SUBSURFACE STRUCTURE OF THE SOUTH POLAR LAYERED DEPOSITS, MARS. R. J. Phillips[1], N. E. Putzig[1], J. W. Head[2], A . F. Egan[1], J. J. Plaut[3], A. Safaeinili[3], S. E. Smrekar[3], S. M. Milkovich[3], D. C. Nunes[3], B. A. Campbell[4], L. M. Carter[4], J. W. Holt[5], R. Seu[6], and R. Orosei[7]; [1]Planetary Science Directorate, Southwest Research Institute, Boulder, CO 80302 USA; (roger@boulder.swri.edu); [2]Dept. of Geological Sciences, Brown Univ., Providence, RI 02912 USA; [3]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109 USA; [4]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, D.C. 20560 USA; [5]University of Texas Institute for Geophysics, Jackson School of Geosciences, University of Texas, Austin, TX 78758 USA; [6]INFOCOM Department, University of Rome "La Sapienza," 00184 Rome, Italy; [7]Istituto Nazionale di Astrofisica, I-00133 Rome, Italy.

Introduction: The South Polar Layered Deposits (SPLD) making up Planum Australe on Mars exceed 3 km in thickness [1] and are composed largely of water ice [1, 2]. Their internal structure had been inferred from vertical exposures such as those on trough walls. The sounding radars MARSIS [3] on Mars Express and SHARAD [4] on Mars Reconnaissance Orbiter penetrate the SPLD and record reflections from interfaces within the ice, which likely represent changes in dust content. By design, MARSIS and SHARAD are complementary instruments. In terms of the SPLD, MARSIS almost always detects a basal reflection [1], whereas SHARAD rarely does, but it resolves internal layering to a greater degree. Here we focus on SHARAD data in an attempt to understand the large-scale internal structure of the SPLD.

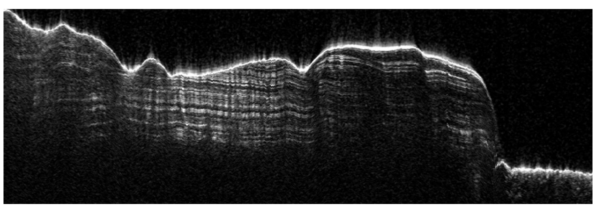

Figure 1. Portion of SHARAD radargram on orbit 5222 crossing Promethei Lingula (Promethei Planum and north are to the right). Time delay has been converted to depth by assuming a real permittivity of 3.15 below the surface. Width of radargram is ~400 km, and height of Promethei Lingula approaches 1 km. There is apparent normal faulting near the north end of Promethei Lingula, though the alternative hypothesis of a drape structure cannot be rejected at this juncture. The apparent dip of layering is to the north and in places is truncated at the surface, as noted earlier [9, 10].

NPLD for Reference: The internal structure of the deposits at the North Pole is simpler than that of the SPLD and it is useful to review what we have learned there, particularly from the radars. The northern cap (Planum Boreum) can be divided into the North Polar Layered Deposits (NPLD) of mostly ice (and a small fraction of dust) overlying a platy Basal Unit (BU) [5] composed of ice, sand, and dust. The NPLD has fine-scale layering, observed in images and SHARAD radargrams, that likely corresponds to 100-Kyr-scale climate forcings [6]. SHARAD also observes packets of this fine-scale layering separated by interpacket regions of very few reflections (hence layers) [6]. This larger-scale packet/interpacket structure may correspond to Myr-scale variations in obliquity. In particular, it is proposed [6] that the three observed interpacket zones correspond to three intervals of low obliquity at ~0.8, ~2.0, and ~3.2 Ma [7] within a total NPLD age of ~5 Myr corresponding to the present epoch of low mean obliquity [8]. A reasonable question is whether or not climate forcings have led to similar structures in the SPLD.

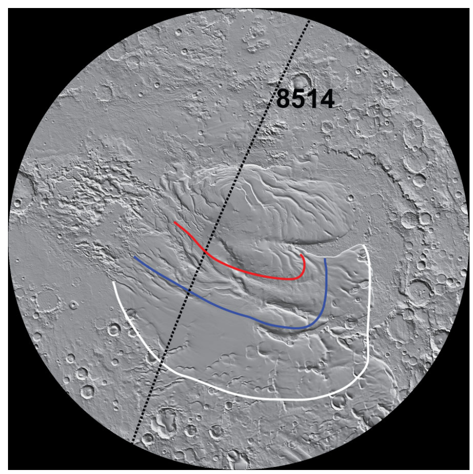

Figure 2. Generalized boundaries of the three radar facies defined in the text. White line is the northern boundary of the plateau facies, blue line is the northern extent of the trough facies, and the red line marks the boundary with the Australe Mensa facies. South polar projection of MOLA shaded relief extends to 72° S. 180° longitude is at the bottom of figure.

