Site Characterization for the RedWater ISRU System. A.T. Russell,[1] N.E. Putzig,[1] K. Zacny [2], [1]Planetary Science Institute, Lakewood, CO 80401, USA, arussell@psi.edu, [2]Honeybee Robotics & Spacecraft Mechanisms Corporation, Pasadena, CA 91103, USA.

Introduction: Since the beginning of the Apollo era, it has been proposed that using resources derived locally during space missions would greatly reduce the cost of operations. This in situ resource utilization (ISRU) can save mass and cost by limiting the supplies brought by crews, and as human space exploration has advanced, investigations into the use of space resources have focused on regolith, carbon dioxide, methane, and water ice. Currently, much research is being done to determine if water ice exists in quantity and form capable of use for life support systems, radiation shielding, processing techniques, and most of all as propellant. The ice that exists on Mars is thought to be in two different forms: pore-filling ground ice and massive subsurface ice, where the latter is typically deeper. Our study focuses on the exploration and extraction of subsurface massive ice using the RedWater system [1].

Ice Resources: Deep (greater than ~ 30 m) subsurface ice resources on Mars existing mostly as massive ice have been identified through geomorphology [2, 3], and radar sounding [4, 5]. There are several morphologically-termed ice masses: Concentric Crater Fill (CCF), Lineated Valley Fill (LVF), and Lobate Debris Aprons (LDA).

Extraction: The RedWater system requires ~ 2m of overburden to stabilize operations on the surface and at least 30m of massive ice below that to operate the rodwell system (Kris Zacny, personal comm.). These system requirements are what we used as minimal constraints in exploring for candidate locations. Previous RedWater studies have suggested using the JPL ATHLETE rover which gives operational capabilities beyond current rover standards (ie. tolerant of higher rock abundance and size-frequency distribution). In any case, the analysis of traversability is beyond the scope of this study. EDL constraints beyond latitude and elevation, as described in the Human Landing Sites Study (HLS2) [6], were also beyond the scope of this study.

Prospecting: The Mars Subsurface Water Ice Mapping (SWIM) project produced a global ice consistency map for various subsurface depths by integrating ice signatures from various datasets [7, 8]. Because the RedWater system needs at minimum ~ 2m of overburden for operational stability, and ~ 30m of ice depth, we used the > 5m depth SWIM 2.0 product (Fig. 1). We constrained the data to include ice consistency values greater than 0, which is consistent with the presence of ice at these depths, when both the geomorphology and radar dielectric measurements are considered (see [7]).

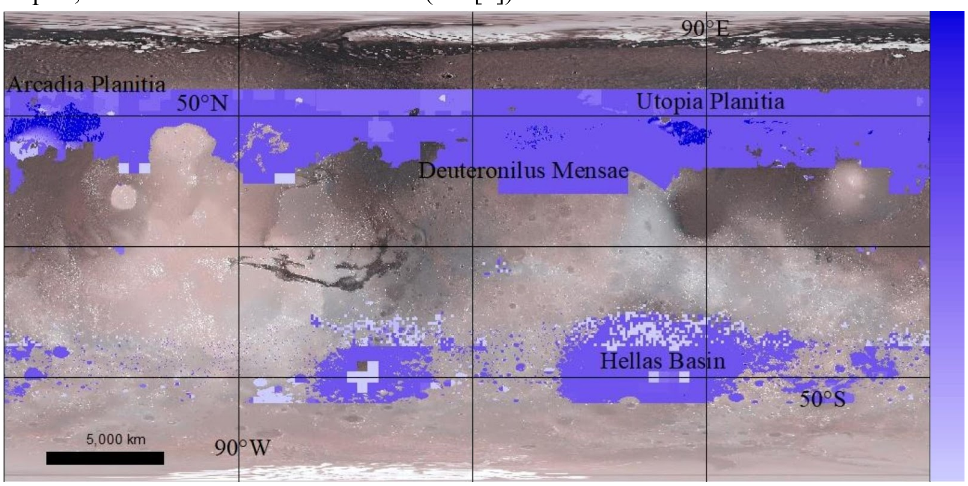

Fig. 1 SWIM 2.0 deep subsurface results. The blue scale shows ice consistency values greater than 0 at depths greater than 5m, with darker blues representing higher values up to 1.0. For values >0.5, Arcadia Planitia covers the greatest extent, followed by Utopia Planitia, Deuteronilus Mensae (Fig. 2), and Eastern Hellas Basin (too sparse to see at this scale).

The SWIM 2.0 products indicate the consistency of massive subsurface ice in the regions of Arcadia Planitia, Utopia Planitia, Deuteronilus Mensae, Protonilus Mensae, and Eastern Hellas Basin. The relative thinness of the ice and its questionable purity in Arcadia Planitia makes this region less desirable for deploying the RedWater system. While the ice reported in the Utopia Planitia region is ~ 100m thick and may meet that aspect of the system's requirements, the question of its purity remains [7], and does not instill confidence in the site being suitable for RedWater. Although the Protonilus Mensae region likely contains vast quantities of relatively pure ice, the roughness properties preclude radar detection of the base of the ice in the majority of the region [9]. Thus the confidence in the presence and purity of the ice in this region is reduced.

