MARSIS SUBSURFACE RADAR SOUNDING OF MERIDIANI PLANUM, MARS: IMPLICATIONS FOR THE PROPERTIES OF THE PLAINS DEPOSITS.

Thomas R. Watters[1], **Carl J. Leuschen**[2], **Bruce A. Campbell**[1], **John A. Grant**[1], **Gareth A. Morgan**[1], **Nathaniel E. Putzig**[3], and **Roger J. Phillips**[4], [1]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, D.C. 20560, USA (watterst@si.edu); [2]Center for Remote Sensing of Ice Sheets, The University of Kansas, Lawrence, Kansas 66045, USA; [3]Department of Space Studies, Southwest Research Institute, Boulder, Colorado 80302, USA; [4]Planetary Science Division, Southwest Research Institute, Boulder, Colorado 80302, USA and Washington University, St. Louis, Missouri 63130, USA.

Introduction: The Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) onboard the European Space Agency's Mars Express spacecraft has been returning data since June 2005 [1]. The MARSIS sounder has to date successfully probed two major units on Mars, the polar layered deposits (PLD) [2] and the Medusae Fossae Formation (MFF) [3]. The radar sounder data clearly delineate the subsurface interface between PLD and MFF materials and the underlying terrain. The PLD at the south and north poles are known to be ice-rich deposits. The MFF deposits occur along the dichotomy boundary and may be composed of volcanic ash, eolian sediments, or an ice-rich material analogous to the PLD. Here, we describe subsurface reflectors that are recognized in MARSIS sounder data over the hematite-bearing plains and etched plains deposits of Meridiani Planum.

The MARSIS Radar Sounder: The MARSIS instrument is a multi-frequency synthetic aperture orbital sounding radar that operates in four frequency bands between 1.3 and 5.5 MHz in its subsurface modes. Its free-space range resolution is ~150 m and the cross-track and along-track footprint sizes range from 10 to 30 km and 5 to 10 km, respectively [1]. The time delay of the peak surface return is corrected to agree with the corresponding MOLA topographic profile along the orbit track to compensate for the high variability in ionospheric phase distortion [3].

Subsurface Detections in Meridiani Planum: The plains material of Meridiani Planum (Fig. 1) are one of the best studied deposits on Mars. They have been the subject of intense observations from orbit and on the ground. The Mars Global Surveyor Thermal Emission Spectrometer (TES) [4] revealed hematite-bearing material that overlies etched deposits containing hydrated sulfates and hydrated iron oxides detected by OMEGA [5, 6, 7, 8, 9]. The Opportunity rover revealed the surface materials of the hematite-bearing plains (HBP) consist of aeolian basaltic sand containing sulfates and hematitic concretions [10]. The HBP deposits, characterized by smooth plains with occasional dunes, are thin relative to the etched plains (EP) deposits that comprise a layered sedimentary sequence thought to have formed or been altered in an aqueous environment [9].

MARSIS Tracks: MARSIS orbits obtained in 2007 (03914 and 03925), 2010 (08247), 2011 (09266), and 2012 (10109) cover the HBP and EP plains deposits east of the Opportunity landing site. Radargrams for the MARSIS orbits show subsurface echoes offset in time-delay from the surface return where the orbits pass over the HBP and EP deposits (Fig. 2, 3). The subsurface echoes are interpreted to be nadir reflections from the interface between the EP deposits and the underlying cratered terrain based on the scale of the time-delay offsets and estimates of the thickness of the EP deposits. Relatively deep subsurface echoes in orbits 03925 and 10109 are about 200 km east of the Opportunity landing site (Fig. 2A, B). Subsurface echoes in orbits 03914 and 08247, located ~50 km further east, show dipping subsurface echoes where EP deposits appear to thin locally to the north (Fig. 3A, B). The maximum offsets in time-delay from the surface return are comparable to those in the MARSIS orbits to the west (Fig. 2A, B).

Implications for the EP Deposits: MARSIS observations provide an opportunity to evaluate the electrical properties of the EP deposits. Estimates of the maximum thickness of the EP deposits are ~600 to 900 m based on elevation differences between the deposits and the adjacent cratered terrain [5, 9]. Analysis of PLD and MFF deposits, where subsurface reflectors with equal and greater time-delays occur in MARSIS observations, suggest a value of bulk real dielectric constant ε' of ~3 (consistent with pure water ice) based on the agreement between the inferred depth of the basal interface and the projection of the surrounding surface [2, 3]. Elevation differences between the HBP and nearby cratered terrain suggest EP deposits are ~800 m thick in areas where the subsurface reflectors are located. Assuming a ε' of ~3, the observed maximum time delays in the EP deposits correspond to a thickness of ~860±60 m, in good agreement with maximum thickness estimated for the EP deposits [9]. If the maximum thickness of the EP deposits is closer to 600 m [5], then larger values of ε' (~6), indicative of a dry geologic medium, are suggested. A real dielectric constant of 3 is consistent with a substantial component of water ice in the EP deposits. This is an intriguing possibility in light of the evidence that the HBP and EP deposits either formed in or were altered by liquid water [9, 10, 11]. As in the case of MFF deposits, however, a very porous, low-density, ice-poor deposit cannot be ruled out.

