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MARTIAN LAVA TUBE CAVES AND MEGA-CAVES REVISITED

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4) Sidney Speleological Society (Australia)
5) Swiss Speleological Society
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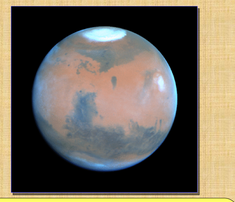
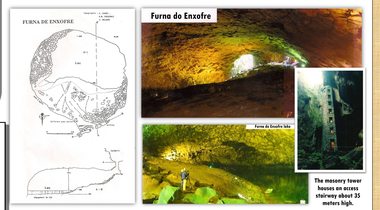


LAVA TUBE CAVES OF EARTH AND MARS

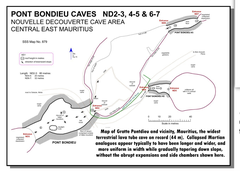
Four decades ago, planetary geologists began to hypothesize that lava tube caves in the lower gravity of Mars and the Moon might attain diameters of as much as 500 meters (e.g., Greeley, 1971 a, b). This idea has persisted, but, currently, our Martian and terrestrial data do not support it. This poster summarizes a study of a representative sample of collapsed Martian lava tube caves. We did not find features which would permit differentiation of examples which collapsed immediately after withdrawal of buoyant molten lava from those which persisted for a time as caves.

Map and photographs of Furna do Enxofre, Graciosa, Azores, with the widest unsupported terrestrial cave roof on record. Photographs by G. Middleton, map by A. Corbel, A . Fossomale and J. Halgard. (From Halliday et al, 2012.)



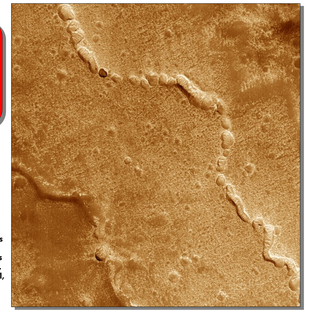
The masonry tower houses an access stairway about 35 meters high.

Since 1971, knowledge of an unsupported basalt roof 300 m wide on Furna do Enxofre (an incipient pit crater in the Azores) has become widespread. Its persistence demonstrates that gravity-induced roof failure is not the principal constraint on width of terrestrial lava tube caves. Also, progress in understanding the origin and development of lava tube caves (e.g., Hon et al, 2004) has shown that several types of lava tube caves form in different ways.

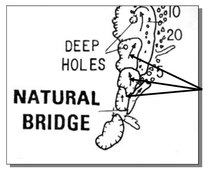


Map of Grotte Pontdieu and visitor, Mauritius, the widest terrestrial lava tube cave on record (44 m). Collapsed Martian analogues appear typically to have been longer and wider, and more uniform in width while gradually tapering down slope, without the abrupt expansions and side chambers shown here.

In 1971, Greeley identified the role of roof plates in the formation of the commonest type of lava tube cave formerly present on Mars (Greeley, 1971, a, b). Within the limitations of Google Mars, we conducted a Mars-wide search for such roof plates. We identified and studied more than 100 such collapsed lava tube caves in lavas of Olympus Mons, Ascraeus Mons, the western flank of Alba Mons, and adjacent plains. In this inventory, we differentiated collapsed lava tube caves from lava channels and stream gullies, and from sinuous and other rilles. We identified roof plates in no Martian rille.



Aerial view of roof plates floating down channel approximately 10 meters wide. (Photograph by R. Greeley, from Docker et al, 1987)



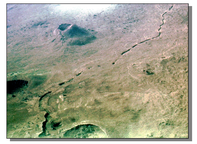
"Compartments" in Lava Beds National Monument, California, depicted on Map 20, Waters et al, 1990.

Photograph by Ron Greeley of Bear Trap Cave, Idaho, perhaps the largest terrestrial example of lava tube cave roofed by roof plates. (From Greeley and King, 1975.)

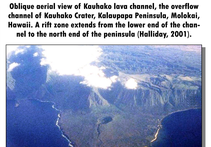
Unnamed example of terrestrial lava tube cave not roofed by roof plates. (Photograph by R. Greeley, from Greeley and King, editors, 1977).

LAVA CHANNELS OF EARTH AND MARS

The type of lava tube cave emphasized by Greeley requires a pre-existing lava channel transporting molten lava. Some terrestrial lava channels, however, are produced by roof failure of lava tube caves regardless of type. Most of these are too choked by breakdown to permit transport of molten lava. Remnants of intra-tubal depositional and erosional features differentiate these from channels which never have been roofed.



