NORTH POLAR DEPOSITS ON MARS: NEW INSIGHTS FROM MARSIS, SHARAD AND OTHER MRO INSTRUMENTS. R. J. Phillips[1], R. Seu[2], D. Biccari[2], B. A. Campbell[3], J. J. Plaut[4], M. T. Zuber[5], S. Murchie[6], S. Byrne[7], A. Safaeinili[4], R. Orosei[8], L. Marinangeli[9], A. Masdea[2], G. Picardi[2], S. E. Smrekar[4], L. M. Carter[3], N. E. Putzig[1], D. C. Nunes[10] and the SHARAD Team; [1]McDonnell Center for the Space Sciences and Department of Earth and Planetary Sciences, Washington University, St. Louis, MO 63130 (phillips@wustite.wustl.edu); [2]INFOCOM Department, University of Rome "La Sapienza," 00184 Rome, Italy (Roberto.Seu@uniroma1.it); [3]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, D.C. 20560; [4]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109; [5]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139; [6]Applied Physics Laboratory, 11100 Johns Hopkins Rd., Laurel, MD 20723; [7]Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona 85721; [8]Istituto di Astrofisica Spaziale e Fisica Cosmica, Istituto Nazionale di Astrofisica, 00133 Rome, Italy; [9]IRSPS - Universita' d'Annunzio, Viale Pindaro 42, Pescara, PE 65127 Italy; [10]Lunar and Planetary Institute, Houston, TX 77058.

Introduction: The north polar region of Mars is an immense sedimentary basin recording up to 3 BY of Amazonian deposition and erosion of ice, dust, and sand of varying composition. The Polar Layered Deposits (Apl [1]), the upper unit of this stack, had been recognized from Viking images [e.g., 2]. The layering, finely-scaled and continuous over large distances, is thought to have resulted from orbital cycles, with variations in albedo resulting largely from different fractions of dust and ice [3, 4]. With the availability of high resolution images from the Mars Orbiter Camera (MOC) and the topographic information from the Mars Orbiter Laser Altimeter (MOLA) from the MGS mission, a new understanding of the polar deposits emerged. Specifically, a stratigraphic Basal Unit (BU) was identified [5], lying over the Hesperian Vastitas Borealis Formation (VBF), pervasive in the northern lowlands, and lying unconformably beneath Apl. BU is considerably different than Apl [1,6,7], principally in its lower albedo, but additionally it is characterized as platy and irregular compared to Apl [6]. Dark material in BU is likely dominated by sand-sized particles. High-resolution images from the HiRISE (High Resolution Imaging Science Experiment) camera on MRO show that BU is an interbedded sequence of ice-rich and sand-rich layers [8]. This is corroborated by the spectral channel for ice of the MRO CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) instrument [9]. Overall, the ice content of BU is decidedly less than Apl. Furthermore, the circumpolar erg, most prevalent at Olympia Undae, is likely material shed from BU [6].

Understanding the origin and evolution of both the Apl and BU units will provide important information on the Amazonian climate history of Mars. The first step in this enquiry is to determine the structure, distribution, and composition of these units. The MRO instrument payload is ideally suited to this task, carrying a sounding radar, SHARAD (SHAllow RADar), in addition to its high-resolution camera (HiRISE) and imaging spectrometer (CRISM). Here we focus on the contributions of sounding radars, both SHARAD and its predecessor MARSIS (Mars Advanced Radar for Subsurface and Ionosphere Sounding), which operates on the Mars Express orbiter and was provided jointly by the Italian Space Agency (ASI) and NASA. SHARAD is an ASI contribution.

Prelude – MARSIS North Polar Results: MARSIS is a complementary instrument to SHARAD (see below), carries out successful subsurface soundings in 1-MHz bands at 3, 4 or 5 MHz, and has a vertical resolution of 150 m (free-space). Early in the data acquisition phase, MARSIS obtained a defining pass (orbit 1855) over the north polar deposits [10]. The radargram showed a strong basal reflection at a depth consistent with the elevation of the surrounding plains and little or no flexure due the weight of the polar cap load. The strength of the basal reflection was surprising, implying little or no electrical path loss through ~2 km of polar deposits. This requires cold ice (<240 K), consistent with the low basal heat flow implied by the lack of a flexural response to the load. Additionally, the modest signal attenuation observed through the polar stack implies nearly pure ice, consistent with the absence of BU in this region [1,6]. In the radargram, bright banding within the polar deposits signifies internal reflections, but individual layers are poorly resolved as might be expected given the vertical resolution of the instrument. Commencing in November of 2006, MARSIS was able to collect additional data at high northern latitudes. Perhaps the most germane result for the discussion here is that the MARSIS radar detects a basal reflection in the erg at Olympia Undae, and by continuity with the basal reflector under the polar stack, suggests that the erg is indeed a continuation of BU, which in the Olympia Undae region is pinching out in contact with the underlying VBF.

