AN OVERVIEW OF SIGNIFICANT CAVE-CONTAINING LAVA FLOWS NORTH OF KONA, HAWAI`I

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Abstract

Lava flows in the northwestern part of the island of Hawai`i cover an area of roughly 590 square km and contain nearly 1,000 lava caves. The area is bounded by the town of Kona on the south, the Pacific Ocean on the west, the boundary between Mauna Loa and Mauna Kea flows on the north, and the western flank of Hualalai, a shield volcano above Kona (summit elevation 2521 meters) on the east.

As of late 2015, over 1,500 entrances to 1,049 lava caves containing 208.5 km of surveyed passages have been documented in fifty Hualalai and Mauna Loa flows in this area. The Hualalai flows contain 946 caves with 168.3 km of surveyed passage. The caves are found at all elevations on Hualalai and cave temperatures range from 30° C on the Pacific coast to 20° C on the upper slopes of Hualalai. The Mauna Loa flows contain 103 known caves at elevations from 70 meters above sea level to 690 meters asl. Of these, 55 have been surveyed with a total surveyed length of 40.2 km.

Of these caves, 78.5 percent of the total number and 87.7 percent of surveyed passages are found in only twelve flows: nine in western Hualalai flows and the other three in Mauna Loa flows. The Hualalai flows contain some of the world's longest and most vertically extensive lava caves. The lava caves in these flows range in age from just over 200 years to up to 30,000 years in age and vary greatly in pattern; from simple linear conduits to challenging multi-level braided and branching complexes.

Some, but not all of the major cave complexes that have been documented in this area include:

- the 27.4 km Hualalai Ranch cave complex with 452 meters of vertical extent
- the 19.7 km Delissea Cave System with 661 meters of vertical extent, the second most vertically extensive cave in Hawai`i
- the 10.8 km Hu`ehu`e (Manini`owali) cave in the historic 1801 flow field with 498 meters of vertical extent
- the 10.7 km Lama Lua-Ka`upulehu cave complex extending over a linear distance of 5.4 km and with a vertical extent of 370 meters
- Um`i Manu, extending for a linear distance of 3.4 km with a relief of 570 meters, the third most vertically extensive cave on Hawai`i.
- Manu Nui, a high gradient cave on the upper slope of Hualalai with a surveyed length of 3.7 km and a vertical extent of 352 meters
- The Pueo-Two Owl-Aluminum Ladder cave complex with 15 km of braided passages

Introduction

Over 1,000 lava caves have been found and documented in a 590 square km area on the northwestern side of the island of Hawai`i (Figure 1).

Figure 1. Study Area Showing Major Caves

This area is bounded by the town of Kailua-Kona on the south and the Waikoloa/WaikoloaVillage vicinity 40 km to the north. A majority of these caves are found in flows from Hualalai, a shield volcano reaching an elevation 2521 m (8271 feet) and covering an area of 751 km^2 (290 mi^2).

The remainder of the caves are found in a variety of Mauna Loa flows.

Acknowledgements

The works described in this paper has been carried out on lava flows in a variety of ownership and management settings. This work would have not been possible without the receipt of permits by State and Federal agencies and the granting of permission by private landowners and leaseholders.

For example, work on the Kiholo Flow was carried out under permits granted by the Hawai`i Division of Forestry and Wildlife (DOFAW) and the Hawai`i State Parks Division. Work on the Old Kiholo Road flow, the Mauka Pu`u Wa`awa`a flow, the Umi`i Manu Flow, and the Puu Anahulu flow was done under a series of research permits issued by both DOFAW and the Hawai`i Experimental Tropical Forest of the U.S. Forest Service. Work in the Ka`upulehu ahupua`a (the Hualalai Ranch and West Ka`upulehu flows) was done with permission of the Hualalai Resort and on the South Kohala flow with permission granted by the Waikoloa Village Association and private landowners.