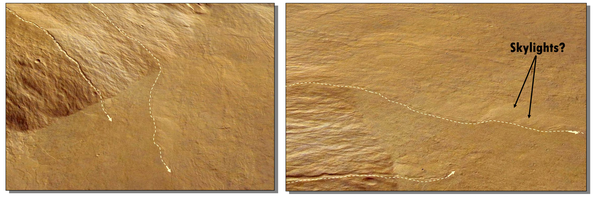
Oblique aerial view of the channel of the 12 km Paikahe lava tube system, Hualalai volcano, Hawaii, USA. Cavernous segments are visible. Near its upper end is a spacious but short braided lava tube cave which has not yet been mapped.



Oblique aerial view of Kauhako lava channel, the overflow channel of Kauhako Crater, Kalaupapa Peninsula, Molokai, Hawaii. A rift zone extends from the lower end of the channel to the north end of the peninsula (Halliday, 2001).

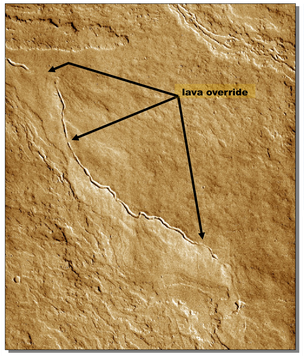
Looking down slope along the course of Kauhako lava channel. Just down slope from its origin, its Google Earth width is 105 meters.

The overflow channel of Kauhako Crater on Hawaii's Kalaupapa Peninsula is near the outbound flight path of many commercial flights from Honolulu to the mainland (Halliday, 2001; Halliday et al, 2009). Initially it was interpreted as a sinuous rille, or as a collapsed lava tube cave (e.g., Coombs and Hawke, 1989) despite the width of its upper portion (105 meters). Shallow overflow levees alongside its upper section document its actual nature.

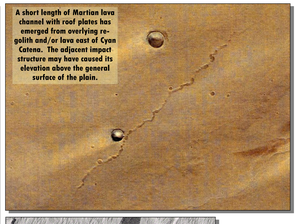


Unitary lava channels on a prominent scarp on the northeast slope of Olympus Mons. The farthest example extends onto the piedmont plain where it follows the crest of a lava finger for several km. Two ovate lava effluxes 0.6 to 1 km in width broke out from branches of this channel or directly from the underlying lava finger and two apical depressions are present which might be termed "skylights", but no roof plates have been identified within any of these lava channels and the underlying lava fingers are not lava tubes.

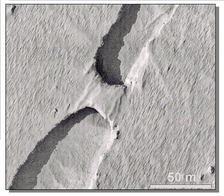
Many Martian lava channels are segmented by lava fingers, tongues or sheet flows. Prior to high definition orbital photography, the resulting gaps in lava channels commonly were interpreted as intact segments of lava tube caves. Now, lava surface patterns can be observed crossing the courses of such channels.



An unnamed lava channel on Olympus Mons (NASA Themis 2 20030405a) originally was interpreted as demonstrating several possibly intact segments of lava tube cave. With higher definition, surface patterns of overriding lava are visible instead. In Hawaii and on the North Island of New Zealand, very short narrow caves have been found where such lavas arch outward and downward upon encountering steep or vertical slopes.



A short length of Martian lava channel with roof plates has emerged from overlying regolith and/or lava east of Cyan Catena. The adjacent impact structure may have caused its elevation above the general surface of the plain.

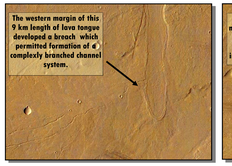


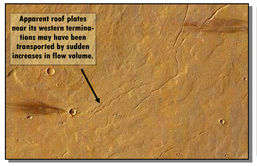
This natural bridge spans a lava channel in Tartarus Colles. Initially it was interpreted as formed of lava debris wedged during the waning stage of an eruption. The size and shape of the large slab suggest an alternate interpretation as an unusually large roof plate. (NASA orbital photograph courtesy Laszlo Kestay.)

FEATURES OF COLLAPSED MARTIAN LAVA TUBE CAVES

For this study, we found Google Mars to be a limited but useful rapid scanning tool. Problems in its use included wide blurred strips of the Martian surface, inability to measure accurately distances less than about 20 meters, a system of coordinates which differs from that used by NASA, and a similar difference of a few percentage points in readings by its electronic "ruler".

Our study process included detailed scanning, in diminishing intensity, of (1) previously identified Martian volcanic edifices, (2) plains with previously identified volcanic features, (3) rilles, (4) plains areas without previously identified volcanic features, and (5) miscellaneous highland areas. Using the criterion of characteristic intra-channel roof plates, we identified more than 100 collapsed lava tube caves, mostly in volcanics of the Tharsis Rise, especially its northern and western strato-volcanoes.





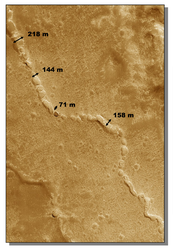
We found that collapsed lava tube caves on Mars occur in patterns generally similar to those presently on Earth, i.e., unitary, branched, and braided (Halliday, 1963), but their channels tend to be wider and much longer, and they taper down slope more uniformly. We also conducted a similar reconnaissance of the surface of the Moon, but found no characteristic roof plates.

