NEW RADAR EVIDENCE FOR GLACIERS IN MARS PHLEGRA MONTES REGION.

A. Safaeinili[1], J. Holt[2], J. Plaut[1], L. Posiolova[3], R. Phillips[4], J.W. Head[5], R. Seu[6] and the SHARAD team [1]Jet Propulsion Laboratory, Pasadena, California, 91109, ali.safaeinili@jpl.nasa.gov; [2]University of Texas Institute for Geophysics, Jackson School of Geosciences, University of Texas, Austin, TX 78758 USA; [3]Malin Space Science Systems, San Diego California; [4]Planetary Science Directorate, Southwest Research Institute, Boulder, CO 80302 USA; [5]Dept. of Geological Sciences, Brown Univ., Providence, RI 02912 USA; [6]InfoCom, University of Rome, "La Sapienza," 00184 Rome, Italy.

Introduction: SHARAD radar sounder has provided new evidence pointing to the presence of large bodies of buried pure ice in both the northern and southern mid-latitude of Mars. The radar evidence pointing to the presence of glaciers on Mars was reported by Holt et al. (2008) and Plaut et al. (2008). Data from earlier missions such as the Viking orbiter images had raised the possibility of the presence of interstitial ice in a set of features called Lobate Debris Aprons (LDAs) on the basis of their flow-like patterns. Head and Marchant [3] summarized examples (in the 30-60° latitude band) illustrating an alternative hypothesis, that these features represented debris-covered glaciers instead of ice-assisted creep of talus. Hauber et al. [4] identified geometric evidence for the past presence of LDA in the expected glacial latitude band. However, before SHARAD data became available, it was difficult to more accurately estimate the amount of ice present in the LDAs, with models of ice-lubricated talus flow predicting as little as 15% ice. SHARAD was designed to probe down to 1 km at Mars. The data have shown that it has penetrated as deep as 3 km in polar terrain.

Debris-Covered Glaciers: The radar data very definitely rule out the presence of a major rock or dust component in the interior of the LDA features examined thus far; arguments are presented in detail in both Holt et al [1] and Plaut et al. [2]. On this basis, we interpret many of the LDAs as containing a very high concentration of water ice, covered by a relatively thin blanket of dust and rock debris on the surface. This surface cover is a sublimation lag and has been an effective thermal insulator [5] that has preserved most of the ice since it was deposited in place during eras of active debris-covered glaciers [e.g., 6,7].

We have identified a new site in the northern hemisphere of Mars (~36.3º N; 162.3º E) that is among the southernmost of the mid-latitude glacial deposits identified to date [3]. The deposit contains ring-mold craters (RMC), geomorphic features that suggest the presence of buried ice [8]. There are some differences between this site and the site at Eastern Hellas [1]. Inspection of the radar data and the Context camera image reveals a relatively rougher surface. This may be related to the less stable environment for water ice at this more equatorward latitude. Any disturbance of the surface debris (thermal blanket) may result in a larger

