RAPID INFILLING OF SMALL CRATERS ON HIGH N. LATITUDE MARS: IMPLICATIONS FOR MISSIONS TO SEARCH FOR EVIDENCE OF LIFE C. R. Stoker[1], E.Z. Noe Dobrea[1,2], S. L. Alkemade[2,3] [1]NASA Ames Research Center, Moffett Field CA 94035, Email carol.stoker@nasa.gov, [2]Planetary Science Institute, Tucson, AZ, 95719; [3]Monash University, Clayton, VIC 3800 Australia

Introduction: The 2008 Phoenix Mars lander mission sampled ground ice at 68°N latitude. Mission results, considered along with climate modeling studies, suggest that high latitude ice-rich regolith at low elevations is habitable for life[1]. While current climate conditions are too cold to support metabolism, climate modeling studies[2] show that variations in solar insolation associated with obliquity variations on 125kyr timescales [3] cause warmer and colder periods to occur in the region. Figure 1 shows that insolation has decreased in the region since 5-10 MY ago when conditions were much more habitable than at present. At 45° obliquity temperatures and water activity allowing microbial metabolism persist down to 75 cm depth [4].

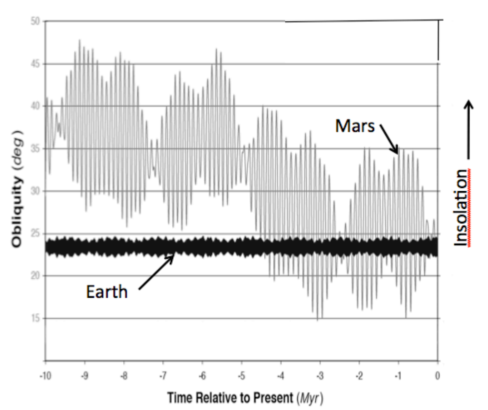

Figure 1. Obliquity on Mars and Earth over the last 10 MY. Insolation at the high latitudes increases with increasing obliquity.

Terrestrial permafrost communities are an example of possible life in the ice-rich regolith. Studies in permafrost have shown that microorganisms can function in ice-soil mixtures at temperatures as low as - 20°C, living in the thin films of interfacial water[5]. In addition, it is well established that ground ice preserves frozen but viable cells, biological material, and organic compounds for long periods of time, and living microorganisms have been preserved under frozen conditions for thousands and sometimes millions of years[6]. If life survives in the high latitude ground ice, growing when conditions allow, biomolecular evidence of life should accumulate in the soils.

Habitable conditions on Mars persisting into modern times, with periodic growth potential, motivates a search for evidence of modern life. The Mars Icebreaker Life mission[7] plans to land in the same high latitude ice-rich terrain visited by Phoenix with a payload designed to search for biomolecular evidence of life. The mission features a 1-m drill to auger subsurface icy material to the surface where it is delivered to payload instruments. The Icebreaker payload fits on the same lander spacecraft used by Phoenix and InSIGHT. The mission can be accomplished for modest cost as a Discovery mission.

Methods: We examined HiRISE images to study the recent geological history of the Phoenix landing site, to understand the geological processes occurring and the stability of the surface. Specifically, we assessed whether erosion or deposition may have removed or buried the materials of interest from the last high obliquity period 5- 10Ma ago.

The geomorphology of the region encompassing the Phoenix landing site appears to have been net erosional over Ga timescales. Pedestal craters as small as 100 meters in diameter are observed throughout the region. The pedestals' surfaces stands about 20-30 meters above the surrounding plains. Crater counts of these pedestal-bearing terrains place them at an age of ~ 1 Ga, implying an average deflation rate of the order of 10 nm/per year. The Phoenix landing site sits on the ejecta of the 600 Ma Heimdal crater which appears deflated [8]. Also, ejecta boulders are detectable in HiRISE data down to the limit of resolution [9]. These are associated with all craters greater than about 250 m and younger than about 1Ga, implying that boulders down to 35 cm in size have not been buried over the past billion years. Together, these observations suggest a net-erosional history for the region.