Introducing SHARAD: The primary scientific objectives of SHARAD are to map and interpret dielectric interfaces in the shallow subsurface (~1 km depth) [11,12]. The radar has a 20-MHz center frequency and a 10-MHz bandwidth, complementing the lower frequencies of MARSIS. Vertical and horizontal resolutions are, respectively, 15 m (free-space) and 3-6 km (cross-track) by 0.3-1 km (along-track).

SHARAD North Polar Results: Figure 1 is a portion of a SHARAD radargram for MRO orbit 1512. The radar returns can be divided into a finely-structured upper unit, about 600 m thick, and a less well defined set of reflections from a lower unit that is up to 1400 m in thickness. The upper unit contains about twenty relatively strong reflectors that likely under-resolve a more finely layered ice-dust sequence [13,14]. The lower unit contains about a dozen apparently distinct reflectors. A relatively weak, diffuse reflector at ~2 km depth coincides with the strong basal reflector observed in MARSIS orbit 1855, which crosses the SHARAD orbital track in this locale. The continuation of the 1512 radargram to the south (not shown) indicates that the deep reflector merges with the surrounding plains surface. It is unclear from this one radargram whether or not the base of the upper unit marks the boundary between Apl and BU, or instead separates two portions of Apl with different dielectric layering properties, with the Apl-BU boundary deeper in the section, if it exists in this portion of the polar cap at all [1,6]. HiRise images [8] clearly show that Apl consists of a shallow-slope-forming upper unit and a polygonally-fractured, steep-slope-forming lower unit. It is possible that the finely-structured SHARAD unit corresponds to the upper HiRISE unit.

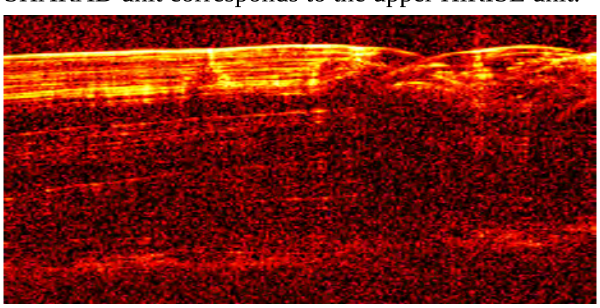

Figure 1. SHARAD radargram on orbit 1512 at ~35°E longitude traversing ~82°-84°N (right to left). The vertical axis is "time," and an approximate depth scale is obtained by assuming a relative dielectric constant of 3, which yields a thickness of ~600 m for the finely structured unit. "Hotter" colors indicate stronger radar returns.

Figure 2 shows a portion of a SHARAD radargram on orbit 1545, which crosses Chasma Boreale in the range 340°-350°E. The basal reflector is evident across the radargram and in fact can be traced in the down-track continuation of the radargram to the edge of the cap at Olympia Undae, but not beyond, as SHARAD does not have the same penetration depth as MARSIS. The finely-structured upper unit is variable in thickness, and nearly disappears on the chasma wall bordering the main lobe of the cap. This is consistent with HiRISE observations [8] if the SHARAD upper unit corresponds to the shallow-slope unit of Apl described above. Additionally, and as in orbit 1512, reflections from within the SHARAD lower unit are observed.

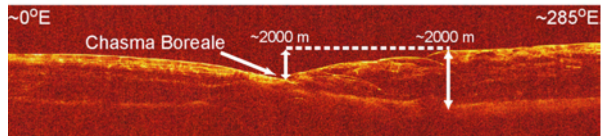

Figure 2. Portion of SHARAD radargram for orbit 1545. The radargram traverses across a portion of the "minor" lobe of the polar cap (centered on ~0°E), across Chasma Boreale, and nears the highest elevation of the "main" lobe of the cap. The full radargram extends to ~210°E and ends in Olympia Undae. The apparent deepening of the basal reflector, mirroring the surface elevations, is an artifact of the slower wave velocity of the polar deposits compared to that of the atmosphere. The arrows indicate that depth to the basal reflector is relatively constant.

Discussion: This brief foray into the northern cap structure shows the promise of combining MARSIS and SHARAD results with other remote sensing data, such as from HiRISE and CRISM. Of course, having a lot more data and putting together the three-dimensional story is necessary.

Geophysics plays an important role in determining the structure of the north (and south) polar deposits. High-resolution gravity data obtained by MRO (and earlier missions) combined with MOLA topography data can provide average column densities across the cap, constraining the ice content of BU. SHARAD and MARSIS provide constraints on volume and on the amount of lithospheric flexure due to the cap load, the latter helping to turn apparent density into real density. Wave velocity in the cap depends strongly on density, so the radar-gravity analysis will be nicely coupled.

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