AREAL EXTENT OF SUBSURFACE BASAL REFLECTORS WITHIN THE SOUTH POLAR LAYERED DEPOSITS.

N. Abu Hashmeh[1], J. L. Whitten[1], B.A. Campbell[2], [1]Tulane University, New Orleans, LA, 70118, USA. [2]Center for Earth and Planetary Studies, Smithsonian Institution, MRC 315, PO Box 37012, Washington, DC 20013. Contact: nabuhashmeh@tulane.edu, jwhitten1@tulane.edu.

Introduction: Among the most areally extensive reservoirs of water ice on Mars, the south polar layered deposits (SPLD) in particular contain compelling evidence of variations in the planet's recent climatological history. The SPLD exhibits interbedded dust of varying thicknesses accumulated at different stages of Mars' recent orbital history [1, 2]. Early analysis of the SPLD stratigraphy was focused along the margins where layers were exposed at the surface [3-5]. Since then, radar instruments in orbit have been used to penetrate the surface of the ice to observe the stratigraphic variations throughout the interior of the SPLD [6-8]. Variations of ice and dust thicknesses show that the SPLD has undergone identifiable erosional and depositional processes before its current stagnation, providing more insight into climate behaviors during its emplacement [9]. Radar investigations have also shown the SPLD interior to exhibit low reflectivity zones, some of which are known to host sequestered carbon dioxide ice that may have played a role in the retention of surface water during past climate conditions [10, 11].

The continued collection of radar data from the SPLD will play a large role in the study of Mars' recent climate history. However, there are observable gaps in the radar datasets that may yield important information about certain parts of the SPLD interior. In particular, the ability of radar to penetrate through the entire SPLD appears to vary with signal frequency [6]. The preliminary work presented here aims to begin addressing the cause of this phenomenon by first mapping out the regions where the signal reaches the base of the SPLD.

Methods: Two orbital radar sounders prove useful for studying the SPLD interior. The Shallow Radar (SHARAD) instrument aboard the Mars Reconnaissance Orbiter (MRO) [12] emits a signal frequency of 20 MHz with a bandwidth of 10 MHz. SHARAD's along-track resolution is 0.3-1.0 km and has a vertical resolution of ~15 m in free space (~8 m in geologic materials). The Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) instrument aboard Mars Express (MEX) [13] is capable of emitting at 1.8, 3.0, 4.0, and 5.0 MHz with a bandwidth of 1 MHz and an along-track resolution of 5-10 km.

The signal reflections are processed to produce radargrams that highlight some of the underlying stratigraphy within the SPLD. One hundred and seventeen incoherently summed SHARAD radargrams [6] covering the south polar region of Mars were analyzed to identify potential basal reflectors. The identified reflectors were then sorted by confidence level with the following classifications: distinct, somewhat distinct/uncertain, and very uncertain.

Distinct features are interpreted with high confidence to be part of the basal reflector; they tend to be vertically removed from and do not exactly conform to the shape of the overlying reflectors (Fig. 1). Somewhat distinct/uncertain reflectors are unmistakably visible but can be harder to distinguish as unique from the overlying reflectors of the SPLD. In particular, somewhat distinct reflectors have a strong signal but could be questionable when trying to distinguish from the lowest reflector in a packet of reflectors. Some of the more uncertain reflectors are detected at the edge of the SPLD and often follow the shape of the ground surface just outside the edges of the ice; however, these signals tend to disappear very quickly and are harder to distinguish from overlying reflectors. The very uncertain reflectors are mostly of the same nature

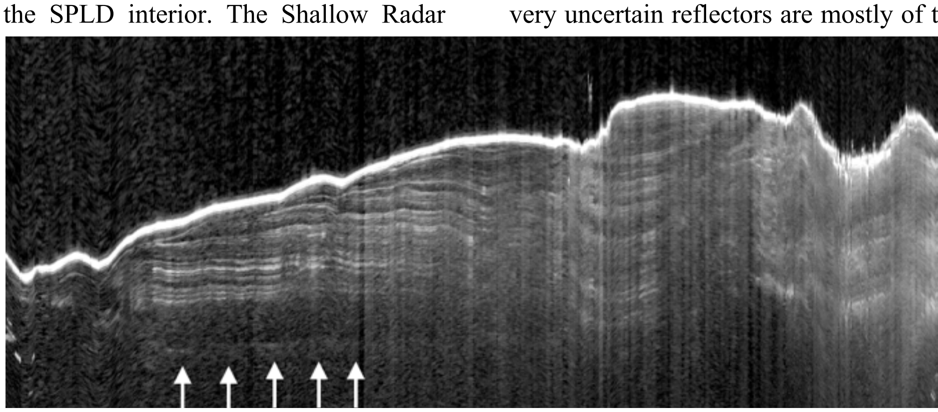

Figure 1. *Example of an incoherently summed SHARAD radargram showing a distinct basal reflector. Track number 9376-01. Only a portion of the radargram is shown.*

as the somewhat distinct/uncertain class, but are faint enough that their edges become difficult to define with precision; alternatively, these signals can be visually apparent but lack a distinct enough shape to resemble a basal reflector surface.