All craters within the 4000 km^2 area of the Phoenix landing ellipse were examined for their degree of degradation using HiRISE images [9 and this report]. Characterization was facilitated by grouping the craters into size bins of 1) less than 100 m, 2)100-300m, 3) 300-1000m and 4) greater than 1000m. The craters in bins (1) and (2) rarely exhibit ejecta blocks, implying that the material impacted is incompetent to depths of 40-60m [9]. In winter the bowls in bin (1) are filled with bright frost. These small craters disappear rapidly (Figure 2) leaving no trace except a circular fracture highlighted by frost in spring (Figure 3). Crater removal rates are substantial: 30 and 100 meter craters lose their relief in about 10^4 years and 10^5 years, respectively. Hence, impact cratering and infilling constitutes a sedimentary process in the region, and potentially a method by which water ice is trapped into the subsurface.

Discussion: In contrast to the generally static to slow erosional history of the region as a whole, net deposition occurs within small craters. The infilling process is likely related to annual deposition of dust during winter when atmospheric CO_2 condenses onto the surface at this latitude, and then sublimates in the spring, leaving the water ice and dust it brought with it behind. Winter images show bright deposits in the fresh craters. The crater bowls may prevent the wind from subsequently removing the icy dust. If a sufficiently large part of the landing ellipse has been resurfaced by impacts and subsequent crater infilling since the latest habitable period, the scientific viability of a mission seeking to target the habitable zone would be compromised. Since the habitable zone extends to no more than 75 cm depth, it is important to determine the fraction of terrain excavated and infilled to at least that depth in the last 10 Myr. Given a crater depth-to-diameter ratio of 1:5, craters as small as 5 m in diameter forming in the last 10 Myr will remove the record of the most recent habitable period. We calculated the fraction of the surface impacted by craters 5-100 m in diameter using the crater production size-frequency distribution function [10,11] and find that 1.2% of the area has been impacted forming craters between 5 and 100 meters in diameter in 10Ma. So, this is the risk that a lander without roving ability will encounter (and therefore sample) a region where the habitable zone has been overprinted by more recently deposited material.

References: [1] Stoker et al. (2010) J. Geophys. Res. Doi:10.1029/2009JE00342. [2] Richardson and Michna (2005) J. Geophys. Res. Doi:10.1029/2004JE002367. [3] Laskar et al. (2002) Nature Doi:10.1038/nature01066. [4] Zent (2008) Icarus 196, 385-408. [5] Rivkina et al. (2000) Appl. Env. Microbiology 66 (8) 3230-3233. [6] Gilchinsky et al. (2007) Astrobiology Doi:10.1089/ast.2006.0012. [7] McKay et al. (2013) Astrobiology 13, 334-353.
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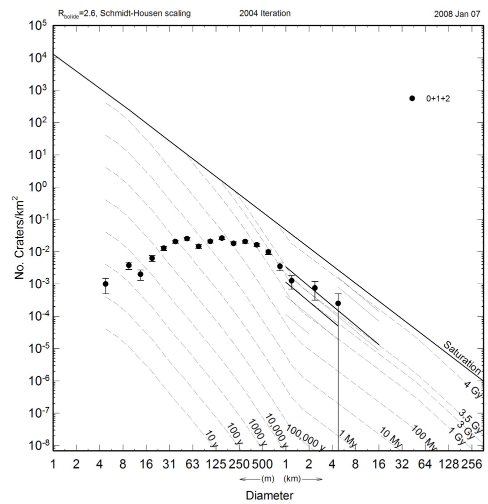

Figure 2. Crater size-frequency distribution plot for craters within the study area.

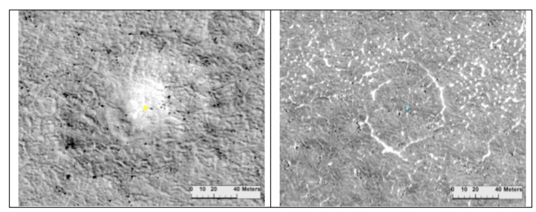

Figure 3. (Left) Small fresh crater showing a bowl with infill and no ejecta. (Right) Small modified crater completely infilled.