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Lunar and Hawaiian Lava Tubes: Analogs and Uses Based on Terrestrial Field Data

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Introduction

Lava tubes and sinuous channels are prevalent in many volcanic settings on Earth and have also been identified on the Moon. Thermal erosion may have played an important role in the final formation of some of these features. Downcutting due to thermal erosion is fairly common on Earth and has been documented during the formation of some active flows on the island of Hawaii and modelled for several sinuous rilles/lava tubes on the Moon. Previously, Coombs *et al.* (1987, 1990)[1,2] discussed the nature and origin of several sinuous rilles and possible lava tubes in the north-central region of the Moon and compared them to similar features in Hawaii. Hörz (1985)[3]and Coombs and Hawke (1988)[4] have suggested that intact lava tubes would be useful in establishing a future lunar base. While most workers agree that these features hold promise for future lunar base expansion, there is sufficient uncertainty surrounding them to warrant further study before committing them to use at the first lunar base site. Thus, in order to understand better the processes that formed these features and their overall character, data was recently collected from more than 400 lava tubes from many different lava flows on three islands in Hawaii. The lava tubes studied were of varying ages from minutes to hundreds of years old and are at various stages of degradation. This paper presents the analysis of the data collected for a large number of Hawaiian lava tubes on the islands of Oahu, Molokai, and Hawaii and extrapolates the results to lunar conditions.

About Lava Tubes

A lava tube may form when the uppermost portion of an active stream of basaltic lava forms a continuous crust. More specifically, depending on the rheology of the lava and the rate of flow, a lava tube may form by one of several methods: (1) An open channel may form a crust that extends from the sides to meet in the middle and eventually thicken and form a roof. (2) Crustal slabs riding along the tops of more vigorous flows may break apart, raft down the channel, and eventually get hung up and refit themselves together to form a cohesive roof. (3) Lava sloshing, overflow and spattering may form levees which may eventually grow upward and inward to form a roof. Or, (4) Lava tubes may form as advancing pahoehoe lava toes leave voids behind (e.g., 2,4,5,6). Thermal erosion may increase the depth and sinuousity of the lava channels and tubes. Once formed, lava tubes may remain intact for years. Terrestrial field evidence as well as calculations by Oberbeck *et al.*, (1969)[7] support the theory that many of these lunar features are evacuated and have remained intact during the millions of years of meteoritic bombardment and seismic shaking to which they have been subjected since their formation.[4] Several large prehistoric and historic lava tubes on Hawaii have maintained their structural integrity despite their great age and location in a region with a high frequency of earthquakes.

Under lunar environmental conditions (lack of atmosphere, lower gravity field), the basaltic eruptions that formed the lunar lava tubes would have been somewhat different than on Earth and would have produced features an order of magnitude greater. Pyroclastic deposits associated with some lunar basaltic eruptions extend as far as several hundred kilometers away from the source vent. Likewise, lunar lava tubes, where present, reach sizes of 100's of meters to kilometers wide by 100's of meters deep and 10's of kilometers long.[1,2,4] Because of these large dimensions and the liklihood that they may be open, the lunar lava tubes should be considered when planning future lunar settlements.

Field Data

In an effort to characterize these features, more than 400 lava tubes were studied in the field. Over 200 were studied in the vicinity of Kilauea in the Volcanoes National Park, 100 within a military bombing range along the north flank of Mauna Loa, and 100 from several localities on the islands of Hawaii, Oahu, and Molokai. Measurements were taken of their horizontal width (H), vertical height (V), depth from surface, roof thickness, floor thickness and, where determineable, the length, sinuosity, and number of flows making up the tube. Figure 1 shows the variation in measurements among all the tubes analyzed. A simple regression was performed on the data to illustrate the non-uniform relationship between the vertical and horizontal components measured for each tube. This correlates with what was seen in the field; that is, no lava tubes were perfectly spherical in cross-section. Rather, the majority of the lava tubes were wider than they were tall, thus the less than one to one relationship.

Also, where possible, a measure of the degree of thermal erosion was estimated. Three lava tubes were identified that exibited definite evidence for thermal erosion. These were located on Oahu, Molokai, and Hawaii. The prime example of thermal erosion is Whittington lava tube on the south shore of Hawaii. This lava tube formed in successive stages and cut its way down through preexisting lava layers that contain tree molds.

A comparison of these measured terrestrial lava tubes with their lunar counterparts suggests that they are very similar, despite the order of magnitude size difference. Earlier modelling of a lunar lava conduit systems[e.g., 1,2] suggests that thermal erosion may have played a role in their formation. Extrapolating the recently collected field data to lunar conditions suggests that we should find a similar trend in the lava tubes found on the Moon. That is, they will vary in vertical and horizontal dimension, with the horizontal being the larger of the two. Also, roof thickness, floor thickness and number of flows making up the tube will also be highly variable as reflected in the data collected for the Hawaiian lava tubes.

Conclusion

Lava tubes did form on the Earth and Moon, many of which are still intact. These features are relatively stable over time, as illustrated by the rigidity of the Hawaiian prehistoric lava tubes as well as the historic tubes located in the bombing range near Mauna Loa. These natural structures should be considered for use in planning for the expansion and advanced stages of the future manned lunar base.

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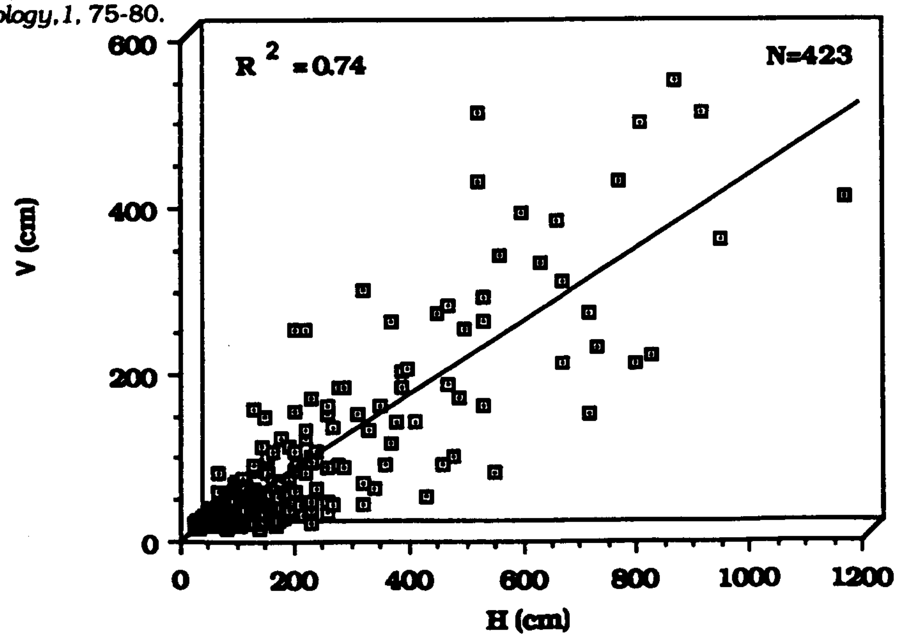

Figure 1: Vertical height (V) vs horizontal width(H) lava tube data from Oahu, Molokai, and Hawaii.