Some radargrams have more than one visible reflector. These potential reflectors were spatially projected in map view to visualize their locations within the SPLD (Fig. 2). Beyond map projections, further analysis will be done to determine the influence of the SPLD's surface morphology and characteristics on the presence of basal reflectors.

Preliminary Results: MARSIS is able to penetrate through and detect a basal reflector throughout most of the SPLD [8], while SHARAD is unable to penetrate through the entire thickness of the ice before being scattered and attenuated. The SHARAD signal is greatly attenuated in the thickest regions of the SPLD, but the signal is also observed to be scattered and attenuated in the thinnest portions of the SPLD, like Ultimate Lingula. This scattering creates a fog-like appearance most readily observable in the thicker regions of the deposit [6]. Due to the different frequency ranges between these two instruments, it is apparent that this phenomenon is frequency dependent.

SHARAD radargrams typically show features at the edges of the SPLD which could be interpreted as the basal reflector. These edge reflectors quickly disappear towards the thicker parts of the SPLD, but they can provide a constraint on some of their boundaries. Out of the 117 radargrams analyzed, 19 contained distinct basal reflectors, 19 contained somewhat distinct features, 57 were uncertain, and 22 were very uncertain.

The majority of these reflectors are found in SHARAD tracks that overlap. Overlapping tracks were referenced to each other to confirm the existence of a reflector; some of these same features appear with different distinctiveness across these overlapping tracks. Most of the identified reflectors are associated with thinner regions along the perimeter of the SPLD, but some notable detections exist beneath the residual polar cap in thicker ice (Fig. 2). In addition, there is an apparent cluster of distinct reflectors around 225º degrees that extend considerably far into the SPLD; another less distinct but still notable cluster exists around 350º degrees. Very few observed reflectors appear to be completely isolated. Since they appear to exist within a reasonably close proximity to one another, clusters of less distinct detections may provide more confidence for identifying the basal reflector within that region.

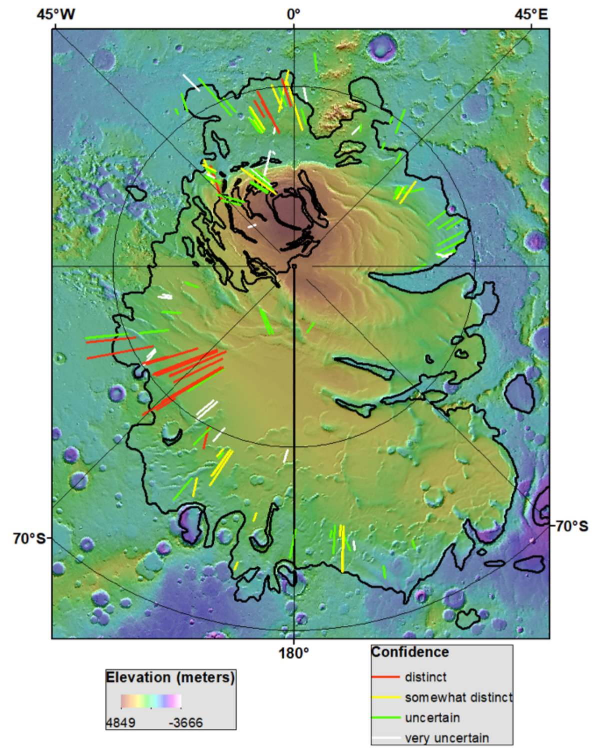

Figure 2. *Basal reflector detections in SHARAD radargrams projected onto the SPLD. Mars Orbiter Laser Altimeter (MOLA) hillshade maps at 128 ppd.*

Future Work: Following this preliminary work, more incoherently summed SHARAD radargrams will be analyzed and added to the dataset. MARSIS has recorded much more data since it was initially used to map the basal interface [14], so these data will also be heavily utilized to re-map the basal interface. MARSIS data will be analyzed using the same techniques presented here to map the basal interface of the SPLD, which will then be used as a reference for the SHARAD reflectors to better constrain the nature of their response.

References: [1] Thomas P. et al. (1992) *Mars* pp. 767-795. [2] Laskar et al. (2002) *Nature, 419,* 375-377. [3] Toon O. B. et al. (1980) *Icarus, 44,* 552-607. [4] Cutts J. A. and Lewis B. H. (1982) *Icarus, 50,* 216-244. [5] Byrne S. and Ivanov A. B. (2004) *JGR, 109,* E11001. [6] Whitten J. L. and Campbell B. A. (2018) *JGR: Planets, 123,* 1541-1554. [7] Milkovich S. M. and Plaut J. J. (2008) *JGR, 113,* E06007. [8] Milkovich et al. (2009) *JGR, 114,* E03002. [9] Smith I. B. et al. (2016) *Nature, 352* (6289), 1075-1078. [10] Phillips et al. (2011) *Science, 332,* 838-841. [11] Bierson et al. (2016) *GRL, 43,* 4172-4179. [12] Seu et al. (2004) *PSS*, *52,* 157-166. [13] Picardi et al. (2005) *Science, 310,* 1925-1928. [14] Plaut J. J. et al. (2007) *Science, 316,* 92-95.