RADAR SOUNDING OF SUBSURFACE LAYERS IN THE SOUTH POLAR PLAINS OF MARS: CORRELATION WITH THE DORSA ARGENTEA FORMATION. J. J. Plaut[1], A. Ivanov[1], A. Safaeinili[1], S. M. Milkovich[1], G. Picardi[2], R. Seu[2], R.Phillips[3]. [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, plaut@jpl.nasa.gov. [2]Infocom Department, "La Sapienza" University of Rome, 00184 Rome, Italy, [3]McDonnell Center for the Space Sciences and Department of Earth and Planetary Sciences, Washington University, St. Louis, MO 63130.

Introduction: The south polar region of Mars contains three major terrain types, each representing a different epoch in Martian history. This pattern was recognized from Mariner and Viking orbiter images, and was documented in Viking-based geologic maps [1]. The oldest terrains are Noachian cratered plains, similar to much of the southern highlands. The youngest terrains, Amazonian in age, include the water-ice-rich layered deposits, and the residual high-albedo ice, which is predominantly CO_2. Intermediate in age is the Hesperian Dorsa Argentea Formation (DAF), which has a notably lower crater density than the Noachian cratered plains, and displays a number of enigmatic features, such as heavily pitted materials and sinuous ridges. The origin of the DAF has been ascribed to various processes, including volcanism, aeolian deposition [1, 2], debris flows [3], and glacial and subglacial activity [4-7]. In this study, we hope to shed new light on the nature of the DAF materials by probing them with orbital subsurface sounding radar, using the MARSIS and SHARAD instruments. MARSIS has obtained substantial coverage of the DAF areas, while only preliminary observations are available from SHARAD.

MARSIS and SHARAD Instruments and Data: MARSIS (Mars Advanced Radar for Subsurface and Ionospheric Sounding) [8] on the Mars Express orbiter and SHARAD (SHAllow RADar) [9] on the Mars Reconnaissance Orbiter (MRO) are synthetic aperture orbital sounding radars. In its subsurface modes, MARSIS typically operates in two of four frequency bands between 1.3 and 5.5 MHz, with a 1 MHz instantaneous bandwidth that provides free-space range resolution of approximately 150 m. Lateral spatial resolution for the cross-track footprint is 10-30 km, and for the along-track footprint, narrowed by onboard synthetic aperture processing, 5-10 km. SHARAD operates at a central frequency of 20 MHz, with a 10 MHz bandwidth, providing free-space range resolution of 15 m. Lateral resolution is 3-6 km cross-track and 0.3-1.0 km along-track. MARSIS data described here were collected during the southern hemisphere campaign of 2005-2006. More than 300 orbits of subsurface sounding data were collected in the south polar region. SHARAD data were collected in the early Primary Science Phase of the MRO mission in late 2006 and early 2007. Results described in this abstract are primarily from MARSIS observations, while results from early SHARAD observations will be presented at the conference.

Observations: The most prominent feature in MARSIS subsurface sounding data of the south polar region is the frequent detection of a subsurface interface below the Amazonian south polar layered deposits (SPLD) [10]. This is interpreted as the interface between the ice-rich SPLD and the lithic substrate. This interface is detected below most of the SPLD, to an estimated depth of 3.7 km in the thickest section of the SPLD (Fig. 1). Beyond the margins of the SPLD, many MARSIS south polar passes display echoes from subsurface interfaces at depths from a few 100 m below the surface to likely over 1 km (Fig. 1). Estimating the depth of such an interface requires an assumption of the speed of the wave in the medium, which is a function of the real dielectric permittivity (equivalent to the square of the refractive index). In the polar region, it is reasonable to expect that the material above the interface is a mixture of ice and lithic material (e.g., basalt). Considering the dielectric properties of these end member materials, the depth corresponding to the interface at the maximum time delay in the example shown in Fig. 1 is between 600 and 900 m, the larger depth being obtained for the ice end member.

The off-SPLD interfaces are observed over a wide area of the south polar region (Figure 2). They occur as far as 1000 km beyond the SPLD margin, on approximately 2/3 of periphery of the SPLD. This includes the floor of the remnant Prometheus basin in the vicinity of 90° E longitude, a broad zone of plains stretching from the Sisyphi Montes/Cavi area around 0° E through Argentea Planum and Cavi Angusti near 270° E, and the smooth area known as Parva Planum between 240° and 270° E. The areal distribution of these interfaces is remarkably similar to the location of the Hesperian Dorsa Argentea Formation as mapped by [1] (Figure 2). This correlation suggests that the radar sounders are sensing characteristics of the upper ~1 km of the subsurface that are unique to the DAF among terrains in the south polar area.