Packet/Interpacket Structures in the SPLD: In fact, SHARAD data reveal that at least one portion of the SPLD contains a packet/interpacket structure. Such structure was first radar-mapped in Promethei Lingula [9] and examined in detail by Milkovich et al. [10]. Figure 1 shows a portion of a radargram from orbit 5222 crossing Promethei Lingula. A complex packet/interpacket structure is revealed, which fades

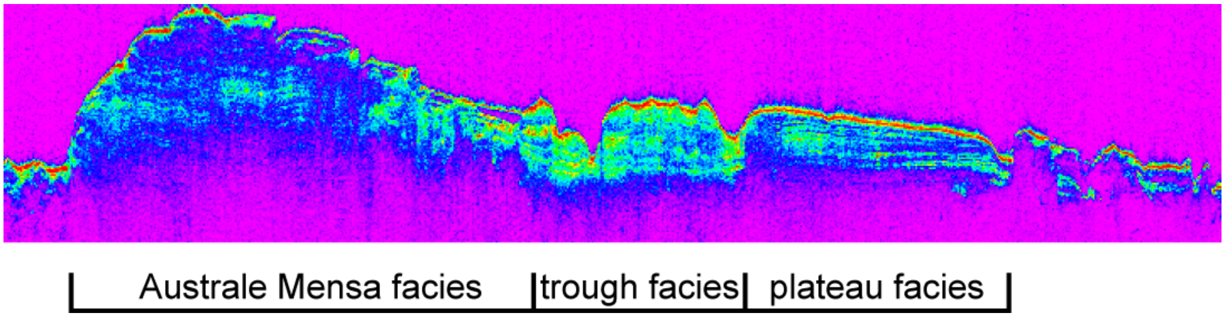

Figure 3. Color-stretched radargram for orbit 8514 (location shown in Fig. 2). Time delay has been converted to depth as in Figure 1. Width of radargram is ~1300 km.

out as it progresses into the main (high-standing) lobe of Planum Australe. In many SPLD radargrams, there are clearly more than three interpacket regions, and this is a minimum as the basal reflector is typically not detected, as noted previously [e.g., 10].

SPLD Radar Facies: We examined a number of radargrams distributed in longitude around Planum Australe and subdivided the data into three radar facies. The packet/interpacket structure corresponds typically to the generally northward dipping plateau centered roughly on 180° longitude (Fig. 2) and is termed the *plateau facies*. As in orbit 5222, the packet/interpacket structure in the other radargrams cannot be traced into the main lobe of the cap, which is characterized typically by a number of weak reflectors not in any obvious packet/interpacket organization. This region is termed the *Australe Mensa facies*. In between these two facies is a region that is badly distorted in the original (time-delay) format of the radargrams because of the complex topography of troughs. In some cases, there is clearly a continuation of the packet/interpacket structure, while in others the radar structure is coarser. For this region we use the term *trough facies*. The approximate boundaries of these three facies are shown in Figure 2.

Understanding why the plateau facies and the Australe Mensa facies are so different has been a challenge since the first SPLD radargrams were available in late 2006. A color stretch of the radargram for orbit 8514 is shown in Figure 3, and the three radar facies are noted. The trough facies shows internal structure, but not of the fine-scale observed in the plateau facies. There is a hint that the trough facies structure continues laterally into the high-standing Australe Mensa portion of the cap as a grouping of relatively bright reflectors. Comparisons to MARSIS show that the SHARAD radar signals do not completely penetrate Australe Mensa. From image analysis, Milkovich and Plaut [11] proposed that the layers exposed in Promethei Lingula region (and elsewhere) form a layered sequence (PLL) that extends throughout Planum Australe but is buried deeply under Australe Mensa. The plateau facies and the trough facies and its possible extension into the subsurface of Australe Mensa may correspond to this layered sequence.

Discussion: If the idea of relating packet/interpacket structures to orbital cycles is correct for both the NPLD and the plateau facies of the SPLD, then the formation interval for the latter must exceed the hypothesized 5 Myr age for the NPLD [8] because this facies contains more interpacket regions than the three proposed to occur in the NPLD formation period [6].

Crater-count-based age estimates of the SPLD [12,13] exceed the age of the NPLD as based on models of ice stability at the North Pole [8]. The packet/interpacket structure in the plateau facies supports this view, but begs the question as to why the stratigraphically higher sequence (BFL of [11]) does not have a similar form, and also why the uppermost portions of the plateau facies in places have no radar reflections at all (e.g., to depths of ~100 m in the Ultimum Chasma region) [14]. That the PLL sequence might be seen deep into Australe Mensa but have a different form than the plateau facies may have more to do with the behavior of the radar signal than with the actual structural form of these layers.

References: [1] J. J. Plaut et al. (2007) *Science*, *316*, 92. [2] M. T. Zuber et al. (2007) *Science*, *317*, 1718. [3] G. Picardi et al. (2005) *Science, 310*, 1925. [4] R. Seu et al. (2007) *JGR*, doi:10.1029/2006JE002745. [5] M. C. Malin and K. S. Edgett (2001) *JGR*, *106*, 23,429. [6] R. J. Phillips et al. (2008) *Science*, *320*, 1182. [7] J. Laskar et al. (2002) *Nature*, *419*, 375. [8] B. Levrard et al. (2007) *JGR*, *112*, doi:10.1029/2006JE002772. [9] R. Seu et al. (2007) *Science* *317*, 1715. [10] S. M. Milkovich et al. (2009) *JGR*, doi:10.1029/ 2008JE003162, in press. [11] S. M. Milkovich and J. Plaut (2008) *JGR*, *113*, doi:10.1029/2007JE002987. [12] K. Herkenhoff and J. J. Plaut (2000) *Icarus*, *144*, 243. [13] M. R. Koutnik et al. (2002) *JGR*, *107*, doi:10.1029/2001JE001805. [14] S. M. Milkovich et al. (2009) *LPS XXXIX,* Abstract #1466.