A SURVEY OF SOUTHEASTERN UTOPIA PLANITIA WITH SHARAD DATA. D. C. Nunes[1], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109 (Daniel.Nunes@jpl.nasa.gov)

Introduction: The Utopia Planitia records events spanning a large extent of the geologic history of Mars, from its formation as a large impact basin and subsequent infill in the Noachian [e.g., 0], to volcanic episodes in the Early Amazonian [e.g., 1]. Numerous features present at Utopia are related to aqueous or periglacial activity that has extended from Late Amazonian to possibly the present day.

SHARAD is the orbital radar sounder provided by the Agenzia Spaziale Italiana (ASI) that is onboard the Mars Reconnaissance Orbiter (MRO). It was designed to explore the shallow subsurface of Mars at sub-kilometer penetrations and depth resolutions on the order of ~15 m [2], and it has been successful in characterizing the interior of ice-rich and volcanic deposits. In their effort to determine the presence of subsurface sources for water at gully sites throughout the martian mid-latitudes, *Nunes et al*. [2010] [3] examined SHARAD soundings at Utopia Planitia. They identified a number of reflectors at southeastern Utopia in association with the hydro-volcanic units originated at Elysium Mons, and initially interpreted them as being possibly due to ice in the subsurface. That initial analysis arose from a limited amount of SHARAD coverage, however, and the suspicion at the time was that the wide geographic distribution of reflectors indicated an extensive regional unit.

In continuation of that initial effort, here are the results from an extensive survey campaign of SE Utopia with SHARAD.

Southeastern Utopia: This area of Utopia Planitia is dominated by major channels and volcanic units emanating from grabens at the western flanks of Elysium Mons [e.g., 4]. These units overlie the knobby and polygonally cracked Vastitas Borealis Formation (VBF) and are divided into four main types [5]: (SL) smooth lobate, (RL) rough lobate, (Et) etched, and (Di) distal from Elysium Mons. [5] interpreted SL to correspond to smooth, lobate lava flows, and RL to correspond to rough debris flows originated as lahars out of the interaction between lavas and ground water/ice. Sources for the RL lahar flows occur lower on the flanks of Elysium Mons, and appear to mark the maximum level of lava sources that interacted with a confined cryosphere/hydrosphere, releasing massive groundwater release that carved the channels present in the midst of SL units. [5] offered their observations and interpretation in support to [6]'s model of a global cryosphere/hydrosphere system. [1] also mapped SE Utopia and identified the RL unit as $AEt_{a,b}$ (fluvial deposits and massive volcanoclastic flows formed from magma-volatile interactions), SL unit as AHEe (lava flows and other volcanics, overlain by $AEt_{a,b}$), and the VBF as ABv_i underlying the aforementioned volcanic units. Dating based on crater counts [7] supports this relative sequence, and attaches an age of ~ 1 to 2 Ga to SL/RL resurfacing ages.

Peppering the Utopia Planitia are craters containing gullies [e.g., 8]. In the northern hemisphere, including Utopia, gullies predominantly occur in craters and are found on all slope orientations. Thermal calculations by [8] estimate that in most of the gully alcoves, their base are equivalent to depths where the subsurface temperature should exceed 273 K. Recently, seasonal dark lineaments have been detected on the slopes of a few southern-hemisphere gullies, and interpreted as briny flows [9]; though not at Utopia, the link between gullies and flow of liquid water has been strengthened.

Understanding the reflectors seen at Utopia bears relevance to not only the geologic history of volcanism and periglacial processes, but potentially to aqueous activity on Mars.

Previous Effort: [3] surveyed SHARAD data covering SE Utopia in search of possible subsurface reservoirs of water feeding the large abundance of gullies in this region. They found numerous subsurface reflectors within ~1 μs of the surface and of intermittent nature, and the geographic spread of those reflectors suggested an extensive regional unit. [3]'s mapping of the reflectors also pointed to a possible correlation between those subsurface reflectors and surface roughness, as they preponderantly occur beneath the smoothest areas (as calculated from the 128 pixel/° grid) associated with the Elysium volcanic flows. Based on the depth of reflectors and on the context of past interaction between volcanism and ground water/ice, the preliminary interpretation for the SE Utopia reflectors were produced by dielectric contrasts resulting from ground ice. SHARAD coverage of SE Utopia at the time of that study was relatively sparse, and an ongoing sounding campaign of this region now offers much improved coverage and the possibility to revisit the preliminary findings of [3].

SE Utopia Campaign: Since the analysis of [3], a SHARAD observation campaign has taken place with the goal of mapping the extent of the shallow reflector and determine its relationship to the different geologic units. This effort, which produced over 90 sounding strips within a box bound by 20°-50°N and 114°-140°E, was intended to encompass an area greater than the Elysium flow units and determine whether reflectors are more widely extensive.

