MARS SUBSURFACE WATER ICE MAPPING (SWIM): GEOMORPHIC MAPPING. N. E. Putzig[1], D. M. Hollibaugh Baker[2], G. A. Morgan[1], Z. M. Bain[1], A. M. Bramson[3], R. H. Hoover[4], M. Mastrogiuseppe[5], M. R. Perry[1], E. I. Petersen[3], H. G. Sizemore[1], I. B. Smith[1], B. A. Campbell.[6] [1]Planetary Science Institute (nathaniel@putzig.com), [2]NASA Goddard Space Flight Center, [3]University of Arizona, [4]Southwest Research Institute, [5]California Institute of Technology, [6]Smithsonian Institution.

Introduction: The Subsurface Water Ice Mapping (SWIM) in the Northern Hemisphere of Mars project supports an effort by NASA's Mars Exploration Program to determine *in situ* resource availability. We are performing global reconnaissance mapping as well as focused multi-dataset mapping to characterize the distribution of water ice from 0º to 60ºN in four longitude bands: "Arcadia" (150–225ºE, which contains our pilot-study region), "Acidalia" (290–360ºE), "Onilus" (0–70ºE, which covers Deuteronilus and Protonilus Mensae), and "Utopia" (70–150ºE). Our maps are being made available on the SWIM Project website (https://swim.psi.edu), and we intend to present final results at the next Human Landing Site Selection workshop, expected to occur in the summer or fall of 2019. Follow us on Twitter @RedPlanetSWIM for project news and product release information.

The SWIM Datasets: To search for and assess the presence of shallow ice across our study regions, we are integrating multiple datasets to provide a holistic view of the upper 10s of m of the Martian subsurface (Figure 1). The individual datasets and methods we employ include neutron-detected hydrogen maps (MONS), thermal behavior (TES and THEMIS), multiscale geomorphology (HiRISE, CTX, HRSC and MOLA), and SHARAD surface and subsurface radar echos.

Consistency Mapping: To enable a quantitative assessment of how consistent (or inconsistent) the various remote sensing datasets are with the presence of shallow (<5 m) and deep (>5 m) ice across these regions, we introduce the SWIM Equation. Outlined in detail by Perry et al. [this LPSC], the SWIM Equation yields consistency values ranging between +1 and -1, where +1 means that the data are consistent with the presence of ice, 0 means that the data give no indications of the presence or absence of ice, and -1 means that the data are inconsistent with the presence of ice. Here, we focus on our mapping of ice consistency values from both shallow and deep geomorphic mapping. For more information about the project and its various techniques and datasets, visit our website and see the other SWIM Project presentations at this LPSC: Morgan at al. (overview),

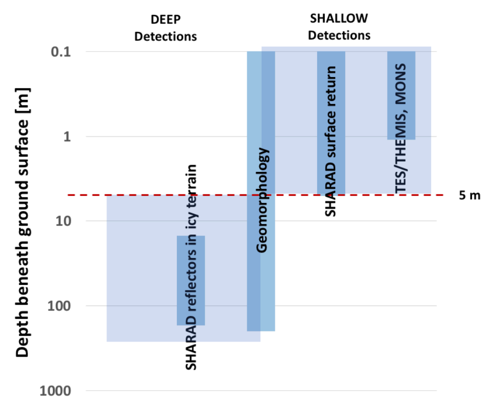

Figure 1. *Various sensing depths of the data sets and surface features used in the SWIM project to search for ice within the Martian subsurface. Geomorphic analysis spans all depths.*

Perry et al. (SWIM infrastructure), Hoover et al. (thermal analysis), Bain et al. (surface reflectivity), and Bramson et al. (radar subsurface mapping).

Methods: Extensive terrestrial research into periglacial and glacial landforms and their connection to formation processes have made geomorphology a powerful tool for inferring the current or past presence of ice on Mars. We mapped the occurrence of periglacial and glacial landforms at a range of scales using images from MRO CTX and HiRISE instruments, THEMIS IR global mosaics [1], MOLA topography and roughness [2], and SHARAD-derived roughness [3]. We also used the range of scales and types of landforms to distinguish between relatively shallow or deep ice reservoirs.

While the presence of periglacial or glacial landforms provides strong evidence that ice existed in the subsurface sometime in Mars' recent past, their occurence does not uniquely confirm that ice remains to the present day. Other datasets, including radar and thermal data, must be used to confirm subsurface ice, which is the major objective of the SWIM project.

