SHARAD SOUNDING RADAR OBSERVATIONS OF THE MEDUSAE FOSSAE FORMATION, MARS.

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Introduction: The Medusae Fossae Formation (MFF) stretches along the Martian equator from 140-240° E. It is characterized by aeolian erosion; grooves and yardangs are present across much of the deposit and exhumed craters are visible where MFF material has been stripped off the underlying plains [1, 2]. The eastern parts of Medusae Fossae correspond to the radar-dark "stealth" region identified in 3 and 13 cm wavelength ground-based radar images [3, 4].

This spatially extensive deposit is thought to be geologically young. It overlies both Amazonian aged lava flows in Elysium Planitia and Noachian aged cratered highlands near the dichotomy boundary [1,5,6]. Several hypotheses have been suggested for the origins of MFF, including pyroclastic flows or volcanic airfall deposits [1,3], aeolian deposits [7], or relic polar layer deposits [6,8]. Sounding radar observations can be used to search for basal interfaces and internal reflectors, and can be used to measure the dielectric properties of the MFF material, both of which may help to constrain the formation mechanisms.

The MARSIS (Mars Advanced Radar for Subsurface and Ionospheric Sounding) instrument on Mars Express has been used previously to study the MFF [9]. MARSIS operates at frequencies between 1.3 and 5.5 MHz, has a free space vertical resolution of 150 m, and can penetrate up to a few km in depth depending on the material [10]. MARSIS has detected basal interfaces beneath most of the MFF, including Gordii Dorsum, Amazonis Mensa, Eumenides Dorsum, Lucus Planum and the far western deposits south of Elysium Mons [9]. Time delay values measured from the MARSIS radargrams correspond to a bulk real dielectric constant value of ~2.9±0.4 for the MFF material [9]. There are two possible explanations for such a low dielectric constant: dry, low-density material like ash, or an ice-rich material [9]. If MFF is composed mostly of dry ash, it must have a very high porosity, even at km-scale depths [9]. MARSIS generally does not see more than one interface; however, in the area between Gordii Dorsum and Amazonis Mensa, there are two distinct interfaces at about 370 m and 740 m depth [9].

Summary of SHARAD radar data: The SHARAD (Shallow Radar) sounding radar on the Mars Reconnaissance Orbiter (MRO) operates at 20 MHz and has a free-space vertical resolution of 15 m [11]. SHARAD cannot see as far below the surface as MARSIS, and it is more susceptible to contamination from surface clutter. However, SHARAD is useful for observing near-surface interfaces and tens-of-meter scale layering that cannot be detected with MARSIS.

During the early part of the MRO mission, SHARAD observed subsurface interfaces underneath thin (100-560 m) sections of the MFF between 150-155° E longitude, on the southern edge of Elysium Planitia [12]. During the past few months, more coverage has been obtained over the eastern MFF sections to the southeast of Olympus Mons. This additional data has filled in previous gaps and has provided a broad coverage across nearly all of Medusae Fossae.

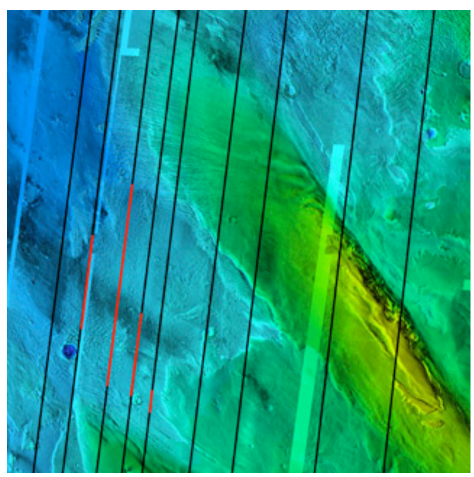

Fig 1: SHARAD orbit tracks across Gordii Dorsum. The lines change to red where SHARAD detects a subsurface interface. Orbit tracks that lie very close to those shown were left off the figure for clarity, but they show the same subsurface features. The underlying map is color-stretched MOLA topography overlaid on THEMIS data.

Subsurface interfaces in east MFF: SHARAD detects subsurface interfaces beneath a flat, dusty portion of MFF that lies between Gordii Dorsum and Amazonis Mensa (e.g. Fig 1). This region corresponds to an area just west of where MARSIS detects the pair of interfaces. The interface seen by SHARAD appears suddenly when the orbit track moves from the plains onto a higher elevation surface, and the interface therefore appears to represent the boundary between the MFF material and the underlying plains. As the orbit tracks move to the east, the MFF material increases in thickness and the subsurface echo becomes gradually fainter until it is no longer visible.

