Visible Evidence of Cave-Entrance Candidates in Martian Fresh-Looking Pit Craters. G.E. Cushing, U.S. Geological Survey, Astrogeology Science Center, 2255 N. Gemini Dr. Flagstaff, AZ 86001. gcushing@usgs.gov

Introduction: A number of pit craters in Mars' Tharsis region exhibit fresh-looking morphologies and unusual thermal behaviors, and may host entrances into caves that exist beneath numerous superimposed lava flows. These pits appear 'fresh looking' (compared to common pit craters) because they have sharp, abrupt rims; vertical or overhanging interior walls; depth-to-diameter ratios > 0.5. Here we present HiRISE observations of Fresh-Looking Pit Craters (FLPCs) on Mars that appear visibly consistent with terrestrial analogs known to contain cave entrances (the term 'fresh-looking' is not intended to imply age constraints).

We use recent HiRISE observations to reinterpret previous work [1] where seven FLPCs were first described using lower-resolution THEMIS observations (at ~25 cm/pixel, HiRISE observes details 1/5000 the resolution of THEMIS). We have since identified the locations of 88 additional candidate FLPCs, mapped their distribution across the Tharsis region, characterized their internal morphologies (when possible), and discussed possible formation mechanisms [2].

Caves often form in terrestrial basaltic volcanoes, and Martian volcanoes (basaltic in composition) tend to form structures similar to those found on Earth [e.g., 3,4]. Accordingly, we expect volcanic-type cave-formation mechanisms to also be comparable. Most purported Martian cave entrances are either difficult or impossible to directly detect with currently orbiting instruments due to limitations such as spatial and temporal resolution, area coverage and viewing perspectives.

Many terrestrial pit craters contain cave entrances and appear to be morphologically comparable to the FLPCs we find on Mars (Figures 1&2). Both the Martian FLPCs, and the terrestrial pits are inferred to have formed via collapse processes in basaltic lava flows. These features are consistently circular (or nearly so), do not have raised rims, and usually have diameters of ~50-250 m.

New insights from HiRISE observations: HiRISE continues to target FLPCs identified in THEMIS and CTX data, revealing interior morphologies in fine detail. In sideways-looking HiRISE observations, FLPCs often have floors that extend out of sight beneath an overhang (Figure 3), and vertical or overhanging interior walls (at least in the direction of solar illumination). The overhanging rims extend over unknown void spaces, and the vertical walls may have candidate cave entrances at their base (Figure 1). We often see a small number of fallen boulders gathered directly beneath overhangs upon otherwise flat and smooth-looking (probably dust-mantled) floors, which indicates that only minor erosion has occurred since the time of formation (Figures 3&4). In FLPCs with overhanging rims and heavily dust-mantled floors, the mantle frequently slopes downward and out of view directly beneath the overhang (Figure 5). This also indicates that ongoing collapse is unlikely because there is no visible evidence that rim boulders have fallen while dust has been accumulating.

Flat floors that exist within some FLPCs may indicate that roof collapse occurred into active magma flowing through a subsurface conduit. This may have been an effective mechanism to remove and transport freshly collapsed material away from the site (either by lateral rafting or by sinking), thus allowing progressive collapse to occur.

Because FLPCs form via collapse into subsurface void spaces [5,6], open cave entrances that lead into persistent laterally extending void spaces may still remain. If the initial void that accommodates collapsed material happens to extend beyond the zone of collapse, then any remaining void may still be accessed unless blocked by fallen debris [5]. Figure 6 shows the oldest currently identified FLPC (located near Elysium Mons, > 1 Ga in age), which indicates that these features can remain stable over time and probably do not evolve into common pit craters

Cave entrances are likely to exist in at least some FLPCs, and cave detection is important to future planetary exploration. Their protective environments offer strong possibilities for future human habitation, and could preserve evidence of whether biological activity ever existed on Mars. Caves will become increasingly attractive and attainable targets as exploration technologies continue to advance.

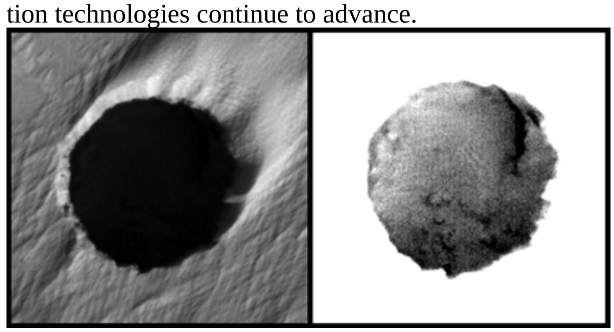

Figure 1: HiRISE image of an FLPC containing a cave-entrance candidate. Left panel shows the dark pit and surrounding dust-mantled surface (topographic features frequently induce yardang formation in this region). Right panel shows the same image stretched to enhance contrast. Note the candidate laterally extending cave entrance at its base. This pit is ~65 m across and >45 m deep.