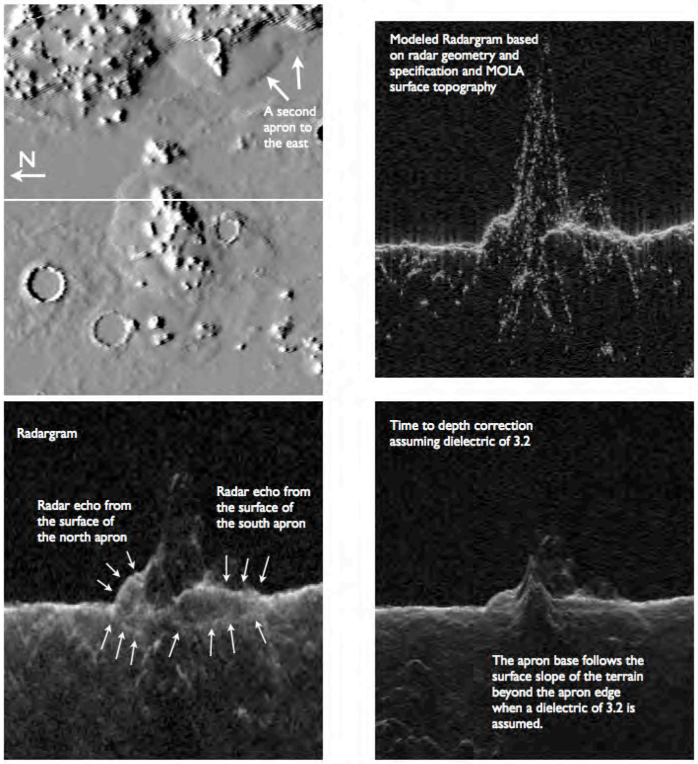

Figure 1: Top left shows the MOLA map with radar track overlaid. The edges of the apron are relatively clearly seen in MOLA map and correspond to where SHARAD data indicates are radar returns from the subsurface. Bottom left image shows the radar data in along-track distance (horizontal axis) and radar signal time of arrival (vertical axis). Careful inspection reveals a fork-like feature where the top echo is associated to the surface and bottom fork signal is associated with the base of the apron. After radar overflies the peak, it detects the base of the apron to south of the peak. This track was a descending track and hence the north is to the left. The base of the fork is observed reasonably well correlated with the boundary of the apron to the south. Top right is an equivalent of the SHARAD radargram but generated using a SHARAD modeling program at JPL that uses only radar specifications and geometry along with available topography from MOLA. We note the absence of the bottom portion of the fork in the model data indicating it cannot be a surface feature limited only by the precision of the MOLA data in this region. Considering the high-fidelity duplication of other surface features we believe the quality of MOLA data used for this model is adequate. The bottom right figure is a transformation of the distance/time to distance/depth assuming a dielectric constant of 3.2. Speed of light is fastest is free space. The raw radargram (left bottom) if interpreted as depth, assume a dielectric of 1 everywhere. However a signal returning from depth traveling though ice (or any other material) would arrive later than expected. The bottom right image corrects for this difference and results in a more intuitive depth image and further corroborates the dielectric of the material being close to that of ice. This assumes that the based of the apron is at level with exposed background

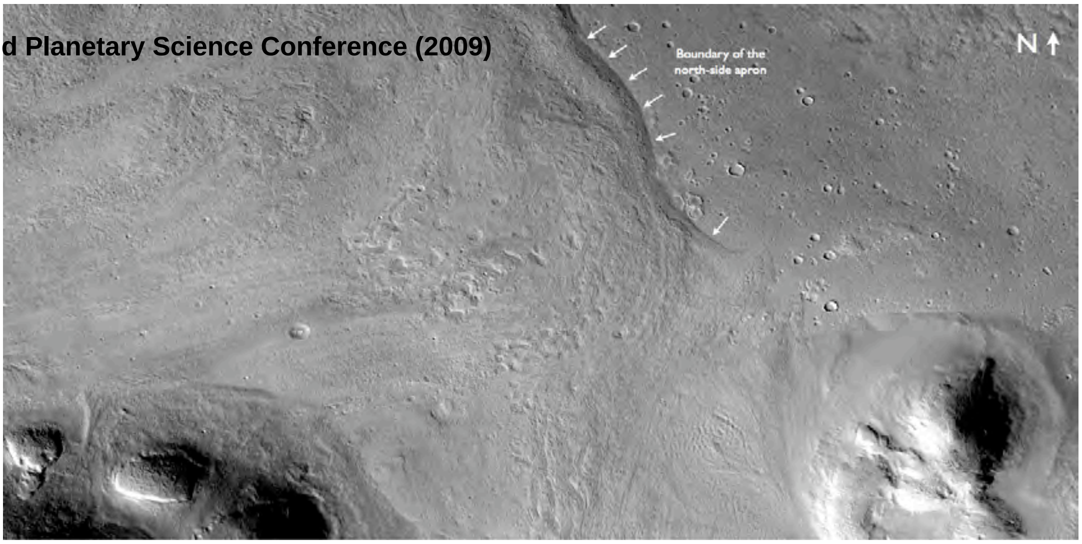

Figure 2: A portion of the apron showing surface roughness due to relatively fresh impacts and sublimation pits in contrast with more impact craters visible beyond the apron boundary. A close inspection of this figure indicates the presence of lineated features emanating from the high ground (lower left) and ending at the boundaries of the apron (upper right).

