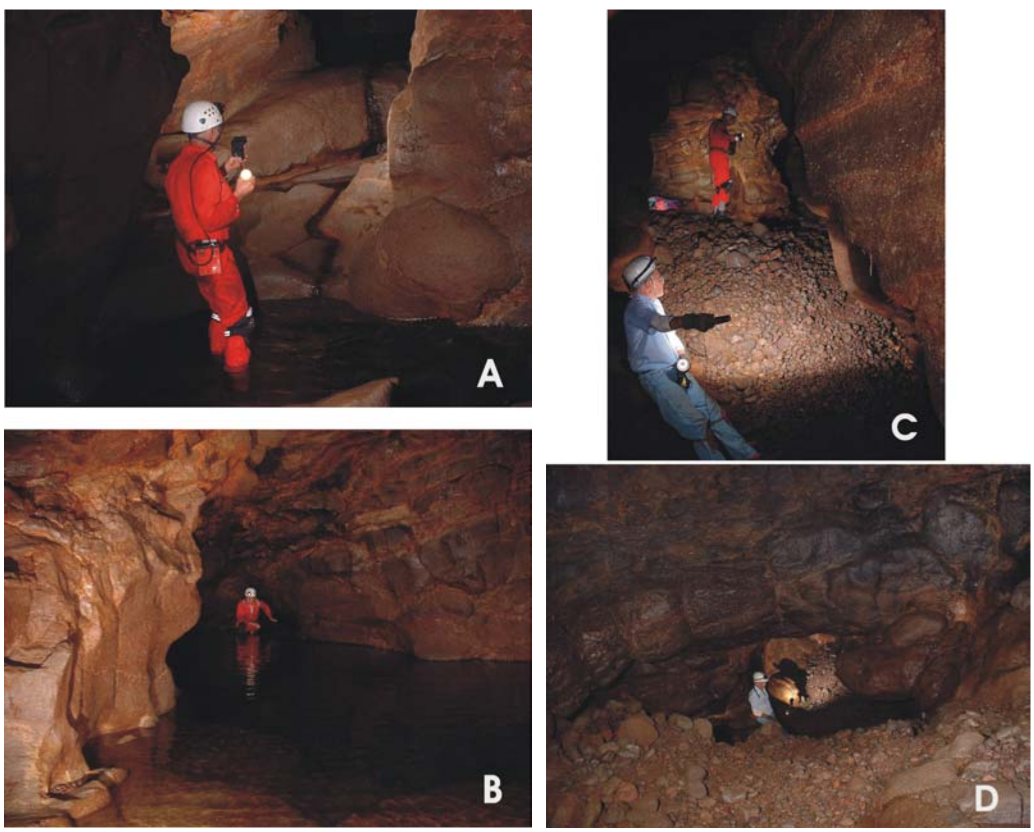

Fig 2: Sump Section: A) Natural rock dam maintaining water level in Echo Lake, a permanent lake even when the sump is empty; B) Echo Lake, which separates the upper and lower parts of the cave. It was first passed in June 2002; C) Chute above Echo Lake. Here, gravel is moved uphill when the cave floods; D) View down the last chute. When the cave floods, the water wells up from this point into the vadose lower section of the cave under a pressure of up to 6 bar.

FEASIBILITY OF PUBLIC ACCESS TO ÞRÍHNÚKAGÍGUR

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Þríhnúkagígur was fully surveyed in two field trips inSpring 1991. Public access to this tremendous volcanic bottle-shaped chimney subsequently has been proposed and discussed several times.

A tunnel to the bottom of the vault has been considered repeatedly. That proposal is not attractive. Although the vault is impressive from the bottom, the view basically is of bare country rock devoid of its original lava coating and formations, for tens of meters upward. This is not especially exciting, nor is standing on the pile of fallen rock at the bottom. Because of weathering of the uppermost part of the shaft and because of falling snow, ice and other debris, danger from rockfall and shatter exists within a radius of 10m from the center line. The possibility of additional rockfall from the overhanging sides of the shaft has not been investigated.

A spiral stairway down the shaft would damage notable lava formations in the narrow funnel at the top. It also would spoil the view of the impressive crater opening at the top of the cinder cone. For the vault to be enjoyed, a spiral ladder hanging from the top would have to be 65m long. Its construction would not be feasible, nor for most persons to descend and ascend it.

