THREE DIMENSIONAL STRUCTURE AND POSSIBLE LATERAL INHOMOGENEITIES OF THE MARS NORTH POLAR BASAL UNIT.
A. Frigeri[1], R. Orosei[1], M. Cartacci[1], A. Cicchetti[1], G. Mitri[1,2], S. Giuppi[1], R. Noschese[1], G. Picardi[3] and J.J. Plaut[4], [1]Istituto di Astrofisica e Planetologia Spaziali, Istituto Nazionale di Astrofisica, via del Fosso del Cavaliere 100, 00133 Roma, Italy (e-mail: alessandro.frigeri@ifsi-roma.inaf.it); [2]Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona, USA; [3]Università "La Sapienza", Rome, Italy; [4]NASA Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA.

Introduction Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) [1] is an orbital subsurface sounder aboard ESA's Mars Express spacecraft [2]. It transmits a low-frequency radar pulse that is capable of penetrating below the surface, and is reflected by subsurface dielectric discontinuities. MARSIS has been used to probe both the south [3] and the north [4,5] polar caps of Mars, revealing their thickness and structure. We report on the results of a campaign of observations of the north polar ice cap of Mars that took place between May and December 2011 in uniquely favorable conditions and produced data of unprecedented quality. The focus of this work is the so-called Basal Unit, a dark, ice-rich, complexely layered geologic unit lying stratigraphically between the polar layered deposits and the Vastitas Borealis Formation [6,7,8,9], and extending beneath most of Planum Boreum [10,11] and Olympia Planitia [5]. The objective of this work is the to study the full three dimensional structure of the Northern Polar Deposit and in particular of the Basal Unit (BU).

Studying the Basal Unit It was recently found [12] that the BU consists of two markedly different units, called the Rupes Tenuis unit and the Planum Boreum Cavi unit. The Rupes Tenuis unit appears to be older, horizontally layered, and lacking erosional contacts. It has been thus interpreted [12] as the result of precipitation and cold-trapping of dust-laden volatiles. The Planum Boreum cavi unit displays cross-bedding, indicating dune accumulation [12]. Bright layers within it are interpreted as being made of ice-cemented dust, while dark layers should consist of weathered basalt fines [12]. It seems likely [12] that, in places, the Planum Boreum cavi unit rests directly on the Vastitas Borealis, without the Rupes Tenuis unit in between. Because the two units in the BU have formed much earlier than the north polar layered deposits, and at some interval from each other [12], they bear evidence of past climatic conditions that were very different from present, so that they "could potentially be a Rosetta Stone for the Martian climate" [13].

Subsurface sounding radar investigations [10,11,5] by both MARSIS and SHARAD [14] revealed that the BU has radar properties that are different from both the polar layered deposits and the Vastitas Borealis Formation [10], probably because of a mostly icy composition, but with a larger fraction of impurities than the polar layered deposits above [10]. The upper surface of the BU exhibits significant relief, with features appearing to be erosional cutbacks and reentrants, indicating a complex accumulation history [11,15]. Higher dust content and the resulting stronger attenuation is thought to be the reason why SHARAD radar signal could not penetrate through the BU and detect its bottom face [10,11]. However, such a volume fraction cannot be much larger than the polar layered deposits, since MARSIS data revealed strong returns from the BU-Vastitas Borealis Formation interface, implying a relatively low fraction of impurities within the BU [5].

Data Processing From the summer phase of the Polar Campaign of data acquisition we have selected 161 radargrams. The radargrams were processed in order to cancel the effect of the ionosphere and to align the primary echo to a datum (Figure 1). In order to detect possible lateral variations of the dielectric constant in the totality of measurements, in the first phase of our study we have converted the time delay of echoes into depths considering a dielectric constant of 3.15 [16].

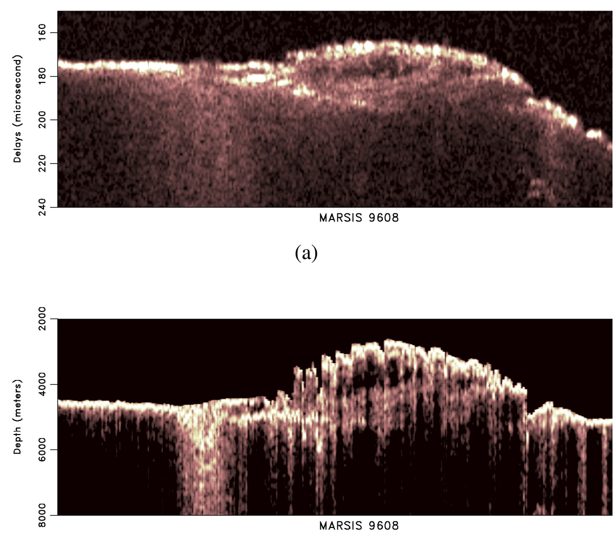

Figure 1: (a) MARSIS radargram for orbit 9608, the ionosphere effect results in a delay of radar echoes on the left side of the figure. (b) In the post-processed radargram, the effect of the ionosphere is removed, echo delays have been converted into depths and first returns have been aligned to the MOLA topography.

