CHARACTERIZATION OF A MID-LATITUDE ICE-RICH LANDING SITE ON MARS TO ENABLE IN SITU HABITABILITY STUDIES.

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Introduction: Here we present landing site analysis to support a Mars lander mission equipped to drill approximately two meters into martian soil and permafrost to conduct in situ science investigations. This notional mission is focused on studying past habitability and analysis of regions capable of preserving the physical and chemical signs of life and organic matter. Studies of the ice-rich subsurface on Mars are critical for several reasons. The subsurface environment provides protection from radiation to shield organic and biologic compounds from destruction. The ice-rich substrate is also ideal for preserving organic and biologic molecules and provides a source of H_2O for any biologic activity. Examination of martian ground ice can test the hypotheses of whether ground ice supports habitable conditions, that ground ice can preserve and accumulate organic compounds, and that ice contains biomolecules that show past or present biological activity on Mars.

Ground ice is expected to be fairly common in mid to high latitudes on Mars given a variety of indirect measurements such as Gamma Ray Spectrometer analysis [1], geomorphology [2, 3, 4], and numerical modeling [5]. However, there are only two regions on Mars where subsurface ground ice has been directly observed: 1) the Phoenix lander site and 2) Amazonis Plantia (near the boundary of Utopia and Arcadia, Fig. 1). The Phoenix lander dug into the subsurface in the martian Arctic to confirm the presence of subsurface ice. In Amazonis Planitia recent impact craters have exposed subsurface ice within the upper meter [6].

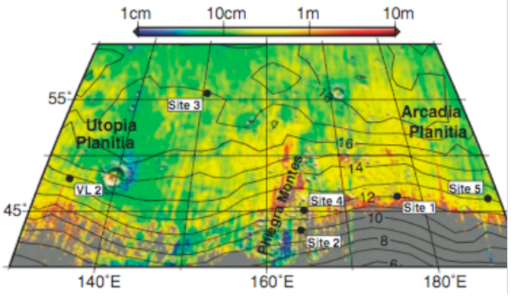

Fig. 1: Map showing location of Viking Lander 2 (VL2) and five sites of recent impact craters excavating subsurface ice. From Byrne et al. 2009 [6].

Landing Site Determination, Initial Region of Interest: Our initial region of interest for the landing site search within the mid to high latitudes is 45N-60N and 130E-190E (Fig. 2). This region was selected based on indirect evidence of subsurface ice as discussed previously and direct evidence of exposed subsurface ice in four newly excavated craters [6]. This region also includes the successful landing site of the Viking Lander 2 (VL2).

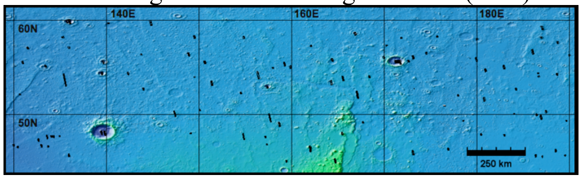

Fig. 2: Initial region of interest, 45N-60N and 130E-190E. Each black stamp indicates a HiRISE image.

The region of interest includes over 100 HiRISE images at different locations. These images have resolutions of typically 25 cm/pixel and can be used to identify medium–size (~75 cm) rocks from orbit, along with larger geological features. Due to their high resolution, we used these images specifically to find potential landing sites. Since we have successfully landed at the VL2 site and have images from the ground and from orbit (Fig. 3), we used the VL2 site as a baseline for ranking other sites with HiRISE images within the region based on our criteria.

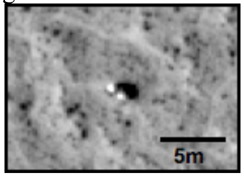

Fig. 3: HiRISE image PSP_001501_2280 of the location of the VL2 site. This images shows rocks, polygonal ground, and the VL2.

Landing Site Criteria: Each site is rated individually in comparison with the VL2 site based on the presence of polygonal ground, rough topography, boulders, craters, and rock density.

Polygonal Ground: Polygonal ground can easily be identified in HiRISE images and its presence indicates a high likelihood of subsurface ice [4, 5]. Polygons were ranked in two ways: presence and definition. Polygon presence is rated as 1) not present, 2) present but not ubiquitous, or 3) polygonal ground is ubiquitous. In HiRISE images, it is apparent that polygons come in a range of definition, ranging from very defined deeply cracked polygons, to less obvious, "undefined" shallower polygons. Polygon definition is ranked as 1) defined, 2) undefined, or 3) a mixture of the two (Fig. 4).