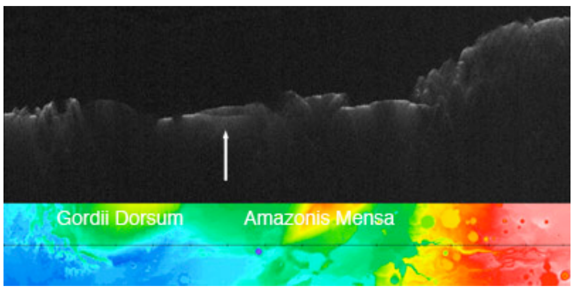

Fig 2: SHARAD radargram (OBS_519702000) showing a subsurface interface in eastern MFF. The lower panel shows the orbit track on color-stretched MOLA topography. The orbit track runs from 13° N on the left to 10.8° S on the right, and has a central longitude of ~210° E.

The deepest subsurface echoes in the SHARAD data for east MFF are ~510 m below the surface, similar to the maximum penetration values in the west. Assuming that the MFF material is deposited on top of flat plains, it is possible to use MOLA topography to measure the deposit thickness and to derive a value for the real part of the dielectric constant as was done with MARSIS [9]. Dielectric constants measured in this way (including SHARAD data from both east and west MFF) range from 2.8-3.5, similar to the values derived using MARSIS.

SHARAD does not detect internal layering within any part of MFF, and Gordii Dorsum and Amazonis Mensa are too thick to allow a detection of the basal interface seen by MARSIS. The northern part of Gordii Dorsum is extremely rough (Fig. 3) and in places the SHARAD surface echo disappears completely. Images of MFF by MOC, THEMIS, and HIRISE show layering within parts of the deposit, including within parts of Gordii Dorsum and surrounding flat areas to the north and east. It is not clear why the visible layers in flat-surfaced areas are not detected by the radar. It is possible that the layers are spatially discontinuous and/or rough, are sloped with respect to the radar, or have a low dielectric contrast that does not strongly reflect the incident radar signal.

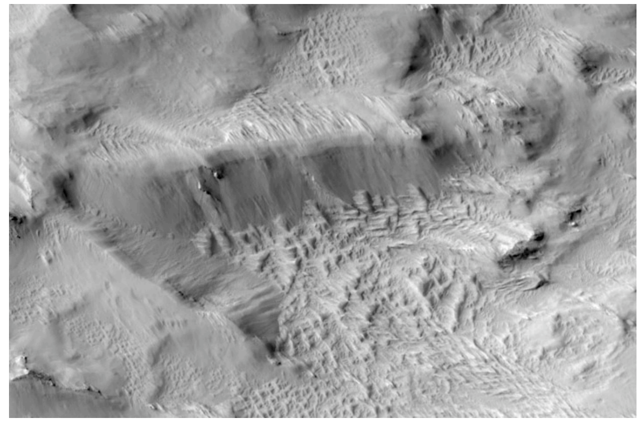

Fig 3: Part of a HIRISE image (TRA_00865_1905) of the northern part of Gordii Dorsum, showing a very rough surface with evidence for darker layers. The image is about 2 km across. The SHARAD surface echo disappears almost completely over this area.

Conclusions: SHARAD sees through up to 560 m of the MFF and detects clear subsurface interfaces in two locations: west MFF between 150-155° E and east MFF between 209-213° E. There is no radar evidence for internal layering in either area, despite the fact that tens-of-meters scale layering is apparent in infrared and visible wavelength images of nearby areas. Values of the real dielectric constant are low, consistent with those derived using MARSIS data. The surface echo is reduced over most of MFF, and completely disappears in parts of east MFF that correspond to part of the radar-dark "stealth" region. These areas are extremely rough at the SHARAD-wavelength scale, and the lack of echo power is most likely due to a combination of surface roughness and a low dielectric constant surface that reduces the echo strength from any small locally flat regions.

References: [1] Hynek, B. M. et al. (2003) *JGR, 108,* doi:10.1029/2003JE002062. [2] Edgett et al. (2000) *LPSC XXXI,* Abstract #1065. [3] Muhleman, D. O. et al. (1991), *Science, 253*, 1508. [4] Harmon et al. (1999), *JGR, 104,* 14065. [5] Bradley, B. A. et al. (2002), JGR, 107, doi:10.1029/2001JE001537. [6] Head, J. W. and M. Kreslavsky (2004), *LPSC XXXV*, Abstract #1635. [7] Tanaka, K. L. (2000) *Icarus, 144*, 254. [8] Schultz and Lutz (1988) *Icarus, 73*, 91. [9] Watters, T. R. et al. (2007) *Science, 318,* 1125. [10] Picardi, G. et al. (2006) *Science, 310*, 1925. [11] Seu, R. et al. (2004) *Plan. Space Sci., 52*, 157. [12] Carter, L. M. et al. (2007), 7th International Mars Conf., Abstract #3207.