RADAR SOUNDING OF LAVA FLOWS IN THE THARSIS PROVINCE, MARS. E. S. Shoemaker[1], L. M. Carter[1], and W. B. Garry[2] [1]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721, [2]NASA Goddard Spaceflight Center, Code 698, Greenbelt, MD 20771

Introduction: The Tharsis volcanic province of Mars is host to the three large shield volcanoes that form a chain along a southwest-northeast line through its center: Arsia Mons, Pavonis Mons, and Ascraeus Mons. The Tharsis Montes are the source of extensive lava flows that are tens to hundreds of kilometers in length. The composition and spatial distribution of these lava flows can provide information about the evolution of the surface and interior of Mars.

Previous surveys of Tharsis [1, 2] using the Shallow Radar (SHARAD) instrument onboard the Mars Reconnaissance Orbiter (MRO) revealed basal interfaces of flows in three distinct regions: both west and northwest of Ascraeus Mons, south of Pavonis Mons, and east of Arsia Mons (Figure 1). Both [1] and

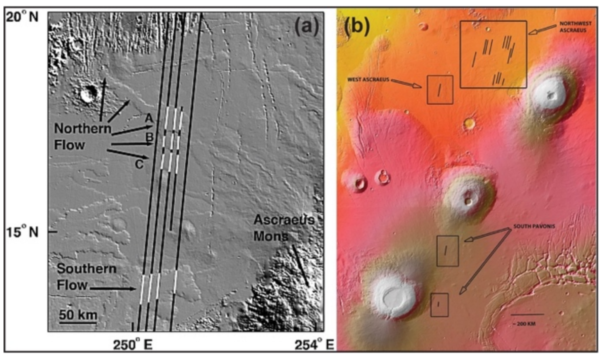

Figure 1. Previous survey results: **(a)** Figure 2 from [1], subsurface interfaces (white) overlaid on the SHARAD orbit tracks (black) on a MOLA shaded relief map. **(b)** Figure 1 from [2]. Mapped locations of subsurface interfaces of lava flows identified by SHARAD on MOLA colorized elevation map.

[2] measured the permittivity and loss tangent of the flows north and west of Ascraeus Mons. Their permittivity values indicate that the flows are dense, likely with a basaltic composition [1, 2]. The loss tangent was measured for subsurface interfaces that are visible at varying depths. The loss tangent values were consistent with those measured for basalts on both the Moon and Earth and are indicative of the presence of radar-wave absorbing minerals like ilmenite or hematite [1, 2].

New coverage by SHARAD and reprocessed radar data from the Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) [3] motivates this improved, in-depth survey of the Tharsis province. We will search for the presence of additional subsurface interfaces and compare results from the two radar datasets.

Methods: We used both the SHARAD and MARSIS radar sounders in our survey of the Tharsis lava flows. SHARAD operates at a central frequency of 20 MHz with a vertical resolution of 15 m in free space which varies with the permittivity of different geologic materials. The horizontal footprint of SHARAD extends 3-6 km cross-track and 0.3-1 km along track [4].

MARSIS operates at 1.8, 3, 4, and 5 MHz in subsurface sounding mode. At 1 MHz, MARSIS has a vertical resolution of 150 m in free space or 50-100 m depending on the permittivity of the material within the subsurface [5].

SHARAD and MARSIS detect regions of strong contrasts in permittivity in the subsurface that appear in the radar image (radargram) at a greater time delay than the bright surface return (Figure 2, panel a). Reflectors can be obscured by cross-track surface echoes (clutter)

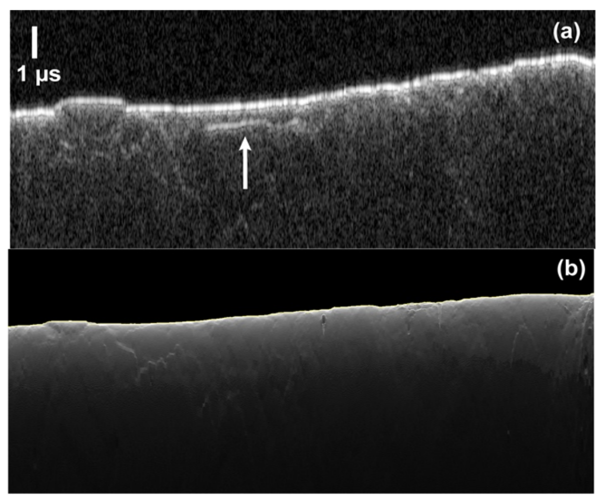

Figure 2. (a) SHARAD radargram 1756402 west of Ascraeus Mons with an ~25 m interface (white arrow) of a flow identified by [2]. Time-delay is along the y-axis and along-track distance is along the x-axis. **(b)** Corresponding cluttergram produced using MOLA topography data. The interface is not present in the cluttergram indicating that it is real.

reaching the receiver at a time delay comparable to that of the reflector. Clutter sources are identified by comparing the radargram to a simulation of surface clutter (cluttergram) produced using topography data obtained by the Mars Orbiter Laser Altimeter (MOLA) instrument (Figure 2, panel b).

