COMPOSITIONAL CONSTRAINTS ON THE MARTIAN NORTH POLAR BASAL UNIT FROM MARSIS RADAR SOUNDING DATA. J.J. Plaut[1], A. Frigeri[2] and R. Orosei[2], [1]Jet Propulsion Laboratory, California Institute of Technology, Mail Stop 183-601, 4800 Oak Grove Dr., Pasadena, CA 91109, plaut@jpl.nasa.gov, [2]Istituto di Astrofisica e Planetologia Spaziali, Istituto Nazionale di Astrofisica, via del Fosso del Cavaliere 100, 00133 Roma, Italy.

Introduction: The Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) onboard the European Space Agency's Mars Express orbiter uses a relatively low frequency radar (1.3-5.5 MHz) to deeply sound the subsurface of Mars [1]. The martian polar plateaus, which consist primarily of ice-rich polar layered deposits (PLD), are especially amenable to deep subsurface sounding at these frequencies. While MARSIS data of the polar regions have been acquired periodically since 2005, the best coverage has been limited to the south polar region. The Mars Express orbit periapsis, where MARSIS data are acquired, has passed over the north pole three times since the start of MARSIS operations, but only during seasons when the surface was mostly illuminated by the sun. Finally in 2011, MARSIS observed the north polar plateau in night time conditions, when the electron content of the ionosphere is low enough for MARSIS to obtain its highest quality echoes. In this paper, new MARSIS data are presented for the NPLD and associated deposits. These low altitude nightside data provide the highest signal-to-noise and lateral spatial resolution yet obtained by MARSIS. The new data have allowed estimation of the dielectric constant (or refractive index) of the lower, "basal" unit of the north polar plateau, providing constraints on its composition.

Previous MARSIS data of the polar plateaus: MARSIS briefly observed the edge of the NPLD during the instrument commissioning phase in 2005. This small dataset provided the first glimpse of the instrument's ice sounding capabilities. The observations indicated that the ice of Gemini Lingula was nearly pure, and that little to no deflection due to the load of PLD ice was occurring in this region [2]. These findings were confirmed by later observations of the area by SHARAD [3-6]. Subsequent MARSIS observations of the north polar plateau, though sub-optimal in geometry and solar illumination, were used to map the position of the lower contacts of the PLD and of basal unit, and to constrain the volume of these units [7]. While SHARAD is generally capable of mapping the upper contact of the basal unit [5], only MARSIS is able to consistently detect and map the lower contact with the underlying lithic substrate (see Figure 1). Presumably this is due to the lower frequency of MARSIS compared to SHARAD, but the exact mechanism (scattering at interfaces or within the volume, frequency dependency of loss) is not well understood. For the south polar plateau (SPLD), successful nightside campaigns resulted in mapping of the basal interface and improved measurements of the total volume of the SPLD [8].

MARSIS 2011 north polar campaign: Between June and December 2011, MARSIS collected over 250 high quality observations of the NPLD. During the prime period of the campaign, the periapsis of the Mars Express orbit passed over the north polar plateau on the night side. This combination of low altitude and night side produced the highest resolution along-track (< 5 km) and the best signal-to-noise due to the absence of ionospheric distortion and absorption. Away from periapsis, MARSIS obtained polar data deeper into the night than on any previous north polar campaign. In addition to the standard mode data, in which 50-100 echoes are processed onboard and not downlinked, numerous segments of raw data were obtained. These include continuous segments up to 25 seconds in duration. This allows for optimized ground data processing, including focusing algorithms which are now routine on SHARAD but have not yet been utilized on MARSIS data.