Figure 2: Some terrestrial pit craters on Kilauea Volcano (e.g., Kau Desert, Hawai'i) appear comparable to FLPCs identified on Mars.

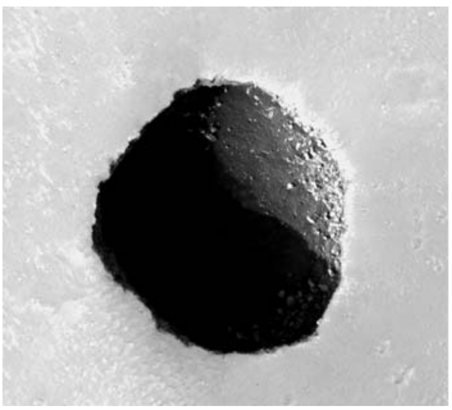

Figure 3: Example of an FLPC that may have formed during a period of subsurface flow activity. The concentration of boulders directly beneath the rim indicates that only minor subsequent collapse has occurred since the floor cooled.

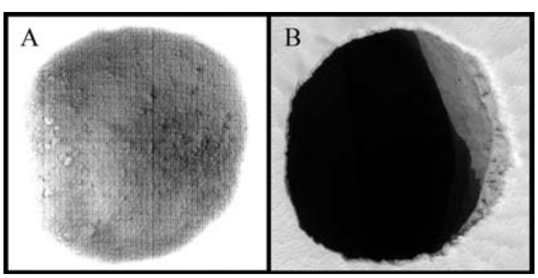

Figure 4: HiRISE images of a pit crater first described in [1]. This pit is ~165 m across and >245 m deep. The image in Panel A has been stretched to the limits of HiRISE's detection ability to reveal boulders strewn beneath the rim. Panel B was observed from a sideways viewing angle of 17.7° to reveal a thick, overhanging rim, a portion of an interior wall, and possibly another large interior overhang.

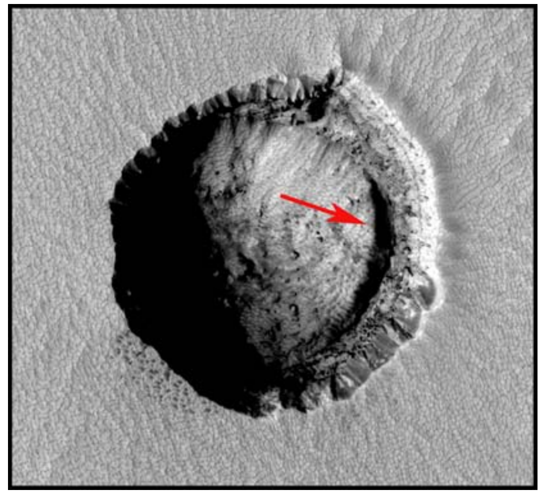

Figure 5: With the spacecraft rolled 12.8° eastward, the crest of an interior dust mound directly below the rim becomes clear (red arrow). The downward-sloping shadowed backside of this mound exists under an overhang and slopes out of view into a void of unknown extent. The crest of this mound is not visible in a near-nadir looking HiRISE stereo companion image. This FLPC is ~215 m across and ~155 m deep at the edge of the shadow.

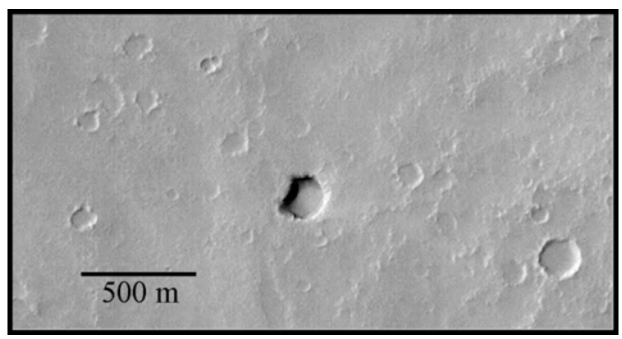

Figure 6: Likely the oldest FLPC identified thus far (located off Elysium Mons' southeastern flank in terrain estimated at 0.7-2.1 Ga [*Werner*, 2005], (CTX: P19_008542_2050; 147.9° E, 22.5° N), this example appears to have a degraded rim and thicker dust mantle on the floor than FLPCs in younger terrain.

References: [1] Cushing, G.E. et al. (2007), GRL, 34. [2] Cushing et al. (2010) in review. [3] Carr, M. and R. Greeley (1980) NASA SP-403. [4] Glaze, L. et al. (2005) JGR, 110, B8. [5] Okubo, C.A. and S. Martel (1998), J. Vol. Geothm. Res., 86, 1-18. [6] Wyrick, D. et al. (2004), JGR, 109, E06005.