An example of collapsed braided lava tube complex on Ascraeus Mons.

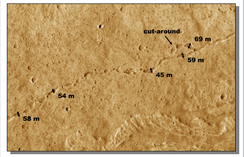
Widths of compartments in this complex measure 77 to 120 meters by the electronic "ruler" of Google Mars. The widest measured to date is 232 meters.

An especially large channel on the northwest flank of Olympus Mons tapers too much for accurate measurement with the Google Mars electronic "ruler" of possible compartments near its down slope end. Such attempted readings varied from 14.8 to 25.5 meters.

To Greeley's seminal descriptions of roof plates and collapsed lava tube caves, we add the concept of rectilinear compartments within boundary channels, formed by non-uniform collapse of accumulations of roof plates. Such features are seen commonly in this part of Mars, and occasionally on Earth (e..g., in Lava Beds National Monument, California and on the lower western slope of Mauna Loa volcano, Hawaii, USA). We found none within rilles.

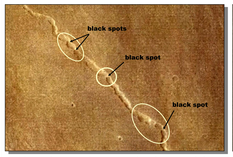


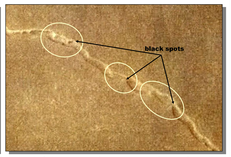
NASA orbital photograph PIA 05790. Channel widths by Photoshop measuring tool are 71 to 218 meters. The widest lava tube collapse recorded on Earth to date is in Idaho's Bear Trap Lava Tube system, at about 140 meters (Greeley, 1971).



In NASA orbital photograph PIA06935, channel widths are 45 to 69 meters, closer to today's terrestrial lava tube widths.

High on the northwest slope of Olympus Mons, we identified several overhanging roof plates, some with associated "black spots". Such features may permit entry into residual cavernous sections of lava tubes a few meters to several hundred meters in length. A new generation of svelte, rip-resistant space suits will be needed for direct investigation, but interim study by self-propelled robots with one or more variable intensity headlamps may be possible from presently planned lowland landing sites.





Further up slope, several occurrences of overhanging roof plates adjoin seemingly intact cave roofs meters to tens of meters long. Most of these overhangs are about 50 meters wide, but a few are 50 to 200 m in width. Whether any of these represent horizontal openings into residual cavernous segments could not be determined. Some are associated with "black spots" which possibly represent smaller vertical orifices of residual spaces amid collapsed roof plates.

OTHER TYPES OF LAVA TUBE CAVES, AND "LOOK ALIKES"

On Earth, comparatively few large lava tube caves have formed by the roof plate mechanism. The well-known open lava channel in New Mexico's El Malpais National Monument contains several partially roofed lava trenches formed by roof collapse of cavernous segments such as Big Skylight Cave. No roofing by roof plates has been identified in this system.

Oblique aerial view of collapse trenches in El Malpais National Monument, New Mexico, USA. They are aligned along an intermittently roofed lava channel 28 meters wide which also contains Big Skylight Cave (second photograph) which contains no roof plates. (Second photograph by H. Marinakis).

Some Martian lava tube caves also may have formed without roof plates. A channel complex southwest of Alba Mons includes three straight collapse trenches 105 to 145 meters wide, in close alignment. The gaps between the trenches may be intact cavernous segments of the tube.

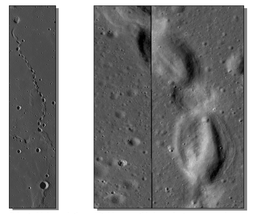
With and without roof plates, Martian lava channels can and should be differentiated from rille complexes containing rounded pits. Only rarely are the rectilinear compartments characteristic of collapsed roof plates replaced by rounded compartment forms.

This channel complex south of Alba Mons includes three straight collapse trenches, and also a length of channel crossing an uncollapsed segment of a tectonic rille. Sections of the rille are visible at the bottom of two funnel pits. In the past, such uncollapsed segments of rilles have been interpreted as intact lava tube caves

Google Mars image of a graben containing numerous round pits. The rectilinear compartments formed by roof plates of collapsed lava tube caves can and should be differentiated from such features.

Radial rilles on Elysium Mons with round pits

Chains of rounded funnel pits exist in Martian terrains where tectonic rilles are deeply buried.



Prior to high-resolution orbital images, this lunar feature commonly was interpreted as a collapsed lava tube cave. (From Oberbeck et al, 1969).

Acknowledgments

We are deeply indebted to the late Ron Greeley for his seminal contributions on this and many other planetary subjects. Our thanks also are due Poul Spudis for bringing to our attention the A.S.U. LROC website. Jody Bailey of the Nashville Grotto of the National Speleological Society designed and produced this poster.

References available upon request to the senior author at bnawrh@bellsouth.net