Principal Pyroduct Processes

by

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Abstract

The exploration of lava caves has made tremendous progress in the last thirty years, not the least fueled by the biannual meetings of the Commission on Volcanic Caves. Lava caves are certainly the third, if not the second, most important cave type by number and total length on Earth (after caves in carbonate rocks and likely before caves in sulfate rocks). Among the many lava caves, or more generally formulated, caves in volcanic rocks, we find different types, secondary or primary in origin. Secondary caves occur along sea shores, along the banks of rivers, along tectonic fissures or in between talus. These caves can be quite large. In Hawai‘i we found a 1 km long and 100 m deep cave cut into layers of lava and paleosol strata by a creek, similar in appearance to an alpine epigenic carbonate rock cave including numerous water falls, plunge pools, scallops, a siphon and an impressive phreatic loop (Kukaiau Cave).

Among the primary cavities we find a series of strange cave types, such as tree casts, even the cast of a diceratherium, hollow intrusions, vents, lava bubbles, pressure ridge caves, or separations in between pāhoehoe sheets. The most common cave type, though, is the post-eruptional conduit that permits molten lava to flow subterraneously for long distances, allowing shield volcanoes to cover large areas with surface slopes of a few degrees only. These caves, colloquially called “tubes” are neither tubular in shape nor are they normally filled by lava when active. Titus Coan, an educated missionary, was the first who reported seeing an active lava conduit on Mauna Loa in 1843. He saw the lava flowing in an open space - a river of molten fire - and coined the term “pyroduct” in analogy to “aqueduct” (the covered, free-flowing water conduits the Romans built to supply water to their cities). Older terms have priority in science, specifically if they do not convey misconceptions.

For almost a hundred years after Coan not much happened in pyroduct-research (apart from the fact that Olafsen had described the origin of pyroducts more or less correctly already in 1774-75 in Iceland) until Tom Jaggar named a newly investigated cave on Kilauea “Thurston Lava Tube”.

The interior inspection of pyroducts and their survey has shown that they not only vary in cross-section between different conduits but also internally. Factor 10 cross-section area changes within the same duct are not uncommon. This tells us that such caves cannot have been filled to their top with lava, but that (apart from the smallest sections functioning as valves) much of the final cave was an underground canyon with a lava river flowing at its bottom. The change in passage cross-section is owed to erosion, downward (for example by lava falls), sideward (by undercutting and collapse of walls) and upward (by ceiling collapse). That pyroducts in fact erode downward was shown beyond doubt when we discovered Pahala ash outcrops in the walls of Earthquake Cave/Kilauea in 1991.

In textbooks (except for Lockwood & Hazlett, 2010), “lava tubes” are described as “over-crusted channels”. Both the recent observations of the ongoing eruption on Kilauea by the colleagues of the Hawaiian Volcano Observatory and the analysis of roof structure of pyroducts, show that the “over-crusting” hypothesis seems to be a rare case, while the majority of analyzed cases is formed by “inflation”. This involves uplift of the primary lava sheet by consecutive later sheets injected from below. The hottest and topographically lowest flow thread forms the later pyroduct.

Three general types of pyroduct cases can be discerned:

(1) The single-trunked conduit. It originates from one lava flow; the resulting cave may drain early braids but eventually the flow concentrates in one trunk passage.
(2) The double-trunked case. It involves conduits active in parallel and influencing each other.
(3) The superimposed-trunked case. It is the most complex pattern, where conduits are superimposed on each other by an increase in erupted lava volume. Here pyroducts cross each other, all active at the same time and drained top to bottom. This causes the most complex cave pattern.

Internally many processes act to alter the cave's appearance. Ceiling collapse may open skylights through which cold air can enter causing the freezing of internal septa (secondary ceilings). This results in the separation of the passage into two (or more) levels. After the activity and during cooling further collapses occur, either opening more skylights or littering the floor of the cave with blocks. During activity, when hot gas fills the upper part of the cave, part of the ceiling can be melted, causing the ceiling to look like a honeycomb. Also, hot air draft can form lava ripples. Furthermore, a score of different rock speleothems may be observed in pyroducts, owing their existence to a variety of transient conditions.