Significant Flow Fields Containing Lava Caves in NW Hawai`i

The lava caves found in NW Hawai`i Island are among the longest and most vertically extensive on earth with five of these caves having a vertical extent of over 300 meters and 34 of them having surveyed lengths of greater than one km. Seventy nine percent of the caves and 86 percent of the surveyed length are in caves found in only 12 of the 38 Hualalai flows and 12 Mauna Loa flows that have been visited. In the remainder of this paper, these flows and their most significant caves will be briefly described. Flow designations and age ranges are those used on the U.S. Geological Survey Geologic Map of the Island of Hawai'i (Wolfe and Morris, 1996). In addition, informal names for the flows are provided in italics. Flow descriptions are provided roughly from south to north.

1. Flow 9313, age group Qh1y (3.0-5.0 ka) *Airport South flow*

Located a few km south of the Kona International airport, the major cave in this flow is a substantial unitary cave (Under the Wall Cave) that extends for a linear distance of 2.5 km and has a vertical range of 125 meters. The upper part of the cave consists of a 10 meter wide and 6 meter high tunnel containing a variety of man-made features including walls, ramps, and platforms. A description and map of the cave are provided in Medville (2002).

2. Flow 9390, age group Qh2 (1.5-3.0 ka) *Airport flow*

This flow, just to the east of the Kona International airport, extends mauka for 7.5 km and contains numerous caves containing cultural materials such as internal walls, platforms, stepping stone trails and ahus. The principal caves in the flow can be found in a line extending from the airport mauka for 5 km and contain 4.4 km of passages.

3. Flow 9410, age group Qh5 (0 to 200 years bp) *1801 flow*

The historic1801 Hu`ehu`e pahoehoe flow field crosses Rt. 19 2.7 km north of the Kona airport. This flow field contains two adjacent flows; the primarily pahoehoe Manini`owali flow and just to the north, the somewhat older channel fed Puhi-a-Pele flow.

Although the most visible cave in this flow is the one having a 5 meter diameter entrance on the mauka side of Rt. 19, 3.5 km north of the Kona International Airport (Puhi-a-Pele flow episode), the major cave is in the Manini`owali flow. This cave, informally called the Hu`ehu`e Cave (also labeled Manini`owali cave in Kauahikaua et. al. 2002), is essentially a single large conduit that extends over a linear distance of 6.17 km and has a vertical extent of 495 meters. Passage dimensions are generally in the range of 5-6 meters in width and 4-5 meters in height. The cave and its geology are documented in Oberwinder (1996), Medville and Medville (1997), and Kempe and Oberwinder (1997). The history of the emplacement of this flow is described in Kauahikaua et. al. (2002).

4. Flow 9395, age group Qh1y (3.0-5.0 ka) *Hualalai Ranch flow*

The source of this 36 square km flow, located 14 km north of Kailua-Kona, is Pu`u Alauawa at 660 meters asl. The flow contains a number of lava caves, the largest of which is the Hualalai Ranch Cave complex, a system that contains over 24 km of passages, the longest surveyed cave in NW Hawai`i (Figure 2).

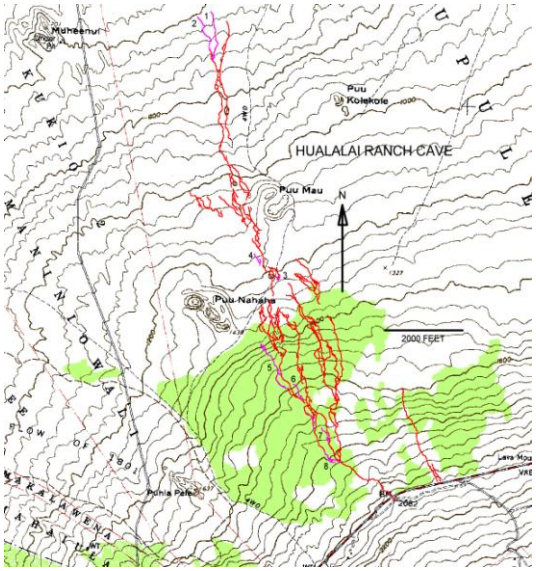

Figure 2: Hualalai Ranch Cave in Flow 9395 (Hualalai Ranch flow)