As every processed radargram is aligned to the same vertical datum, we ingested them into *OpendTect*, a Free

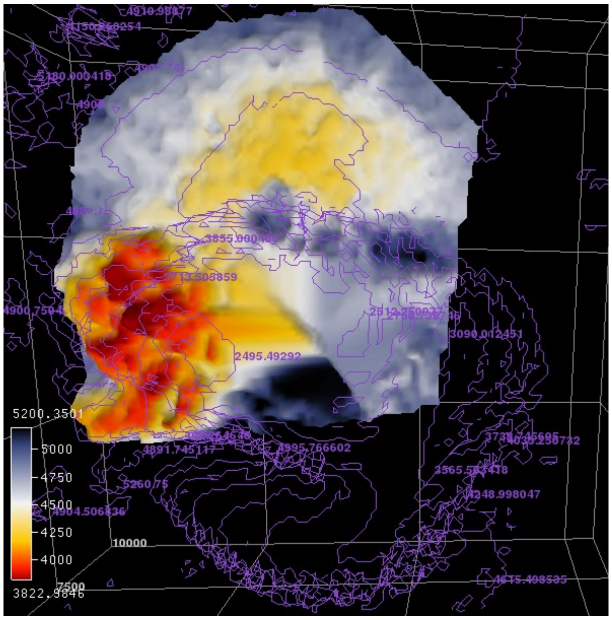

Figure 2: Color-coded depths of the top of the BU, the 250 m violet contours represent the topography of the ice-cap. Maximum elevation of BU is on the left, below the ice cap. In the upper part of the Figure the BU coincides with the topography of Olympia Undae, and the continuity of BU is broken by a trough in the Olympia Cavi area.

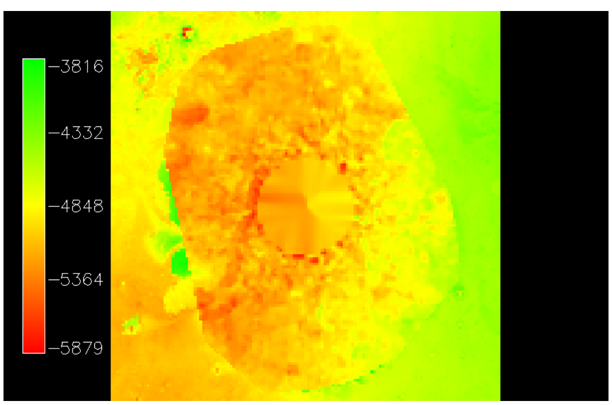

Figure 3: The depths of the base of the North Polar deposits (Figure 2) imported in a Geographic Information System and merged with the topography of the Northern Plains. While on the rightmost part of the figure the elevation of the northern plains and the base of the cap are similar, in the leftmost portion the radar-derived topography beneath the BU is more than 1000 meter lower than that of the area around the cap.

Open Source Software [17] for the interpretation of seismic and radar geophysical data in three dimensions. A volume of data has been generated by interpolating the 161 radargrams. We detected the base and the top of the BU first on bi-dimensional radargrams, using a semi-automatic supervised method, then these measurements have been extended within the whole volume of data. The result of this analysis are the maps of the echoes coming from the top and the base of the BU, revealing the overall morphology of the BU (Figure 2).

Results and Discussion We find weak echoes within the BU that appear to outline a two-layer structure (Figure 1), perhaps corresponding to the Rupes Tenuis unit and the Planum Boreum Cavi unit. This was found through visual inspection, however, because echoes within the BU are too sporadic to be automatically picked, further data processing and analysis is needed to confirm the result. Figure 3 shows the topography below the ice cap derived using the dielectric constant of water ice to convert echo delay time into depths. It can be seen that a large discrepancy is found between the radar-derived topography and the MOLA topographic dataset in those areas were the BU is the thickest. This implies that the BU has a dielectric constant significantly greater than that of water ice, and thus that it contains a much larger dust fraction than the NPLD above them. Varying the dielectric permittivity of the BU, the alignment between topography outside and beneath the polar cap can again be obtained, and the resulting permittivity can be used to estimate the dust content within the BU [18]. We find, however, that no single value can produce the correct topographic relationship over the whole BU, which implies either that the topography of Planum Boreum beneath the polar cap is not a regular continuation of the topography outside the cap, or that the dielectric permittivity of the BU, and thus its dust content, is laterally inhomogeneous. Work to verify these two hypotheses is currently ongoing.

References [1] Picardi G. et al. (2004) Planet. & Space Sci., 52, 149. [2] Chicarro A. et al. (2004) in Mars Express: the Scientific Payload, 3. [3] Plaut, J. J. et al. (2007) Science, 316, 92. [4] Picardi G. et al. (2005) Science, 310, 1925. [5] Selvans M. M. et al. (2010) J. Geophys. Res., 115, E09003. [6] Byrne S. and Murray B.C. (2002) J. Geophys. Res., 107, 5044. [7] Edgett K. S. et al. (2003) Geomorphology, 52, 289. [8] Fishbaugh K. E. and Head J.W. (2005) Icarus, 174, 444. [9] Herkenhoff K. E. et al. (2007) Science, 317, 1711. [10] Phillips R. J.et al. (2008) Science, 320, 1182. [11] Putzig N. E. et al. (2009) Icarus, 204, 443. [12] Tanaka K. L. et al. (2008) Icarus, 196, 318. [13] Fishbaugh K. E. et al. (2008) Icarus, 196, 305. [14] Seu R. et al. (2007) J. Geophys. Res., 112, 5. [15] Brothers T. C. et al. (2010) LPS XLI, Abstract #2590. [16] Matzler C. (1998) in B. Schmitt et al. (eds.) “Solar System Ices”, Kluwer [17] Stallman R.M. (1990) Comp. Ethics and Soc. 308-317. [18] Plaut J. et al.(2012) this volume