RADAR EVIDENCE FOR ICE IN LOBATE DEBRIS APRONS IN THE MID-NORTHERN LATITUDES OF MARS. J.J. Plaut[1], A. Safaeinili[1], J.W. Holt[2], R.J. Phillips[3], B.A. Campbell[4], L.M. Carter[4], C. Leuschen[5], Y. Gim[1], R. Seu[6] and the SHARAD Team. [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, plaut@jpl.nasa.gov, [2]University of Texas Institute for Geophysics, Jackson School of Geosciences, University of Texas, Austin, TX 78758, [3]Southwest Research Institute, Boulder, Colorado 80302, [4]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, D.C. 20560, [5]Center for Remote Sensing of Ice Sheets, University of Kansas, Lawrence, KS 66045, [6]INFOCOM Department, University of Rome "La Sapienza," 00184 Rome, Italy.

Introduction. Martian lobate debris aprons (LDAs) are thick (100s of m) masses of material that extend up to several 10s of km from high relief slopes and terminate in lobate fronts [1-3]. Their geomorphic expression and restricted occurrence in latitude has led numerous workers to conclude that LDAs contain a significant fraction of ice [1-6]. In this study, we present new evidence from the SHARAD (Shallow Radar) sounding experiment on Mars Reconnaissance Orbiter (MRO) that suggests that LDAs in the Deuteronilus Mensae region of the mid-northern latitudes consist mostly of ice. The current presence of large ice masses at these latitudes has important implications for the climate evolution of Mars, and for future targets for in situ exploration.

Lobate debris aprons of Deuteronilus Mensae. LDAs were first observed in Viking orbiter data, and were interpreted to be members of a class of features indicative of the presence of ground ice [1-3]. Deuteronilus Mensae (40-51N, 14-35E), part of the dichotomy boundary "fretted terrain" [7] contains a high concentration of LDAs [8]. The LDAs occur at the base of scarps of mesas, knobs, craters and valley walls [9]. Relief of the "parent" features is generally 1-2 km, and most of the LDAs themselves have 300-800 m of relief relative to the surrounding valley floors. LDAs are typically ~10 km long, measured perpendicular to the trend of the parent scarp, with a range of lengths of 5-25 km. Analysis of topographic profiles of LDAs showed them to be consistent with viscous deformation of ice [10]. Image data show many features indicative of flow and surficial modification likely related to the presence of subsurface ice in LDAs of this region and elsewhere on Mars [e.g., 1-4, 9-13]

SHARAD data. SHARAD is an orbital subsurface radar sounder on MRO operating at a center frequency of 20 MHz [14]. Vertical resolution is 15 m (free space), with a horizontal footprint of 0.3-1 km by 3-6 km. Data were processed using a focused synthetic aperture technique. SHARAD has demonstrated the capability to probe several km deep in ice-rich polar deposits to detect a lower boundary with a presumably ice-poor substrate [e.g., 15]. To date, SHARAD has acquired ~20 observations across the Deuteronilus LDAs. LDAs show a distinctive signature in SHARAD radargrams: a single, surface interface seen on the valley floors "splits" into two interfaces at the distal margin of the LDA (see figure). As the ground track proceeds up the LDA toward the parent scarp, the lower echo appears at greater time delays. This behavior is essentially identical to that observed at the margin of polar layered deposits in martian sounding data [16-17]. When the groundtrack reaches the parent scarp, the lower echo abruptly disappears. The complex topography of the fretted terrain frequently generates surface "clutter" signals that can appear at time delays similar to subsurface interface detections. To distinguish clutter from subsurface detections, we have generated radargrams of the expected clutter using high-fidelity simulations and MOLA gridded topography data. Many of the LDAs show late echoes not predicted by the clutter models, making them candidates for subsurface detections. Because potential clutter-producing topography may occur at scales smaller than the MOLA grid, we plan to run simulations using high resolution DEM data, such as those derived from the Mars Express HRSC camera. However, in many cases, inspection of MOLA topography and higher resolution imagery indicates that surface clutter cannot be responsible for the lower echoes, and we thus conclude that SHARAD is detecting subsurface interfaces deep within the LDAs.

