THE ANOMALOUS RADAR TRANSPARENCY OF CENTRAL ELYSIUM PLANITIA AND AMAZONIS PLANITIA. D. E. Stillman, R. E. Grimm and K. P. Harrison, Department of Space Studies, Southwest Research Institute, 1050 Walnut Street, Suite 300, Boulder, CO 80302, dstillman@boulder.swri.edu.

Introduction: The Shallow Radar instrument (SHARAD) on the Mars Reconnaissance Orbiter (MRO) has been successful at penetrating into icy deposits [1-3], but most of the rocky units are opaque to SHARAD. The main exceptions to this are the youngest major volcanic surfaces, Cerberus Fossae 2 and 3 units and Amazonis Planitia 2 north unit [4]. We suggest that these units have low radar loss because they have so far been insufficiently exposed to liquid water.

Geologic Interpretation: SHARAD transparent units stretch from Central Elysium Planitia (CEP) (5 ^{o}S–10^{o}N, 150–180^{o}E) through Marte Vallis and into Amazonis Planitia (AP) (17–37^{o}N, 185–207^{o}E). The morphology of the surface indicates a volcanic origin [7,8]. This volcanic surface clearly overlies widespread fluvial activity that carved extensive channel systems [9-11]. Cerberus Fossae cut across this flat surface and have acted as conduits for the release of water and lava onto the surface within the last 200 Ma [12], and possibly as young as 2 Ma [9]. Lava flows also originated from at least seven volcanic shields in the region [13].

The extent and smoothness of these lava flows indicates a very low-viscosity. While this unit is the smoothest on Mars at scales of 0.9, 2.4, and 9.6 km [14], it also has one of the highest depolarized backscatters on Mars at 12.6 cm [15]. This backscatter is so high that the surface roughness would need to be larger than that of Hawaiian a'a flows or be enhanced by volume scattering of a low-loss regolith [15].

Subsurface Mapping: We used SHARAD to map the subsurface reflectors seen in the CEP and AP (Fig. 1a). AP only has one subsurface reflector with depths as great as ~100 m [16]. CEP was divided into seven regions, where many continuous reflectors exist (Fig. 1b). These regions are marked by single and multiple reflectors. In region D, we observed a sequence of four stacked units (Fig. 2). Region C contains two stacked units which outcrop (Fig. 2). We also observed that one large unit, region E, extended at least 800 kms and possibly through Marte Vallis and into Amazonis Planitia.

Subsurface Composition: Radar velocity or dielectric constant ε' cannot be uniquely derived from the SHARAD data due to the single offset geometry of the experiment and lack of subsurface point reflectors. Therefore, the best way to determine ε' is by choosing locations where the thickness of the transparent structure can be estimated [1-3,17]. We determined a ε' of 7.5-9 by assuming the top two units observed in region E are flat (Fig. 3). Many assumptions must be made to determine the material composition from a ε' at a single frequency, however such a high ε' rules out any possibility of massive ice (glaciers). Dry basalts, ice-rich basalts, and/or inter-mixed units of basalt and ice cannot be ruled out by the ε'. However, rootless cones are only found in areas with one subsurface reflector; therefore our interpretation is that these are dry basaltic flows underlain by fluvial sediments [18]. The value of ε' is representative of a dry basalt with a bulk density of 2.8-3.3 [19], which are the most likely values for basalt [20]. These lava flows vary in unit thickness from 20–50 m.

Elysuim Transparency: The transparent units of the CEP and AP are the most radar transparent regions on Mars that are not associated with ice. We calculate that the opaque regions must have a loss greater than 0.15-0.58 dB/m, which is the minimum attenuation rate needed to detect a reflector just below SHARAD's blind zone of 20-40 m (assuming SHARAD has a dynamic range of 50 dB, a -11 dB subsurface reflection coefficient, and a surface ε' of 5-9).

We hypothesize that these units are so radar transparent because they are the youngest volcanic units on Mars. Consequently, the region may have a different composition than the rest of the Martian subsurface. Significant attenuation is known to come from three volcanic minerals: gray hematite [21], magnetite [21], and ilmenite [22]. The concentration of gray hematite is very minute over most of Mars. Magnetite only attenuates at much higher frequencies than SHARAD. Ilmenite, which causes the majority of the loss of lunar basalts, has a low loss over a broad range of frequencies and will cause loss at SHARAD frequencies. However, ilmenite concentrations of Martian basalts are much lower than in the lunar Mare. Therefore, we do not believe that composition changes can cause the change in attenuation.

Instead of variations in primary mineralogy, we suggest that the radar loss over the majority of Mars is related to water. Noachian and possibly Hesperian units have been chemically altered by water creating phyllosilicates [23]. A small concentration of phyllosilicates can significantly attenuate radar energy due to the rotation and/or translation of unfrozen adsorbed water [24].