References: [1] Picardi G. et al. (2005) *Science*, 310, 1925-1928. [2] Plaut J.J. et al. (2007) *Science*, 316, 92-95. [3] Watters T.R. et al, (2007) *Science*, 318, 1125-1128. [4] Christensen, P. R., et al. (2000) *JGR*, 105, 9623– 9642. [5] Hynek, B.M. et al. (2002) *JGR*, 107, 5088, doi:10.1029/2002JE001891. [6] Arvidson, R.E. et al. (2003) *JGR*, 108, 8073, doi:10.1029/2002JE001982. [7] Gendrin, A. et al. (2005) *Science*, 307, 1587–1591. [8] Arvidson, R.E. (2005) *Science*, 307, 1591– 1594. [9] Griffes J.L. (2007) *JGR*, 112, E08S09, doi:10.1029/2006JE002811. [10] Squyres, S.W. et al. (2004) *Science*, 306, 1698–1703. [11] Andrews-Hanna J. C. et al. (2007) *Nature*, 446, 163-166.

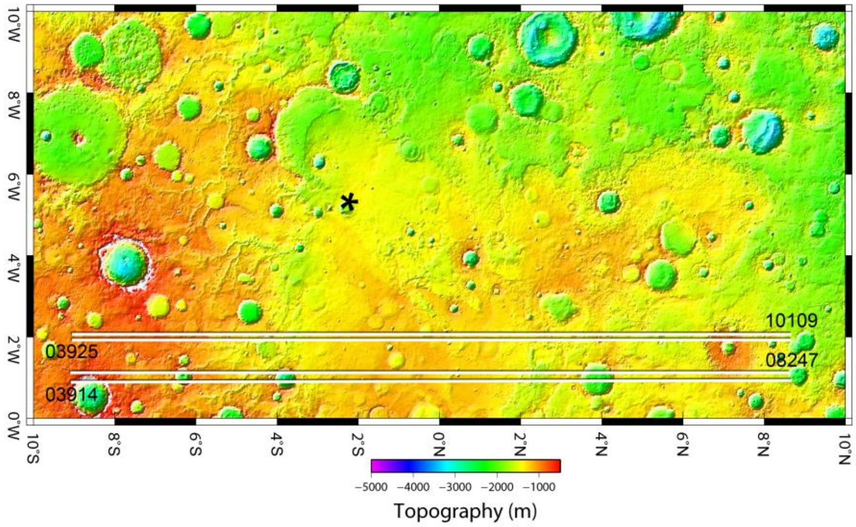

Figure 1. Mars Orbiter Laser Altimeter (MOLA) color-coded shaded relief of the Meridiani Planum region. The approximate locations of MARSIS orbit tracks 03914, 03925, 08247, and 10109 are indicated by white lines. The location of the Opportunity Rover is shown (*).

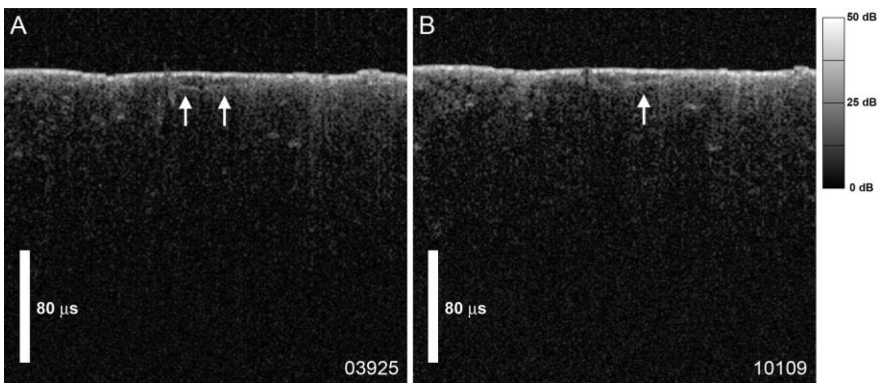

Figure 2. Radargrams showing MARSIS data for orbit 03925 (A) and 10109 (B) where echoes are plotted in time-delay versus position along the orbit. The subsurface echoes (white arrows) are offset in time-delay from the surface echo and are interpreted to be nadir reflections from the interface between the EP deposits and the cratered terrain.

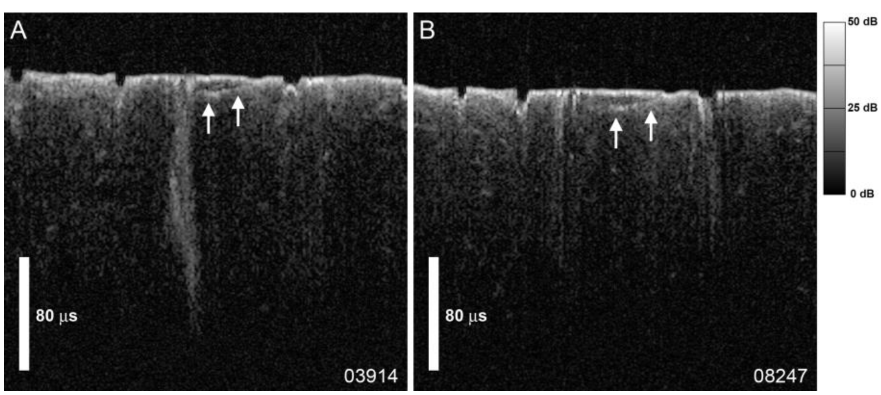

Figure 3. Radargrams showing MARSIS data for orbit 03914 (A) and 08247 (B) where echoes are plotted in time-delay versus position along the orbit.