THE KEOKEO CAVE SYSTEM IN HAWAII

Peter Bosted[1], Tomislav Gracanin[2], Veda Hackell[2], Tim Scheffler[3], Stephan Kempe[4]
[1]*PO Box 6254, Ocean View, HI 96737 USA*, *bosted@jlab.org*
[2]*Houston, Texas, tnv@att.net*
[3]*Dept. of Anthropology, University of Hawai`i at Hilo, scheffle@hawaii.edu*
[4]*University of Technology Darmstadt, Schnittspahnstr. 9, D-64287 Darmstadt, Germany, kempe@geo.tu-darmstadt.de*

Abstract

The Keokeo lava tube system lies within a lava flow that apparently originated in the Pu‘u o Keokeo vent on the Southwest Rift zone of Mauna Loa, on the Big Island of Hawaii. The lava flowed 1,500–3,000 years ago from the source near 2,200 m elevation all the way to the ocean, a distance of some 28 km. A large lava tube system has been discovered spanning most of the extent of the flow. The cave system is often braided into parallel branches, as well as being formed on up to four vertical layers. The system is sometimes segmented by ceiling collapse or lava sumps. As of this writing, 40.6 km of passage has been surveyed in segments ranging from 10 m to 4 km long. The deepest passages are readily distinguished because the lava downcut through a thick layer of ‘a‘ā, which is seen when the wall linings peel away. In places, there is evidence of downcutting through two ‘a‘ā layers. There are many white and orange crusts, frostwork, and coatings throughout the system, which could be the subject of a mineralogical investigation. Microbial mats are fairly common as well. Ohi‘a tree roots support a variety of cave-adapted species, including crickets, spiders, isopods, planthoppers, and moths. Two as-yet-undescribed species were recently found in the system. Other interesting resources in the system include bird and bat skeletons, and occasional native Hawaiian water collection and shelter sites.

1. Introduction

The Big Island in the U.S. state of Hawai‘i is home to the majority of major lava tube (pyroduct) systems (e.g., Kempe 2012) in the world. The second longest system in the world, the Kipuka Kanohina system, originates in the SW rift zone of Mauna Loa, within the Kahuku Unit of Hawaii Volcanoes National Park (HAVO), and passes under the Hawaiian Ocean View Estates (HOVE) and Kula Kai subdivisions, reaching almost to the ocean. Recently, another major system has been identified, also originating in the SW rift zone. The passages of the system are shown as the red lines in Figure 1. The system is formed in the Qk2 Mauna Loa flow which extends from the presumed source at Pu‘u o Keokeo (altitude of 2,200 m), all the way down to the ocean, some 28 km distant. The estimated age of the flow is 1,500 to 3,000 aBP (Sherrod et al. 2007).

2. Exploration History

Some of the lava tubes in the system were used by the original Polynesian settlers, arriving in the islands as long as 1000 years ago (cf. Wilmshurst et al. 2011). There is no evidence of such ancient occupation in the current survey.

In most of the 1800’s and 1900’s, the entire flow was on the property of the very large Kahuku Ranch. Ranch-hands and farm children sometimes visited the caves, although there is no written record of their underground activities. Above ground, initials and a date carved into the rock, along with the evidence of two empty bottles, tally with an account of George Jackson counting being present in 1868 near the source of the flow that year, at an elevation of about 1800 m. The upper portion of the Keokeo flow became part of Hawaii Volcanoes National Park (HAVO) in 2004. The lower portion was sold to private developers (Nani Kahuku Aina) in 2006, and the small parcel between these was acquired by The Nature Conservancy in 2015.

Systematic exploration of the Keokeo system began in 2011. Some entrances were found from satellite and aerial photos. The great majority of them were found on surface hikes, or by entering one entrance and coming out another one. To date, over 500 entrances have been identified. Of these, about two thirds have been explored and surveyed. For the entrances within HAVO, an initial reconnaissance of all of the passages accessible from a given entrance was made with a qualified archaeologist in order to determine if sensitive cultural resources were present.

To date, there have been about 250 field trips to the flow, of which roughly one fifth were to locate entrances, one fifth for archaeological reconnaissance, and the remainder for detailed mapping and photography. About 40.6 km of passage has been mapped in segments ranging from less than 10 m to over 4 km in length. The segments are usually separated by trenches formed by the collapse of the original tube. In other cases, especially where the gradient is low, the lava completely filled the passages when it cooled, making for lava sumps.