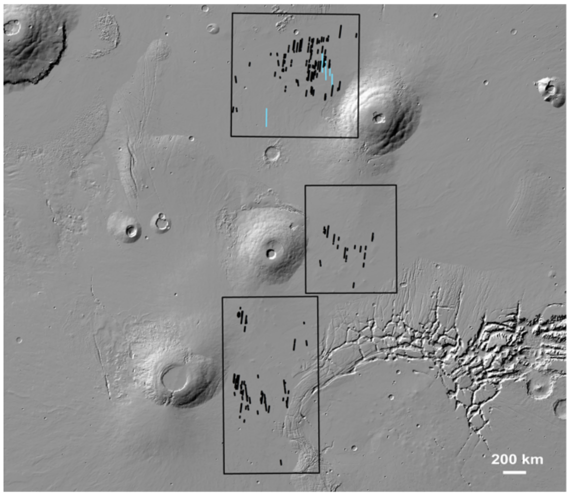

Figure 4. The three ROI surveyed in Tharsis (black boxes). Mapped reflectors found with SHARAD are in black and reflectors found with MARSIS are in light blue overlaid on MOLA shaded relief. North is up in this figure.

We examined both dayside and nightside SHARAD and MARSIS observations. We focus on identified subsurface interfaces within three regions of interest (ROI) in our survey (Figure 3, black boxes).

For each identified reflector associated with a lava flow for which a topographic expression can be measured using MOLA, we perform a depth correction of the radargram [6] in order to determine the permittivity and thickness of such flows. The plains surrounding the flows north and west of Ascraeus Mons are fairly flat [1] and so we assume that the lava flow lies on a flat surface and that a straight line beneath the flow can be extrapolated from the plains on either side. By converting time-delay to depth assuming values of the permittivity (ε' of ~7-11 for basalts) based on previous studies [1, 2], we can adjust the depth of the interface until it is flat, which provides the thickness of the flow.

Results: Within the ROI, we detected subsurface interfaces in 82 SHARAD tracks and 5 MARSIS tracks (Figure 3). Additional tracks north and west of Ascraeus Mons have reflectors in the northern and southern flow complexes (Figure 1, panel a) [1]. The reflectors found east of Pavonis Mons with SHARAD and west of Ascraeus Mons with MARSIS have not been previously mapped by other surveys. Additional reflectors found south of Pavonis Mons and east of Arsia Mons complement those found in SHARAD track 1728801 [2]. Many of the lava flows associated with these reflectors are not visible in MOLA topographic maps or Context Camera (CTX) images. However, recent mapping of Arsia Mons and its surrounding plains [7]

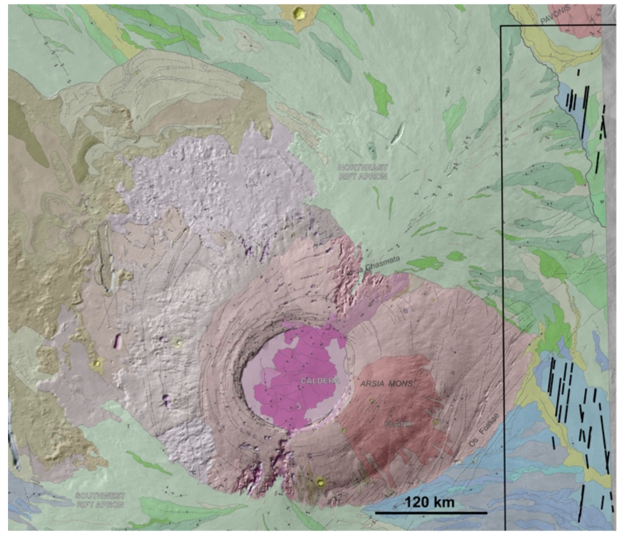

Figure 3. Geologic map of Arsia Mons and its surrounding plains [7] overlaid on MOLA shaded relief. The extent of the ROI visible is in black. Many reflectors are coincident with the light blue plains units east and northeast of Arsia Mons. North is up in this figure.

finds excellent agreement between several plains units mapped as ponded lava flows (Figure 4). SHARAD track 1728801 lies within these mapped plains and is concave in shape [2]. This concave reflector indicates that this plains region coincides with preexisting topography buried beneath these flows from Arsia Mons warranting further modeling and investigation of this track and adjacent tracks to determine the overall shape.

Conclusions and Future Work: SHARAD and MARSIS detect additional interfaces in regions from previous surveys near Ascraeus Mons and Arsia Mons [1, 2] as well as in a new region east of Pavonis Mons. These interfaces can provide information on the dielectric properties as well as a thickness of the lava flows. We will calculate the permittivity and loss tangent for the remaining candidate radargrams and compare the lava flow properties and stratigraphy between different areas to better understand the history of volcanism in Tharsis.

References: [1] Carter et al. (2009a) *GRL*, *36*, L23204. [2] Simon et al. (2014) *JGR, 119*, 2291-2299. [3] McMichael et al. (2017) *IEEE Radar Conference*, 0873-0878. [4] Seu et al. (2007) *JGR, 112*, E05S05. [5] Picardi et al. (2004) *Planetary & Space Science, 52,* 149-156. [6] Carter et al. (2009b) *Icarus, 199*, 295-302. [7] Garry et al., 1:1M Geologic Map of Arsia Mons, *In Revision with USGS.*

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