Eastern Hellas Basin is a possible target for the RedWater system, as it contains 100s of meters thick subsurface ice. Further imaging from the MRO High Resolution Imaging Science Experiment (HiRISE), and 3D radar processing will further improve the confidence of successfully deploying the RedWater system to this region.

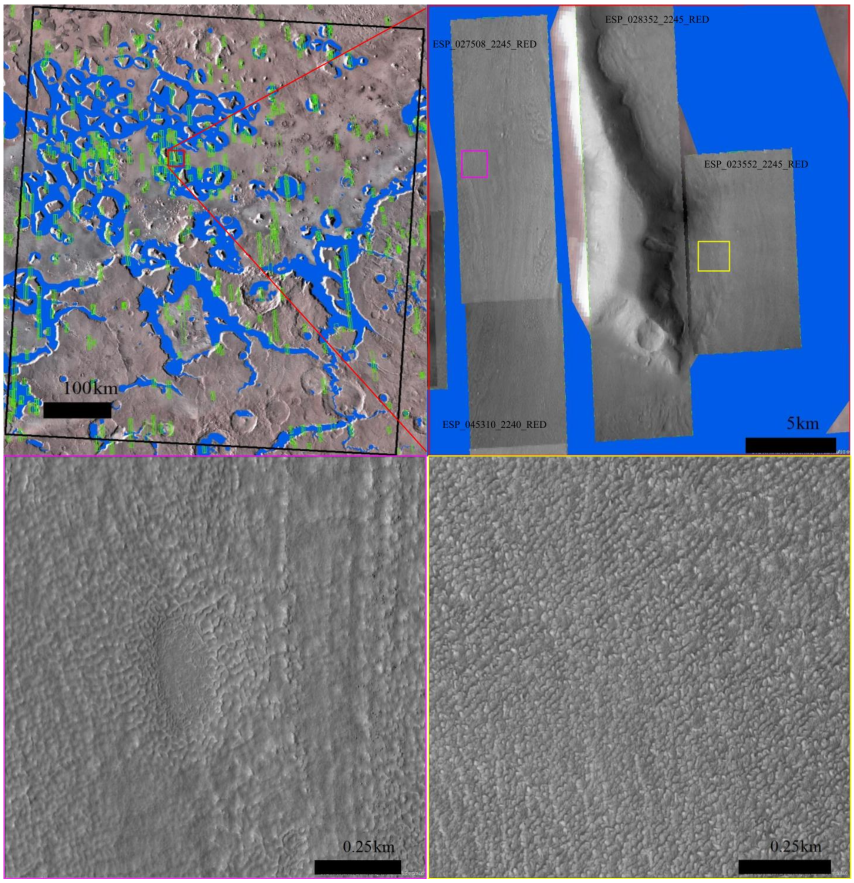

Fig. 2 HiRISE coverage of Deuteronilus Mensae. The upper left image shows the DM3D study area outlined in black with HiRISE coverage outlines (green) over glacial landforms (blue). It is apparent that the majority of HiRISE images cover the periphery of LDA. The upper right image is a zoomed in view (red box in the upper left image) of an LDA with rendered HiRISE images (IDs are labeled on top of each image) over an area midway between a central massif and the periphery. The lower left and lower right images are zoomed in views of the magenta and yellow boxes, respectively. Both lower images show examples of surface textures indicative of subsurface ice.

The high purity of the glacial landforms in the Deuteronilus region as evidenced by the high strength of the basal radar reflections and the thickness of the ice measured by the highest fidelity product available (i.e., using the 3D radargram) points to the LDA of this region as a primary target for sending the RedWater system.

The study of LDA in the DM3D radargram mapped an area of 31,000 km2 of subsurface ice [10]. Imagery from (HiRISE) covers ~ 25% of this area, and is mostly constrained to the periphery of the LDA, which was targeted to characterize their glacial morphologies and origins (Fig. 2). These portions of the LDA are likely rougher than the interior areas, potentially introducing a bias in the assessment of traversability and EDL capabilities with respect to current technologies. An increase in the distribution and coverage of high-resolution imagery across the LDA may result in the discovery of areas of greater feasibility of the traversibilty and EDL accessibility in Deuteronilus Mensae.

Conclusion: The LDA in the Deuteronilus Mensae region are the prime candidates for the RedWater system. Prior studies have demonstrated that the LDA in this region are high-purity ice glaciers that are 100s of meters thick with gently sloping surfaces and that are located equatorward of 50°N latitude. Targeting LDA areas midway between the central massifs and the periphery for HiRise imagery and stereo pairs, for use in DTMs, should be a priority to further analyze the EDL and traversability constraints. A successful deployment of the RedWater system to one of these glacial landforms will demonstrate the extractability of water ice and constrain the scalability and maturation of ice resources to ice reserves.

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