The cave is located just north of the NW rift zone of Hualalai with passages branching out in a distributary pattern. From its upper (mauka) end, a single passage can be followed makai (toward the ocean) for over 450 vertical meters, branching into a multi-level complex of parallel passages. At its mid-section, the cave contains numerous parallel passages up to 20 meters beneath the flow and extending laterally for 600 meters across the flow. The cave has a linear extent of over 4 km and is described in Rosenfeld (2001) and Davis (2003).

5. Flow 4822, age group Qh2 (1.5-3.0 ka) *West Ka`upulehu flow*

Adjacent to the historic (1800-1801) Ka`upulehu a`a flow and on its western margin, this pahoehoe flow contains another complex of large caves. Although 20.0 km of passages have been surveyed in this flow, half of the total (10.5 km.) is found in two long, aligned caves extending over a linear distance of 5.5 km.

The upper of the caves, Lama Lua, is described in Medville and Davis (2007). The cave has 5.5 km. of passage with the highest entrance being a collapse pit, 10 meters in diameter and 8 meters deep leading to a 15 meter wide and 10 meter high passage nearly 20 meters beneath the surface. This passage can be followed down the flow for nearly 3 km to lower entrances (Figure 3).

Figure 3: Passage in Lama Lua
Photo credit: Nevin Davis

A parallel passage 700 meters below the Lama Lua entrance extends to the ENE for over 2 km before ending at a lava seal beneath the adjacent historic Ka`upulehu a`a flow. The surveyed distance to this point from the Lama Lua entrance is 2.65 km., entirely in darkness. The two parallel passages in Lama Lua are 550-600 meters apart, comparable to the lateral extent of the Hualalai Ranch complex. In addition to its length and depth, the cave is noteworthy for the presence of an olive-green copper-vanadium-silicate mineral of unknown crystal structure. This mineral is in the form of a thin, uniform coating on floor breakdown and along cracks on passage walls. The mineral and the analysis of its composition is described in White (2010).

The lower of the two caves; Ka`upulehu Cave, has 5 km. of surveyed passages, extending over a linear distance of 2.2 km. and is a continuation of the Lama Lua Cave. This cave consists of a unitary passage with occasional braids. It ends at a lava seal 200 meters above Rt. 19 over a linear distance of 2.2 km. Lama Lua and the Ka`upulehu Cave are separated by two shatter rings each of which is about 60 meters in diameter and are 275 meters apart. The rings are a result of filling of the cave passage beneath and a breakout to the surface with subsequent draining of lava back into the cave as described

in Kauahikaua et. al. (1998). However, the lower of the rings contains a short cave with 1 meter high passage that lies beneath the perimeter of the ring, forming a single loop.

6. Flow 9334, age group Qh1y (3.0-5.0 ka) *Kiholo flow*

This flow crosses the coastal highway (Route 19) at the Kiholo Bay scenic viewpoint at mile post 82. The flow contains over 215 caves from sea level to its mauka end at an elevation of 480 meters asl, a distance of 7.2 km. Unlike the flows described above, this flow does not contain a single massive conduit but rather numerous shallow caves, 3 to 5 meters beneath the surface, that parallel each other with no apparent overall pattern. Seventeen of the caves in this flow are over 300 meters in length with the longest being 1270 meters in length. The Kiholo Bay State Park Reserve occupies the distal part of the flow, on the makai side of Rt. 19. Many caves in this part of the flow contain significant quantities of cultural materials; e.g., constructed walls and modified entrance areas.

