STUDIES OF LAVA FLOWS IN MARS' THARSIS REGION USING SHARAD RADAR. M. N. Simon,[1] L. M. Carter,[2] B.A. Campbell,[3] R.J. Phillips,[4] S. Mattei,[5] [1]Department of Geophysical Science, The University of Chicago, 5734 S. Ellis Avenue, Chicago, IL 60637 (msimon3@uchicago.edu) [2]NASA Goddard Space Flight Center, Code 698, 8800 Greenbelt Road, Greenbelt, Maryland 20771 (lynn.m.carter@nasa.gov) [3]Center for Earth and Planetary Studies, Smithsonian Institution, MRC 315, PO Box 37012, Washington, DC 20013 [4]Southwest Research Institute, 1050 Walnut St., Boulder, CO 80302 [5]CO.RI.S.T.A., VIA J.F. Kennedy, 5 80125 Naples, ITALY

Introduction: The Tharsis area is the largest volcanic province on Mars. Physical models show that Tharsis-area lavas, including long flows originating in rifts near Ascraeus and Pavonis Montes, had viscosities consistent with basaltic compositions [4]. Prior work using radar data have also shown that some flows have dielectric properties consistent with basalts [3]. In this work we surveyed all available SHARAD radar data across the Tharsis area to better understand the composition and stratigraphy of the lava flows.

SHARAD, a sounding radar on the Mars Reconnaissance Orbiter, operates at 20 MHz with a 10 MHz bandwidth, and it has a free-space vertical resolution of 15 m [5], and a 5-10 m vertical resolution in common geologic materials. The lateral resolution of SHARAD is 3 to 6 km, reducible to 300 to 1000 m in the along-track direction with synthetic aperture focusing [5]. SHARAD data are displayed as radargrams, with along-track distance on the x-axis, and range-delay time increasing downward on the y-axis [3]. SHARAD is able to determine the dielectric properties of lava flows, provided that it can detect a subsurface interface. Radar measurements of dielectric properties of these detected flows can provide information regarding their composition and density. This information can be used to compare the dielectric properties and permittivity of lava flows to that of planetary surface materials [3]. The long, leveed flows on Mars, including those in which SHARAD detects the subsurface may be similar to many terrestrial basaltic flows [4].

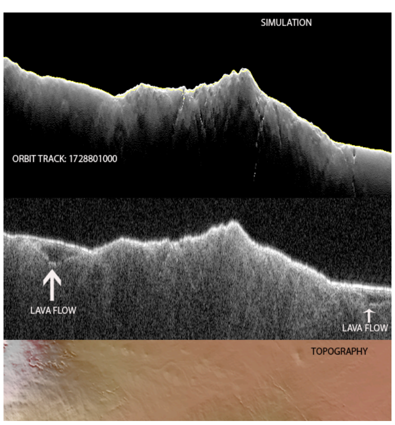


Figure 1: Focused radargram of orbit track 1728801000 showing subsurface interfaces beneath the flow located south of Pavonis Mons. The upper image corresponds to a clutter simulation based on MOLA topography that confirms that the interface is not caused by surface reflections. The lower third of the figure is the surface topography along the orbit track.

Data Analysis: Calculating Permittivity and Loss Tangents

SHARAD data can be used to measure the complex dielectric constant of the lava flows. We are able to estimate the permittivity of the flows by comparing the measured time delay of returns from the subsurface with altimetry measurements of the flow heights relative to the surrounding plains [3]. Permittivity of rocks is largely dependent on the density. Basalts are denser than other volcanic rocks like rhyolite, so they yield higher permittivity values. The permittivity, denoted by ε', can be calculated by using the equation:

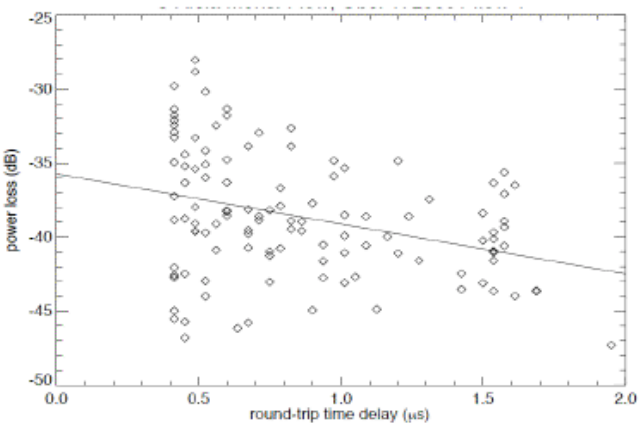
$$\varepsilon' = \left(\frac{c\Delta t}{2h}\right)^2$$

where h is the height relative to the surrounding plains as measured from MOLA topography and Δt is the two-way time delay between the surface and subsurface echoes measured from the radargram. This equation did not yield physically plausible permittivities for all of the lava flows analyzed in the Tharsis region, likely due to an inability to accurately measure h in some types of terrain. For the lava flows with reasonable values (ε' < 15) northwest of Ascraeus Mons, ε' values ranged from 7.6495 to 11.622, with an average of 10.09. For lava flows south of Pavonis Mons and additional four lava flows northwest of Ascraeus, it was not possible to measure ε' and analysis of the flows is restricted to loss tangents only.