Electrical properties and compositional constraints. We can use SHARAD data to constrain the real and imaginary (loss term) dielectric constant of the LDA material, and thus obtain indications of composition. Following the methodology of [18], we can estimate the real part of the dielectric by assuming that the detected interface is the continuation of the valley floor surface beneath the LDA. In most cases, a real dielectric of about 3 (corresponding to pure ice, among other materials) brings the lower echo into alignment with the surroundings after a time-to-depth conversion. An alternative to this solution is that the LDA material has a dielectric greater than 3, and that the detected interface actually lies at an intermediate depth within the LDA and is not concordant with the valley floor. We can constrain the loss term by examining the decrease in echo power from the detected interface with depth. We observe a typical rate of decrease of ~2 dB/μs for the 2-way echo, equivalent to 10-15 dB/km 1-way attenuation for a range of real dielectric constant of 3-6. These attenuation values correspond not to pure ice, but are consistent with a mixture of ice and a lossy contaminant, with a contaminant fraction no more than a few 10s of percent. While ice-free low-loss materials could also explain these observations, we note that the radar observations are entirely consistent with material dominated by ice. The vast amount of corroborating evidence for ice-rich LDAs from image and topographic data supports this view. We also note that a high fraction of ice in the LDA material is consistent with the hypothesis of [8], that moats around certain mesas at lower latitudes are the footprint of former LDAs that were efficiently removed in response to changing environmental conditions, with the implication that the bulk of the removed LDA material was ice.

Implications. The presence of ice at mid-northern latitudes, if confirmed, has important implications for the history of water and climate on Mars. The paucity of craters on the LDAs indicates that if not formed in mid-to-late Amazonian time, they were at least *de*forming in that period. It remains to be determined if the source of the ice was from the subsurface or the atmosphere. In either case, current thick ice deposits at the mid-latitudes of Mars should be considered as targets for future landed missions. If accessible, the ice could be analyzed for biomarkers and potentially utilized as a resource. SHARAD data of LDAs in other regions of Mars, including the Eastern Hellas area of the southern hemisphere [19] show similar signatures of deep penetration and relatively low loss.

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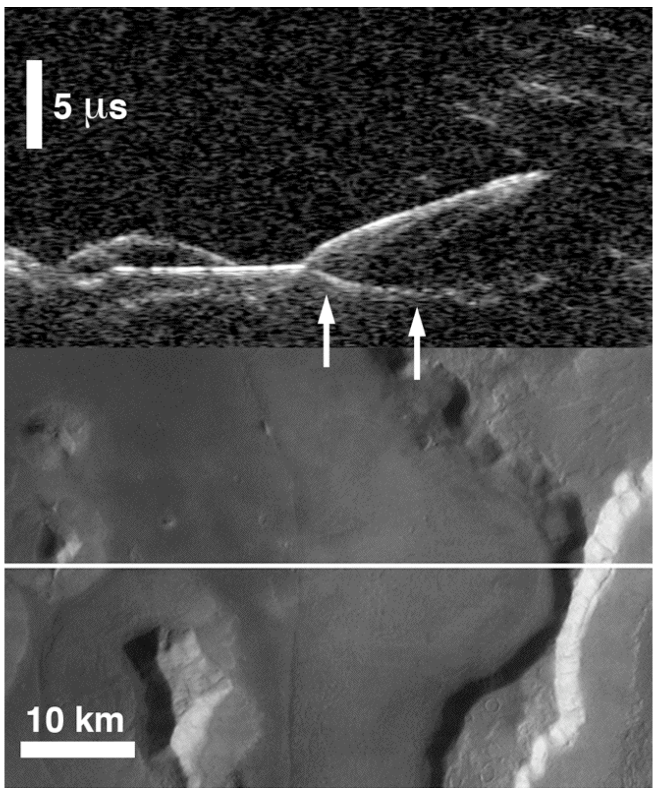

SHARAD radargram (top) and HRSC image (bottom) of lobate debris aprons in Deuteronilus Mensae (41.8N, 18.4E). Arrows indicate detections of a subsurface interface in the radargram. Relief on the LDA is about 700 m. [Credit: SHARAD and HRSC teams].