7. Flow 4698, age group Qh1y (3.0-5.0 ka) *Old Kiholo Road flow*

In the vicinity of Pu`u Wa`awa`a and at an elevation of 500 meters asl, this flow extends for nearly 9 km. toward the ocean. The caves in this flow are shallow: only 3-5 meters beneath the surface and contain numerous small entrances. These caves however, are highly braided and complex, perhaps indicating lava flowing in multiple diverging and recombining lobes before the molten cores of these lobes were evacuated with resulting braided caves remaining. The largest of the caves in this flow, Pueo Cave, contains over 6.5 km. of passages in an area less than 0.2 km^2 (Figure 4).

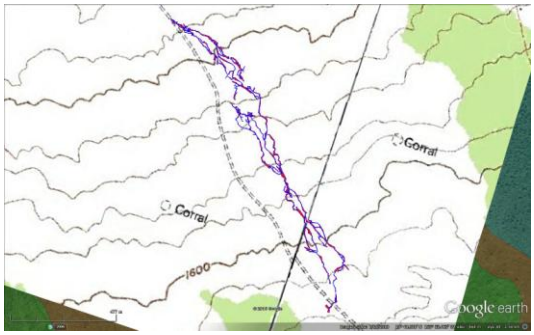

Figure 4: Pueo Cave in Flow 4698 (Old Kiholo Road flow)

The cave contains over 40 loops and is one of the most complex of the Hualalai caves. Pueo Cave is described in Medville (2008). A similar cave (Two Owl Cave) is 150 meters below Pueo Cave but separated from it by a lava seal. It contains over 5 km of similarly braided passage. Aluminum Ladder Cave, 500 meters makai of Two Owl Cave, has the same pattern and has 3.5 km of passage.

8. Flow 5477, age group Qh1y (3.0-5.0 ka) *Umi`i Manu flow*

This small flow contains a single cave extending for nearly the entire length of the flow. The cave, Umi`i Manu, literally Bird Trap, is named after the numerous skeletal remains of the extinct Hawaiian flightless goose (Branta rhuax), collected in this cave by ornithologists from the University of Hawai`i and the Smithsonian Institution. The upper end of the cave is at an elevation of 1890 meters and is only 300 meters below the source vent for the flow. The cave extends for a linear distance of nearly 3.4 km and has a vertical extent of 570 meters, the third most vertically extensive lava cave known, after Kazumura Cave and, as noted below, the Delissea System. Umi`i Manu consists of a single large conduit, generally 5 meters wide and high and follows the steepest gradient of the flow for its entire length. In addition to the fossil goose bones, the cave contains the skeletal remains of other birds, including rails, petrels, and nenes. The cave is a good example of a high gradient conduit with very little meandering or braiding of passages. An outline map and summary are provided in Medville (2003).

9. Flow 4889, age group Qh2 (1.5-3.0 ka) *Mauka Pu`u Wa`awa`a flow*

With over 225 documented caves containing over 40 km of surveyed passages in an area of only 8 sq. km., this flow contains perhaps the greatest concentration of lava caves on Hawai`i. Located above the Pu`u Wa`awa`a Trachyte cone and ranging in elevation from 900 to 1600 meters asl, the area contains numerous entrances leading to a complex of linear and braided caves extending laterally for 1.6 km. The principal documented cave to date is the Delissea Cave System containing nearly 20 km of passages in a large distributary pattern extending over 661 meters in vertical range, the second most vertically extensive lava cave on Earth. Other major caves include Upper Owl Cave with 3.1 km of passage and the Henahena/Bee Flat cave

complex with 2.3 km of surveyed passage. Several of these caves contain numerous fossil bird bones including the extinct Hawaiian Goose (Branta rhuax). Ongoing studies in these caves involves documenting their content; e.g., bird bones, roots, and native and invasive flora in entrances as well as recording entrance locations and conducting surveys.

