Mega-caves of Mars Revisited: Speleological Information Systems in Planetary Scence and Technology.
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Introduction: In 2010, the Mars Exploration Program Analysis Group asserted that quantitative understanding of exogenous habitability of Mars likely would become the primary focus of Martian exploration efforts in the following decade (1). This MEPAG white paper did not mention caves. Extensive parallel literatures in planetary and speleological communities, however, have discussed the advantages of caves for astronaut habitation (search for life in Martian caves is a separate consideration). The IUS Commission on Volcanic Caves is concerned about an obvious lack of cross-fertilization between these literatures. Several types of caves are potential candidates for exogenous habitations on Mars: lava tube, littoral, talus, piping (suffusion), glacier, and perhaps other types of caves. Of these, only lava tube caves have been identified conclusively to date.

In the early years of planetary science a mindset evidently developed that, as a result of the lower gravity of Mars and the Moon, their lava tube caves must be significantly larger than those of Earth. As recently as 2011, several papers at LPI's First International Planetary Caves Workshop discussed architectural and/or engineering projects intended for such mega-caves, either parallel to the surface or at the bottom of pit craters commonly believed to be their skylights. Five months later, at the 43rd Lunar and Planetary Research Conference in March 2012, a poster prepared by an international team of speleologists presented field observations and orbital photographs of such pit craters (2). It confirmed Dana's concept of terrestrial pit craters as sites of former lava lakes with withdrawal of their lava columns (3), and found no evidence of associated lava tube caves. It thus appears that both communities can learn from the other's literature.

The March 2012 poster left unanswered intriguing questions about other supposed mega-caves of Mars and the Moon, with and without skylights. Currently in preparation is a paper which will consider some of these issues at the 2012 GSA Annual Meeting, a venue where we have presented other papers on Martian caves and terrestrial analogues (4, 5, 6). This present paper is an interim report.

Photographic measurements of partially collapsed lava tube caves on Mars: The largest recorded width of a terrestrial lava tube cave (Grotte de Pont Dieu,Mauritius) is about 45 meters. Widths of collapse pits and trenches on Earth vary from the barely perceptible to more than three times the width of adjacent segments of lava tubes (7). Orbital photographs of partially collapsed segments of both large and small lava tube caves of Mars have been published, mostly without scales useful in this study. Several 2004 Mars Orbital Camera (MOC) photographs however, were published with accompanying explications which included the width of the area shown in the photograph. Measurements with a simple ruler and a calculator can determine the approximate width of large features on such orbital photographs. If care is taken to exclude rilles of other types, this simple process seems to demonstrate no collapsed segment of lava tube cave wider than about twice the maximum width of terrestrial examples. While this elementary process clearly is inadequate to determine precise widths of these Martian features, it demonstrates that large collapsed lava tube caves of Mars photographed by MOC are only of the same order of magnitude as those on Earth. Other orbital photographs apparently show smaller Martian lava tube caves which are of the same magnitude as smaller terrestrial examples.

Constraints on widths of lava tube caves: Field observations suggest that inherent characteristics of basalt lava constrain the sizes of lava tube caves on Mars, the Moon and Earth. Furna do Enxofre (Graciosa, Azores) is a near-circular incipient pit crater formed by stoping. It has an unsupported basalt roof span about 300 m in diameter (8). This span demonstrates that some constraint(s) other than gravity limit the width of other types of voids in basalt.

Late in the 20th Century, a thorough field study of recent flow fields of Hawaii's KilaueaVolcano clarified the origin and development of lava tubes and caves, including certain constraint mechanisms. Lava tubes form in several different ways, Especially in low slope areas like those where they characteristically are seen on Mars, tubes form after a period of unconstrained flow through inflated flow lobes, as an inherent part of a complex three-part process (9). One of the most important constraints was found to be friction of enlarging viscoelastic confining layers during inflation of pahoehoe flows (9). Unlike its direct role in breakdown and roof failure in mines and other types of caves (10, 11), gravity thus is understood to play only an indirect role in formation of lava tube caves.

"**Walk-in" caves on Earth and Mars**: Parameters of "walk-in" caves on Earth strongly suggest that mega-caves are not essential for exogenous habitations on Mars (12). Procedings volumes listed on the website of the IUS Commission on Volcanic Caves, the large data base on lava tube caves compiled at Arizona State University, and publications of various units of the National Speleological Society and its international counterparts offer underutilized resources for most uses suggested for non-existant mega-caves of Mars.

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