3. Geology

The geology of one of the longest segments of the system, Upper Kahuenaha Nui, was studied by Ingo Bauer as part of his Master’s thesis (Bauer 2011). The cave survey of this segment yielded a total length of 1,850 m, a total vertical extent of 55 m and an average slope of 5.7°. The cave features a main trunk that is up to 18 m wide and 11 m high. Its floor is in part formed by terminal ‘a‘ā. Above this trunk passage, there are numerous small to very small interconnected pahoehoe-floored passages. It was possible to study the cave formation process at the two entrance collapses (pukas in Hawaiian). The trunk passage appears to be formed by eroding an underlying ‘a‘ā rubble layer.

In places even the underlying ‘a‘ā core layer has been cut into. Above, a stack of seven superimposed pahoehoe flows with small meandering passages occurs, forming the primary roof of the cave. The lava flowing in this stack of sheets managed to combine into one flow, eroding the main trunk underneath. After cave formation first an ‘a‘ā flow and then a thin pahoehoe flow transgressed the area. The cave’s roof partly collapsed, not only exposing the transgressed ‘a‘ā, but also forming the two entrance pukas. This cave-forming mechanism is fundamentally different from the standard lava tube formation modes “inflation” and the “crusting-over of channels” (e.g. Kempe 2012).

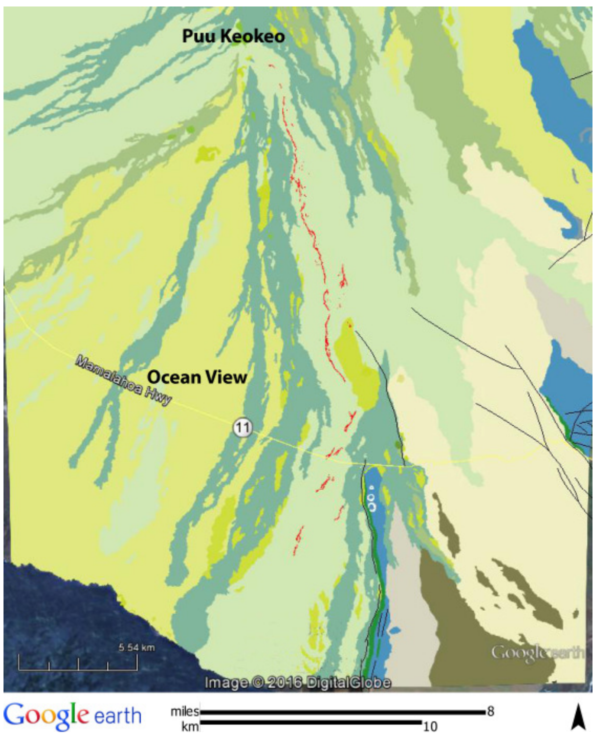

Figure 1. Geologic overview of the Keokeo flow on the south slope of Mauna Loa. The red lines show the approximate location of explored passages. The distance from the top to bottom of the figure is about 30 km, and north is up. The Keokeo flow is colored light green. Older flows are yellow and green, while modern flows are colored blue. The thin black lines indicte faults. Highway 11 crosses the figure from left to right just below the middle.

While detailed geologic studies have not been done in other segments of the system, the mode of down-cutting into an ‘a‘ā layer appears to persist throughout the main, lower level trunk passages. This is most often revealed by wall coatings, typically 0.2 to 1 m thick, that have peeled away, generally falling towards the center of the passage, and leaving a pile of exposed ‘a‘ā rubble behind. Often the ‘a‘ārubble is stained orange or red, due to formation of hematite by oxidation of the ferrous iron contained in the basaltic glassby. One of the more dramatic examples is shown in Figure 2.

Figure 2. Illustration of wall-lining peeling away to reveal a thick layer of red ‘a‘ā rubble behind. Bob South is the model. Photo by Peter and Ann Bosted.

Throughout the system, the larger entrances are often the best place to study the stratigraphy. Where there are clean ceiling collapses, it is sometimes possible to count the number of pahoehoe sheets and ‘a‘ā layers.

Figure 3. Stephan Kempe (in red) and Tim Scheffler above one of the largest entrance to the system. Photo by Peter and Ann Bosted.