Shallow-ice landforms: Thermal contraction-crack polygons <~25 m are abundant in mid- and high-latitude terrains [4] and certain types may indicate ice within the top meters of the near surface. Polygon type depends on both climate and subsurface ice conditions [5]. Where HiRISE images are available, we identify and classify polygons based on criteria from previous work [e.g., 4].

Other small-scale features and textures such as pits and cavities <10 m in diameter that may be related to sublimation of subsurface ice are also identified in available HiRISE images.

Deep-ice landforms: The mid-latitudes are host to inferred ice-dust “mantles” that are meters to tens of meters in thickness and that drape and smooth topography. In some locations, the mantles are disrupted by pits and scalloped terrain a few to tens of meters in depth and diameter. These features are attributed to the sublimation of subsurface ice, implying that the mantles may contain ice throughout their thickness. Recent evidence [6] confirms the pervasive ice-rich nature of young mantle units.

Lobate debris aprons (LDA), lineated valley fill (LVF), concentric crater fill (CCF), and other glacial-like forms (GLF) imply much greater concentrations of ice and are recognized based on characteristic flow patterns, convex-upward topography, and surface textures [7]. We use and verify recent mapping of these features by [8]. In addition, we use the databases of [9] and [10] and our own observations for the presence of smaller glacial features confined mostly to alcoves within the walls of plateaus and massifs.

Mapping approach: We initially used a combination of SHARAD surface roughness and images to map the general distribution of mantles inferred to be ice-rich in nature. Our current efforts focus on regions of interest (ROI) within our study areas, identified through our SHARAD reflectivity and subsurface reflector mapping. For efficiency, we employ a modified grid-mapping [11] and random sampling scheme to map the spatial occurrence of periglacial and glacial landforms across the ROIs and contained units. While CTX images cover most of the ROIs, HiRISE images are more spatially limited. Inferences on the presence of small-scale features like polygons in areas not covered by HiRISE are therefore based on interpolations between images over the same geomorphic unit.

Preliminary Results: In the Arcadia pilot-study region, we identified two broad areas of SHARAD surface roughness that are consistent with the presence of mantle units. CTX and HiRISE images show classic sublimation pitting and textures attributed to the presence of subsurface ice.

Our ROI covering Erebus Montes within Arcadia has low SHARAD surface power associated with both mantle and LDA landforms. HiRISE images reveal that the LDA have smooth mantle coverings and pitted and polygonal textures (Figure 2) that indicate ice at shallower depths than that typically inferred for LDA glacial ice. The mantle also extends into the plains and displays more complex “brain terrain” textures.

At the 50th LPSC, we will present completed maps of the distribution of observed periglacial and glacial landforms within each of the study swaths and ROI, including their inferred consistency with the presence of subsurface ice.

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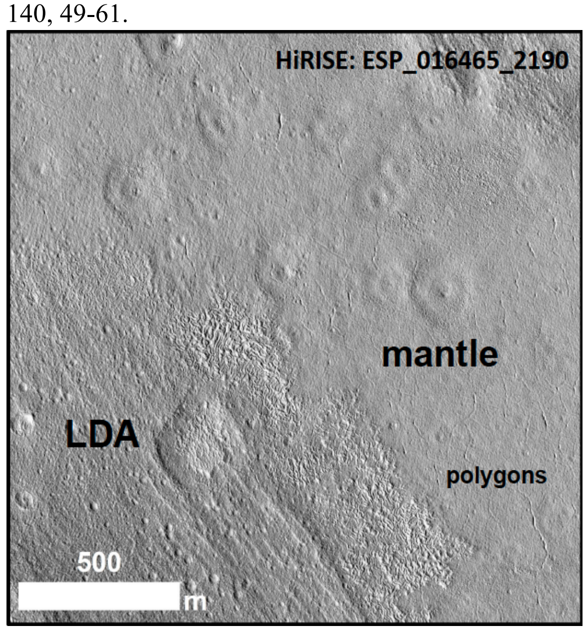

Figure 2. *HiRISE image of an LDA surface in Erebus Montes of the Arcadia study region. The surface shows smooth mantle with polygons and expanded secondary craters, suggesting shallow ice. See Fig. 2 of Bain et al. [this LPSC] for the location and map of radar surface reflectivity, which also supports the presence of ice.*