Pumice, volcanic ash, and tuff have permittivity values between ~2.5 and 3 [7], whereas most terrestrial and lunar basalts have ε' values between 7 and 11 [2]. The permittivity values calculated for the flows northwest of Ascraeus yield results that most closely resemble basaltic flows. In cases where the subsurface interface is visible at different depths, spanning tens of meters, it is also possible to measure the loss tangent (tan δ) of the material. The loss tangent can be written as [1]:

$$\tan\delta = \frac{\varepsilon''}{\varepsilon'} = \sqrt{\left[2*\left(\frac{\lambda}{4\pi c\Delta t}\ln(L)\right)^2+1\right]^2-1}$$

where λ is the SHARAD free-space wavelength of 15m and L is the power loss per unit of time Δt. The loss tangent describes how much radar power is lost as the wave travels through the flow, and it relates to the chemical composition and density of the material. In the case of flows northwest of Ascraeus Mons, separate fits of power loss versus time delay were made for eight orbit tracks. During the standard processing, each orbit track is normalized to the noise background [3]. The same method was applied to the two tracks south of Pavonis Mons.



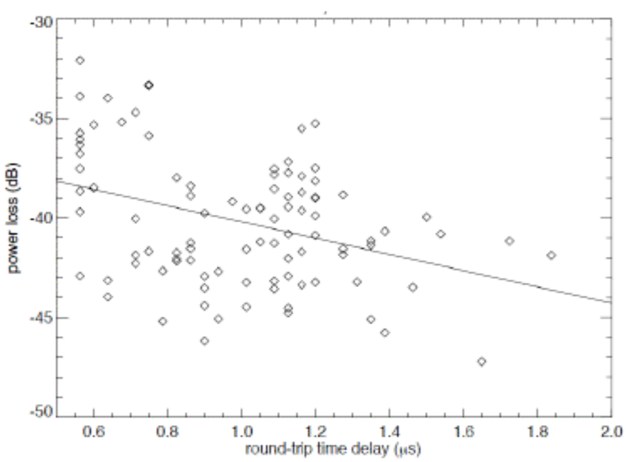


Figure 2: Round trip time delay vs. power loss for one track with two separate lava flows south of Pavonis Mons.

For flows northwest of Ascraeus Mons, the loss tangent values calculated were between .0004461 and 0.0145. For flows south of Pavonis Mons, the loss tangent values calculated were between 0.007849 and 0.0288. The measured loss tangents are common values for terrestrial and lunar volcanic rocks, including basalts [2]. Loss tangents between 0.01 and 0.03 imply a low to moderate concentration of radar-wave absorbing minerals such as ilmenite or hematite.

Geologic Discussion: SHARAD is unable to see subsurface interfaces for flows that are located far from the summit and rift zone regions. Interfaces detected by SHARAD are associated with late-stage, rift zone volcanism. There are a few possible explanations for this observation. First, it is possible that some lava flows that are clearly visible in topographic and imaging data are undetectable by SHARAD because they are older and have been weathered by ice or water. Since SHARAD can only detect interfaces beneath flows with low loss tangents, this compositional weathering change may make the flow base similar in dielectric properties to the substrate, and thus not detectable by SHARAD [6]. Second, it is possible that the late-stage Tharsis volcanism produced lavas with different permittivity values and loss tangents than earlier stage eruptions. It is also possible that SHARAD detects interfaces only in areas where a significant layer of low density material such as dust or ash accumulated on the surface before the lava was emplaced. In areas where lava flows are stacked in sequence with no density contrast, SHARAD will not be able to detect any interface.

Conclusions: The permittivity and loss tangent values calculated for the flows northwest of Ascraeus Mons and south of Pavonis Mons are consistent with the calculated values for basalt. The only plausible way to change the permittivity values enough for the flows to be considered felsic (lower density) would be to change the h value and make it larger. This could occur if the flows were sitting in tens of meters of depression corresponding exactly to flow boundaries, but this does not occur in either of the regions that were the primary area of focus. It does not appear that the h value could plausibly be large enough to yield felsic flow values, therefore the values are more consistent with basaltic flows. In both of the target regions emphasized, the flows yielded loss tangent and permittivity values consistent with basalt when these values could be accurately calculated.

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