A few months ago, a new idea came to the author. At about -60 m, the shaft could be accessed through a 200 m tunnel. With reflection and study of our maps, the idea became even more attractive. At that level, a grid view balcony under the closed NE vent would be under an overhang of solid rock where the shaft widens. Thus it would be sheltered from falling rock and snow. Intact lava formations are impressive at this level, and would be in no danger of damage. The sight downward into the widening chamber is as if one were standing on the top of a 20-story building inside a mountain. Two such buildings would fit in this space, side by side. The openings of two tunnels about 4 x 4 m would occupy only about 1:1000 of the wall space. Between such tunnels, a balcony for lighting would do trivial damage to the walls. A light, stable chain fence around the opening at the top would suffice for protective work, thus making the awesome pit accessible and conserving it at the same time.

Whether or not this engineering project can really be done has not been decided, but preliminary work has begun. The author would welcome constructive input.

VOLCANIC AND PSEUDOKARSTIC SITES OF JEJU ISLAND (JEJU-DO), KOREA: POTENTIAL FEATURES FOR INCLUSION IN A NOMINATION FOR THE WORLD HERITAGE LIST

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Scientific research has been conducted on various features of Jeju Island, looking toward a nomination as a World Heritage Site. The Island contains a variety of volcanic landforms and more than 100 lava tube caves of geological and speleological significance. It essentially consists of one major shield volcano, Hallasan (Mt. Halla), with satellite cones around its flanks. Especially notable features include maar (Sangumburi), parasitic cones (Geomunoreum and Seongsan-Ilchubong), giant lava tubes (Bengdwi Cave, Manjang Cave, Gimnyeonsa Cave, Dangcheomul Cave and Susan Cave), an exposure of columnar jointing at Daepodong, a volcanic dome (Mt. Sanbang) and the Suwolbong tuff deposits. Especially notable are the lava tube caves, which show a complete flow system and display perfectly preserved internal structures despite their age of 0.2-0.3 Ma BP. Dangcheomul Cave contains calcareous speleothems of superlative beauty.

Four aspects are identified which demonstrate the congruence of specific features to criteria for World Heritage status:

1) The volcanic exposures of these features provide an accessible sequence of volcanogenic rocks formed in three different eruptive periods between 1 million and a few thousands years BP. The volcanic processes that made Jeju Island were quite different from those for adjacent volcanic terrain;

2) The listed features include a remarkable range of internationally important volcanic landforms that contain and provide significant information on the history of the Earth. The environmental conditions of the eruptions have created diverse volcanic landforms;

3) The largest and most spectacular lava tube caves are located in the western and north eastern parts. With a length of 7.416 km, Manjang Cave is one of the longest and most voluminous. Its single passage contains two (locally three) levels. Other, shorter caves (i.e., 4.481 km (Bengdwi Cave) are more complex in form. Susan Cave is a beautifully formed classical lava tube with 4.393 km in length;

4) Of great significance are the abundant carbonate speleothems seen in some low elevation lava tube caves. This phenomenon is very uncommon, and the spectacular caves in which it occurs on Jeju Island are generally acknowledged to be world’s leading examples. Dangcheomul Cave can be considered to be the world’s most beautiful lava tube cave containing calcareous speleothems.

CLOSED DEPRESSIONS ON PAHOEHOE LAVA FLOW FIELDS AND THEIR RELATIONSHIP WITH LAVA TUBE SYSTEMS

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Closed depressions have long been recognised as significant features of basaltic pahoehoe lava flows, but their origin has been greatly misinterpreted. Many depressions have been classified as collapse features, while some scientists deny the presence of collapse forms and regard all such features as lava rise pits. In their study of Icelandic pahoehoe lava flow fields the present authors recognise the presence of five different types of closed depressions, which they classify as: open skylights in the roofs of lava caves, conical depressions caused by surface collapse into underlying voids, lava rise pits, shallow sags from the draining of lava rises, shatter rings or collapsed tumuli.

This paper will describe examples of the different types of depressions from the Laki lava flow field (Skaftáreldahraun) and the Hallmundarhraun, and will discuss the role of lava tubes in their formation. It will be seen that an understanding of the forms of closed depressions assists interpretation of the style of emplacement of historic and ancient lava flow fields.