amount of ice sublimation, thus producing a rougher surface, as suggested by the abundant sublimation pits seen in the central part of Fig. 2. Radar evidence for increased surface roughness is a higher level of surface clutter in the SHARAD radargram. SHARAD's shortest wavelength is 12 m and as a result it is sensitive to roughness at the surface as low as few meters at a footprint of 3 km cross-track by 400 m along-track. The effect of the clutter is evident in the model radargram shown in Fig. 1 (top right). Part of the clutter is much finer than roughness captured by MOLA altimetry data and this is seen as incoherent late returns. Although, we could not rule out the point that the observed clutter could be due to internal scattering, inspection of the Context image provide evidence for the level of roughness that explains the observed incoherent scattering visible in the radargram. This is in contrast to a lack of volumetric scattering at both Eastern Hellas site and the Deuteronilus site. Both of these sites are more poleward in the southern and northern hemisphere. Assuming a dielectric of 3.2 for the apron yields a maximum depth of 180 and 130 meters for the northern and southern aprons respectively. The extent of the apron in the north is ~12 km and in the south ~25 km (although not shown in the image since the track was cut off at the boundary of the image). A very rough estimate for the area underlain by water ice at this site is ~100 cu. km. These findings support the idea that lobate debris aprons are debris covered glacier remnants dating back to a former Late Amazonian mid-latitude glacial climate period and that significant ice remains sequestered below the surface today [9].

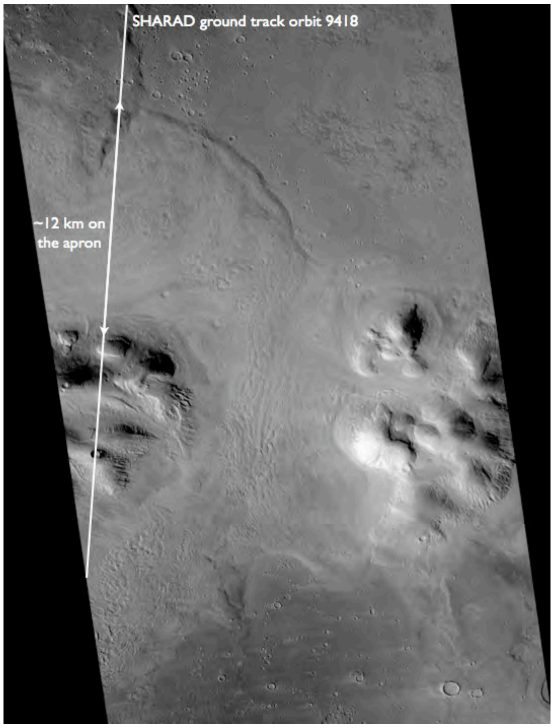

Figure 3: An overview CTX image showing the full track on the northern part of the apron but missing the southern part of the radar track

References:

[1] J. Holt et al., Science Magazine (2008). [2] J. Plaut et al. (2008) *GRL*. [3] Head and Marchant (2006) 37th Annual Lunar and Planetary Science Conference, abstract no. 1127. [4] Hauber et al. (2008) J. Geophys. Res., 113, E02007, doi:10.1029/2007JE002897. [5] J. Helbert et al., LPSC 39, #1909, 2008; [6] J. Head et al., *GRL* 33, L08S03, 2006; [7] J. Head et al. *EPSL* 241, 663, 2006; [8] A. Kress and J. Head, *GRL* 35, 35501, 2008; [9] J-B Madeleine et al, *LPSC 38* 1778, 2007.