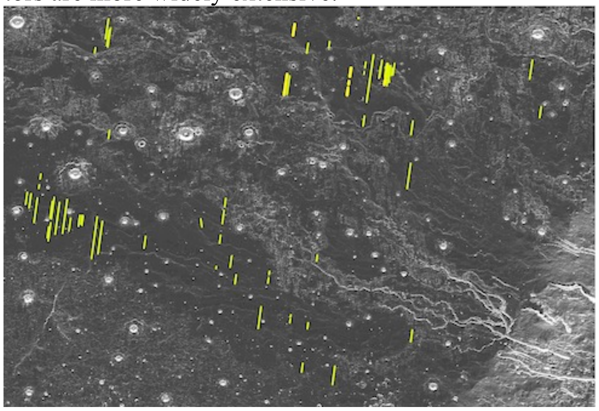

Fig. 1 – Location of SHARAD subsurface reflectors (colored lines) in SE Utopia superposed on MOLA 128 pixel/° slope map (darker is smoother).

Mapping the subsurface reflectors seen in this more voluminous data set again shows these reflectors to be intermittent along their length and to occur almost exclusively beneath the smooth surface of the lobate lava flows (Fig. 1). Perhaps more curiously, these subsurface reflectors do not necessarily correlate with individual surface features (Fig. 2); while in some cases reflectors can be correlated with individual lobate flows, in others they cross flow boundaries. Individual reflectors do not extend across the width of the SL unit either, but they also appear beneath SL kipukas left uncovered by the lahar RL units. Delay of reflectors beneath the surface tends to be $< \sim 1\mu s$, and while most reflectors are nearly parallel to the surface above it, there are cases where reflectors merge with the surface reflection and terminate. Relative strength of the reflectors from radargram to radargram is variable, and while one observation shows a subsurface reflector, an adjacent observation that is only 3 km apart may not. As such, the lateral continuity of a subsurface unit is difficult to determine.

Discussion: A crucial question in interpreting the SHARAD observations at SE Utopia is whether they are truly restricted to beneath the Elysium smooth lobate flows or whether this correlation is due to the fact that surface scattering of the radar energy at the neighboring rougher units masks the reflectors. The smoothness of the lobate lava flows is asserted over baseline scales from 9.6 km to 600 m [10], as determined from the MOLA gridded products, and over baselines comparable to the MOLA shot footprint (75 m) [11]. The later is close to the center wavelength of the SHARAD signal (15 m) and more relevant to the surface scattering of SHARAD waves. Little variability in MOLA-pulse roughness is seen across the SL unit, so it cannot explain the apparent lateral discontinuity of the reflectors. Path losses through individual lava flows is not very plausible either, as reflectors in adjacent radargrams may terminate or continue through the boundary of a single lava flow (Fig. 2).

One possible explanation being currently pursued is that the reflectors are weak enough to be attenuated by minor variations of interface or overburden properties, or weak enough to be easily masked by modest changes in the noise floor of the SHARAD data. This explanation would also support the laterally intermittent nature of the reflectors and their absence from the VBF unit to the south of SL, where morphological evidence (such as polygons) supports the presence of subsurface ice.

Considering relative permittivities between 3 and 9, which span the range for water ice (3.15) and bulk basalt (5 to 9), maximum depth of reflectors (1 μs delay) ranges between 85 and 5, which is more than the thickness of individual flows (<20 m) but entirely plausible for the thickness of the entire volcanic stack. The reflectors may, therefore, correspond to the contact between SL and VBF.

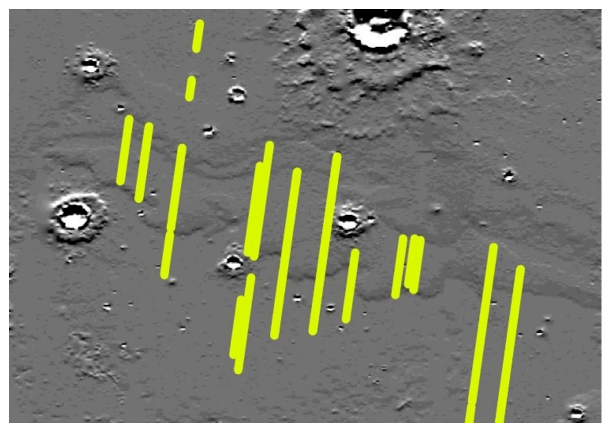

Fig. 2 – Location (117.7°E, 31.2°N) of some SHARAD subsurface reflectors (while lines) beneath Elysium smooth lobate lava flows at Utopia Planitia. Background is MOLA 128 pixel/° shaded relief. Reflectors not always correlate with individual surface features, such as individual flows. Image is ~150 km across.

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