The cave passages often contain white, orange, and sometimes pink or green minerals. These most commonly occur as crusts or coatings on the ceiling, walls, and sometimes on the floor. There is a noticeable correlation of mineral coatings with high wind velocities near major entrances and constrictions where the Venturi effect makes for strong air flow. The relatively dry climate of the region likely stops the minerals from being dissolved, because they are much more common here than in the wet areas of Hawai‘i. Based on sampling in the nearby Kanohina system, most of the white minerals are probably calcite, gypsum or opal, although epsomite and mirabilite can be found. A typical medium-size passage with white, orange, and red coatings, and an ‘a‘ā floor over smooth linings, is shown in Fig. 4. In some areas, the minerals are in a frostwork-like morphology, as illustrated in Figure 5.

Figure 4. Ann Bosted in typical medium-sized passage with many mineral coatings. Photo by Peter and Ann Bosted.

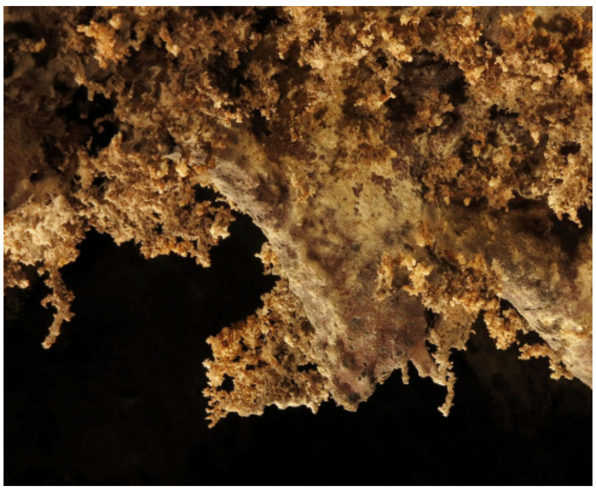

Figure 5. Delicate frostwork minerals on ceiling lava drips. Photo by Peter and Ann Bosted.

4. Biology

The Keokeo flow covers a large elevation range (from sea level to about 2,200 m), but the endemic Hawaiian Ohi‘a tree can be found throughout almost the entire range. This tree is very important to the cave biology, because it is adapted to putting its roots down into lava tubes, often going right through to the floor below. Some of the roots are well over 10 m long and bundles up to 30 cm in diameter occur. An example of thick forest of Ohi‘a tree roots is shown in Figure 6.

The tree roots are an important source of nutrition and water for a host of cave-adapted species. Including crickets, millipedes, spiders, isopods, moths, and planthoppers. The very rare thread-legged doodle bug was observed in one location, as well as two as-yet-unidentified species.

Another important source of the cave biology is the large number of goats that use the caves as night-time shelters.

Figure 6. A thick forest of ohi'a tree roots. Photo by Peter and Ann Bosted.

They supply nutrition by their excrements and the degradation of their dead bodies. The goats are generally found at lower elevations. At higher elevations, the most common mammal bones are Mouflon (a form of wild sheep), cattle, occasional horses, rats, and mongooses. A typical passage with an ungulate skull is shown in Fig. 7.

Figure 7. Typical passage with mouflon skull in the foreground. Photo by Peter and Ann Bosted.

Well-preserved fossil bird bones are also sometimes found, especially in deep passages far from entrances, where they are protected from weathering. Some of these may be from now-extinct species. A systematic study has not been done yet, however. One of the best-preserved examples is shown in Figure 8. This is most likely the head of one of the petrel varieties. In one remote cave location, over a dozen Hawaiian hoary bat skeletons were found very recently.

Microbial mats are found throughout the system. None have been studied as of this writing.

Figure 8. Fossil bird head. Photo by Peter and Ann Bosted.

Finally, the deep entrances provide a haven for certain rare and endangered plants. The moister climate is a boon to the Hapuʻu (tree fern). Large Koa trees can also be found in deep pukas where the steep sides have excluded cattle, which would otherwise eat and trample the young trees. An example of abundant native vegetation in a skylight puka is shown in Figure 9.

Figure 9. An overhanging skylight with native vegetation. Photo by Peter and Ann Bosted.

5. Prospects

With about 200 or more entrances to investigate, clearly more work is needed just to finish the exploration, mapping, and photo-documentation of the Keokeo system. Meanwhile, there are many opportunities for detailed studies of the geology, biology (both macro and micro), extinct birds, and archeology. Combined with refined dating techniques such as paleo-magnetic measurements, it may be possible to determine how many different flow episodes were involved in forming the Keokeo System, and over what time period. Potential investigators would need to obtain a permit from the National Park Service or other land owners.

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