Discussion: What are the detected interfaces and what do they tell us about the DAF? The sounding data do not provide unique compositional information, but they do offer constraints on the electrical properties which, in combination with observations from other sensors, can narrow the range of hypotheses. A simple model of the radar propagation involves a layer of lower dielectric constant material overlying a half-space of higher dielectric constant material. The absolute and relative echo strengths of the surface and subsurface interfaces, and the time delay between them, are inputs into such a model; the results are a narrowed range of electrical properties, specifically, the complex dielectric constant of the upper layer, and the real part of the dielectric constant of the lower layer. The roughness of these surfaces is another parameter to consider, as it affects the backscatter behavior. In the case of the DAF interfaces, as a first hypothesis we consider the upper layer to consist of ice-rich regolith, overlying a relatively ice-poor lithic substrate. We find that the radar data are consistent with such a scenario, with a substantial fraction of ice required in the upper layer. This preliminary result raises a number of interesting questions. For example, is this putative ice-rich layer connected with the shallow (~1 m) ground ice detected by the gamma ray and neutron detectors on Mars Odyssey [11]? Is the material (including H_2O ice) a fossil sediment from the original deposition of the DAF? How much H_2O is present, and how significant is this reservoir in the global water inventory of Mars? Further data collection, including high resolution observations from SHARAD, and integrated analyses of radar and other remote sensing data should provide answers to some of these questions.

References: [1] Tanaka, K.L and D.H. Scott (1987) USGS Map I-1802-C. [2] Plaut, J.J. et al. (1988), Icarus 76, 357. [3] Tanaka, K.L. and E.J. Kolb (2001), Icarus 154, 2. [4] Kargel, J.S. and R.G. Strom (1992), Geology 20, 3. [5] Head, J.W. and S. Pratt (2001), JGR 106, 12175. [6] Milkovich, S.M. et al. (2002), JGR 107, 10.1029/2001JE001802. [7] Ghatan, G.J. and J.W. Head (2004), JGR 109, 10.1029/ 2003JE002196. [8] Picardi, G. et al. (2004), ESA SP-1240, 51. [9] Phillips, R.J. et al. (2007), JGR, in press. [10] Plaut, J.J. et al. (2006), LPSC 37th, abstr. 1212. [11] Boynton, W. et al. (2002), Science 297, 81.

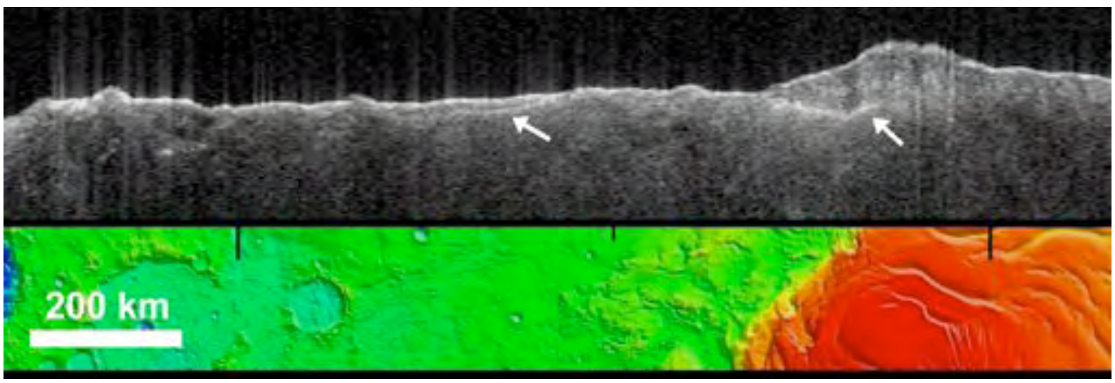

Figure 1 (above): MARSIS radargram from orbit 2638, and MOLA topography along the ground track. Left arrow indicates subsurface interface associated with DAF unit. Right arrow indicates subsurface interface below SPLD. DAF interface has a maximum time delay of 10.5 μsec after the surface return, which corresponds to a depth of 600-900 m, depending on the speed of the wave in the material. DAF feature is from 75°-80° S, along 320° E. Basal interface below the SPLD is at estimated depth of 3.2 km.

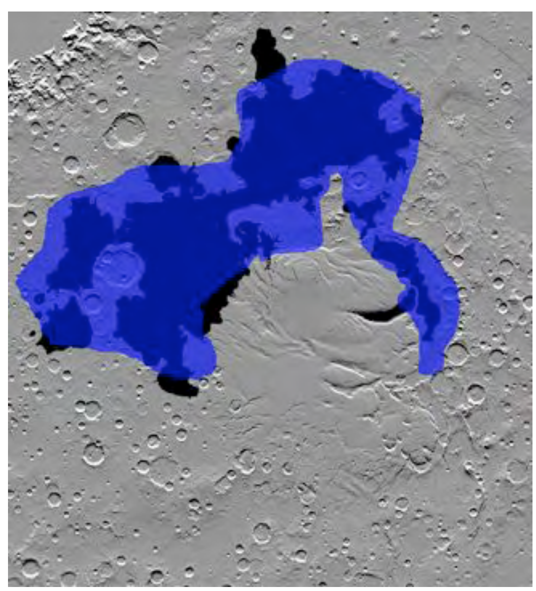

Figure 2 (right): MOLA shaded relief map of the south polar region, with color overlays of the DAF as mapped by [1] in black, and of the distribution of shallow subsurface interfaces detected by MARSIS in blue. The high degree of correlation suggests that MARSIS is detecting characteristics of the subsurface unique to the DAF among the terrains in this region.