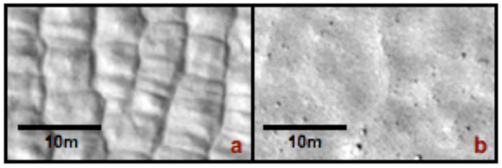

Fig. 4: (a) Defined polygons. HiRISE ESP_011494_2265, (b) Undefined polygons. HiRISE PSP_006842_2310.

Uneven topography: In order to safely land and operate the drill successfully, uneven topography and sharp slopes should be avoided. Therefore, we took note of the presence of large apparent slopes, uplift, cracks, cliffs, and any other apparent rough topography. The presence of rough topography was rated based on the amount of rough topography with categories of 1) no rough topography, 2) ubiquitous roughness, or 3) rough topography is present but not ubiquitous.

Boulders: Unusually large rocks in HiRISE images are potential hazards because they may cause uneven slopes, and they could cause damage to the lander. Boulders are rated based on their presence: 1) not present, 2) some boulders are scattered within the region, 3) groups of boulders are present but not ubiquitous, or 4) boulders are present everywhere.

Craters: Craters usually have uneven topography and boulders, which make them potential landing hazards. Since a large portion of HiRISE images are of large craters specifically, we divided the rating into two groups: 1) “big crater” meaning one large crater taking up most of the HiRISE image, and 2) “small craters” are craters that do not take up the majority of the HiRISE image but need to be noted. "Big craters" typically have diameters that are comparable to the width of the HiRISE image and take up the majority of the image. "Big craters" are rated based on their coverage of the image: 1) no big craters, 2) a big crater present but it only covers a portion of the image, or 3) a big crater is present and covers the entire image. "Small craters" are craters that do not take up the majority of the HiRISE image but need to be noted. They are rated by the amount of craters present: 1) no small craters, 2) a few craters (1-2), 3) more than a few small craters (3-4), 4) or many craters (greater than 4).

Rock Density: The VL2 landing site has a fairly high rock density. For our notional life detection mission, it would be optimal to land in a site with the least amount of rocks possible because they may be mission/landing hazards. Rock density is therefore very important to our search, and is rated in comparison with the VL2 site: (rated 0 if) no rocks, (1) only a few rocks, (2) more than a few rocks but less than the rock density of the VL2 site, (3) the rock density of the VL2 site, (4) more rocks than VL2 but it is not incredibly dense, or (5) very high rock density (Fig. 5).

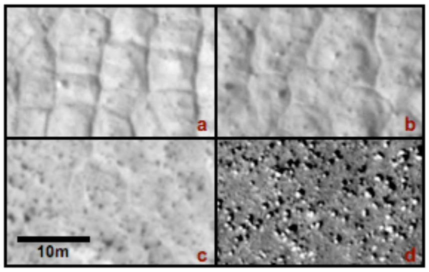

Fig. 5: Some rock density examples at the same scale:
(a) rock density 1, ESP_011323_2265 (b) rock density 2, ESP_011323_2265 (c) VL2 site baseline, rock density 3, PSP_001501_2280 (d) rock density 5, PSP_006842_2310.

Results: An optimal landing site was determined to be one of the five sites identified by Byrne et al. [6] with exposed subsurface water ice. This site is centered at 188.5E 46.16N, found within HiRISE image ESP_011494_2265. This site is our current optimal landing site because it has ubiquitous defined polygons, no boulders, very few areas of high rock density, minimal rough topography, few craters, and direct evidence of subsurface ice in the newly excavated crater (Fig .7).

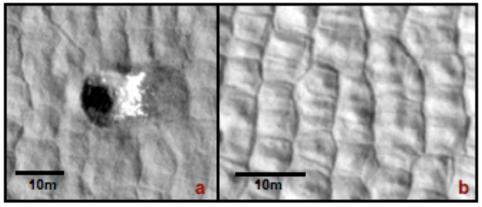

Fig. 7: ESP_011494_2265. (a) exposed subsurface ice in new crater (b) typical surface example with defined polygons and no rocks.

There are only a few very small areas of uplift and higher rock densities, and only a few small crack-like features with smooth edges. This site is our prime landing location presently, and more HiRISE images are being requested adjacent to this location in order to cover a larger area for the landing ellipse.

References: [1] Boynton, W.V. et al. (2002) Science, 297, 81-85, 2002. [2] Squyres, S.W., et al. (1992) in Mars, 523-554. [3] Levy, J. et al. (2009) JGR, 114, E01007. [4] Mellon, M.T. (2009) JGR 102, 25,617-25, 618. [5] Mellon, M.T. (1995) LPSC XXVI, 1995. [6] Byrne, S. et al. (2009) Science 325, 1674.