Due to the lack of liquid water in the Amazonian, chemical alteration would have been much slower. However, atmospheric water vapor can still have a drastic affect on radar attenuation. Olhoeft et al. [22] measured that the radar loss of a pristine lunar regolith sample increased by a factor of 15 (0.0026 dB/m to 0.041 dB/m) when exposed to air for 30 months. When the water was removed, the sample still had a larger loss than when it was pristine due to chemical alterations. The specific surface area of lunar regolith was also found to increase by a factor of 2 to 6 after being exposed to water [25,26]. The enhanced radar loss comes from the translational movement of the adsorbed water along the double layer in response to an electric field. Laboratory results indicate that the first monolayer of adsorbed water is bound too tightly to cause loss at radar frequencies [27]. However, additional monolayers create a broadband (1mHz–10 GHz) loss that is slightly higher at lower frequencies. This loss increases with additional monolayers until the adsorbed water is so loosely bound that it is able to rotate. This loss has been measured in JSC Mars-1 [21], plagioclase [21], hematite [28], and lunar regolith [22] with just a few monolayers of water. Better laboratory studies on how just a few monolayers can increase loss are needed, but we have estimated from our preliminary measurements and those of Olhoeft [27] that only 1.5-3 monolayers of water can increase the loss to >0.58 dB/m. A global equivalent layer (GEL) of 38 cm is needed to wet the rocky surfaces of Mars down to 20-40 m with 1.5-3 monolayers assuming a specific surface area of 1.5 m^2/g (slightly altered terrestrial basalt [29]). Assuming this takes 15 Ma (age difference between radar-transparent and radar-opaque units of northern AP [4]); this would yield a rate of 25 nm/yr or 2.5%/yr of the GEL currently in the atmosphere.

Therefore, we suspect that the SHARAD opaque rocky units on Mars have at least 1.5-3 monolayers of water in the top 20-40 m. We suspect that it takes 10-20 Ma for this water to diffuse in from the atmosphere, thus leaving the youngest units of the CEP and AP drier and radar transparent.

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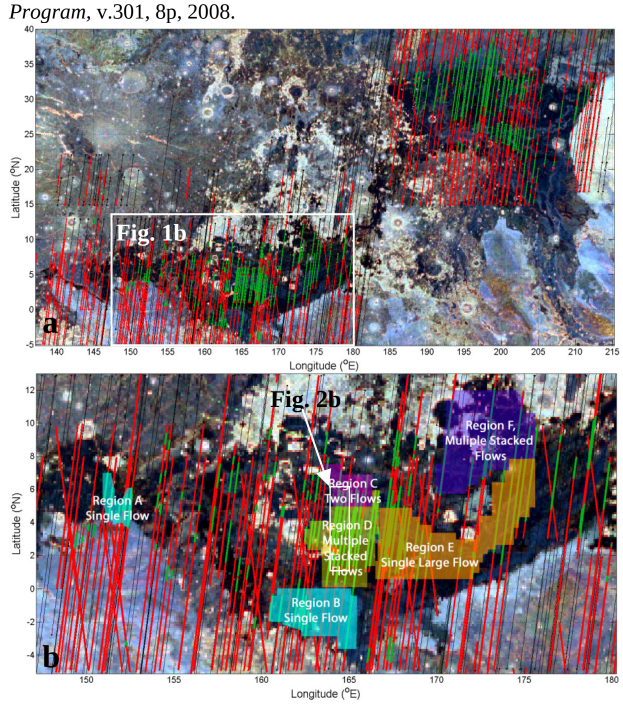

Figure 1. (a) SHARAD penetration map where: background map is surface roughness [14], green shows subsurface reflectors, red shows an absence of reflectors. **(b)** Zoom in of CEP showing seven different regions of continous reflectors. Reflectors in AP have just one reflector [16].

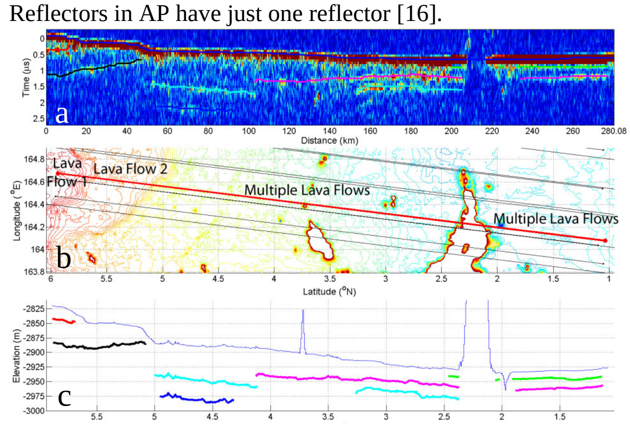

Figure 2. (**a**) SHARAD line 0585081 goes through region C and D of the CEP. (**b**) SHARAD lines overlayed on MOLA topography. Lava flow 2 also concurs with lava flow ζ from [13]. (**c**) Time-depth corrected reflections using a ε' = 8.25. ε' was fit by making the bottom of lava flows 1 and 2 flat.