Observations of the basal unit: The lower section of the north polar plateau consists of a distinct, complex, layered unit commonly called the "basal unit" (BU). Visible images suggest the unit has a higher lithic content than the overlying NPLD, and outcrop morphology and associations with current dune features have led to the suggestion that the BU is sand-rich [9-11]. While much of the lower contact of the BU was mapped using previous MARSIS data, some areas could not be mapped due to limited coverage or poor signal-to-noise [7]. In particular, BU in the region including the Rupes Tenuis scarp and plateau, where a thick section of BU is exposed without overlying NPLD, was poorly imaged in past data, but is clearly detected in the recent data (Figure 1). The echo time delay between the surface return and the lower contact of the basal unit can be used to estimate the speed of the radar wave in the material. Assuming that the relief at Rupes Tenuis represents the entire thickness of BU at this location, we obtain a real dielectric constant of approximately 4, significantly higher than that of pure ice, or of the NPLD alone observed at Gemina Lingula [2, 4]. Evidence for such higher dielectric constants is found elsewhere in the BU in recent MARSIS data [12]. The values suggest a substantial non-ice component to the BU composition. For a mafic component, the fraction could be as high as 50%. If the lithic material is some other composition (e.g., gypsum), the fraction could be even higher. While the new data suggest a large fraction of non-ice composition, the fact remains that much of the MARSIS signal penetrates to the base of the BU without significant absorption, indicating low losses and hence placing some upper bounds on the nature of the lithic component. Futher analysis and mapping of the propagation of MARSIS signals through the BU will allow a more accurate volume estimate of the unit, and a revised estimate of its total volatile inventory. This revision is likely to be downward from [7], since that study obtained thickness estimates using a pure-ice propagation speed. Further comparisons with SHARAD data, particularly with optimized processing of raw echoes, can help address issues such as the physical mechanism of the different response of the two radars to propagation through the basal unit, and the fundamental question of the cause of reflections internal to the PLD in the radar sounding observations.

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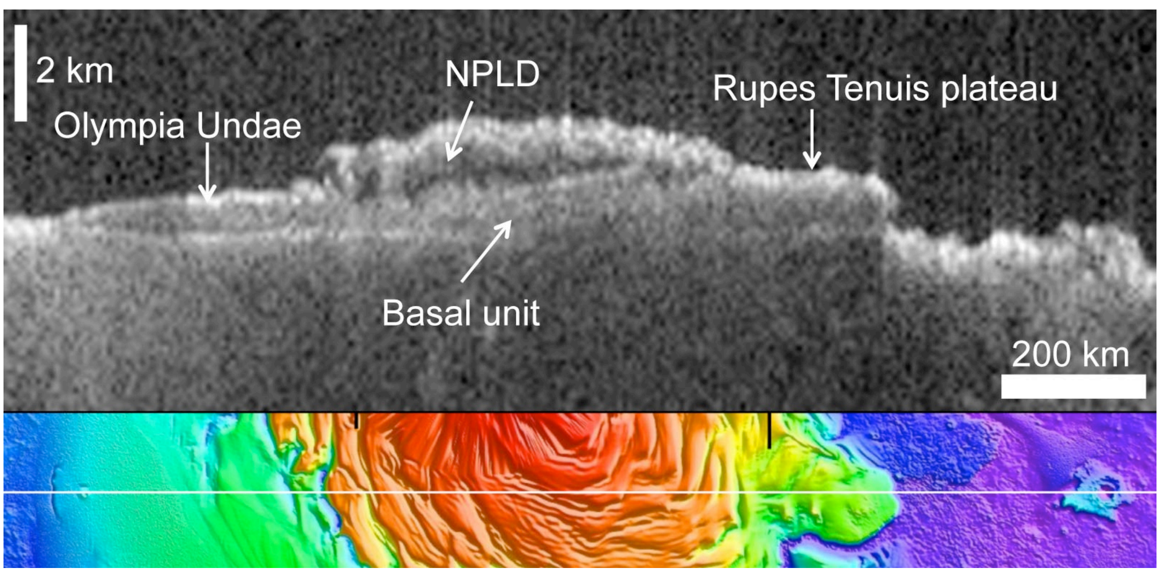

Figure 1. MARSIS observation 9548 of the north polar plateau, obtained in 2011. The vertical dimension has been converted from time to distance, using the propagation speed of radar waves in ice. The basal unit is marked by a diffuse echo signature, with a relatively sharp upper boundary and a generally reflective lower contact. This lower contact, presumably with the underlying Vastitas Borealis formation, is approximately flat-lying in this profile, and extends across the entire plateau, from beneath the Olympia Undae dunes at left to the base of the Rupes Tenuis scarp at right.