10. Flow 4627, age group Qk1y (3.0-50. ka) *Puu Anahulu flow*

One of the three major Mauna Loa flows in the area, this flow extends from the Mamalahoa highway (Rt. 190) makai nearly to Rt. 19 along the coast, a distance of nearly 9 km with a vertical range of almost 600 meters. The flow is bounded by the Pu`u Pohaku Road on the east and the historic 1859 flow on the west. The flow contains a series of aligned large volume caves, seven of which are over a km. in length. The longest of these is called the West Hawai`i Landfill System and contains over 4.2 km of braided passages up to 8 meters in width and height. The distal end of this cave extends for nearly a half kilometer beneath the adjacent historic 1859 flow before ending in rockfall.

11. Flow 9327, age group Qk7 (11-30 ka) *Paniolo flow*

This is the oldest major cave-containing flow and is also a Mauna Loa flow. Extending from sea level to an elevation of 100 meters asl over a linear distance of 3.7 km, the flow contains several large volume lava caves, the most well known of which is the historic Paniolo Cave. The cave also contains a massive stone wall at one of its entrances. The flow has a low gradient with a smooth surface. Other caves in this flow also contain cultural materials such as rock rings and ahus constructed at entrances. The caves in this flow are only 3-5 meters below the local surface and tend to end in either rockfall or in infilling with unoxidized black lava from the adjacent historic 1859 flow.

12. Flow 4528, age group Qk2 (1.5-3.0 ka) *South Kohala flow*

The northernmost of the flows containing substantial caves in NW Hawai`i is also a Mauna Loa flow, located in the South Kohala District. Extending for 540 vertical meters over a linear distance of 10.5 km., this flow contains over 16 km of passages in a linear series of eight large volume caves (Figure 5).

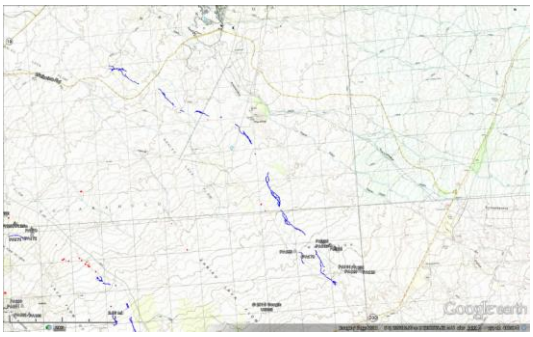

Figure 5: Lava Caves in Mauna Loa Flow 4528 (South Kohala flow)

Several of these caves contain deposits of a fine volcanic ash/mud mixture on the passage floors (Figure 6).

Figure 6: Passage in Pu`u Hinai Dust Cave
Photo credit: Ted Lappin

At its mauka end, the flow and 5 meter diameter passage in its highest cave are terminated by a`a fill from a younger flow, indicating that both the flow and its caves could continue mauka, were it not for the intrusion. Makai, the flow and its lowest elevation cave also end beneath a younger flow.

Summary

A substantial amount of work has been carried out in documenting the lava caves of NW

Hawai`i over the past 25 years. We observe that although there are some variations in the physical nature of caves within a flow, more substantial differences in the lava caves are observed to exist when the caves are compared between flows. Several flows contain single or a linear series of large diameter unitary caves; e.g., flow 9319 (Under the Wall Cave), flow 9410 (the Hu`ehu`e Cave) and flow 4528 in South Kohala. Others contain distributary networks; e.g., flow 9395 (Hualalai Ranch System), 4822 (Lama Lua), and flow 4889 (Delissea Cave System) or multiple lines of parallel caves with no obvious single conduit; e.g., flow 9334 above Kiholo Bay. Yet other flows contain complex braided caves at a single horizon; e.g., flow 4698 (Pueo Cave, Two Owl Cave, Aluminum Ladder Cave).

Although efforts have been made to investigate each flow in order to document every significant entrance and lava cave, much work remains to be done. Many entrances can be seen on aerial imagery, both in the flows discussed above and in other, as yet unvisited flows and it is expected that both the number and variety of lava caves in NW Hawai`i will continue to increase.

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