CHARACTERIZATION OF LAVA FLOWS IN THE ELYSIUM-UTOPIA REGION OF MARS USING SHARAD DATA.

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Introduction: Elysium volcanic province is the second largest region of volcanic unit on Mars. Extensive flows erupted from the northwest slopes of Elysium volcanic province stretch thousands kilometers and overlie the Vastitas Borealis Formation (VBF) in the southern Utopia Planitia. The thickness of these lava flows is an important indicator of lava eruption flux and shed light on volcanic history of the the Elysium volcano, the second largest volcano province on Mars.

Radar sounder can penetrate Mars surface with low loss tangents and detect subsurface structures, and could be applied to uncover the thickness of layered lava flows. There have been two radar sounding instruments employed in Mars missions: Mars Adcanced for Subsurface and Ionosphere Sounding (MARSIS) on ESA's Mars Express [1] and Shallow radar (SHARAD) on NASA's Mars Reconnaissance Orbiter [2]. Previous radar detections in low and middle latitudes revealed in the material composition of Medusae Fossae Formation (MFF), surface lava flows and ground water ice [3-7].

Clear subsurface reflectors in the Elysium-Utopia region with SHARAD data have been reported, and the reflectors are interpreted as the signature of ice-rich layer near or at the surface [8]. The morphologic evidences such as giant polygons indicate the possible appearance of subsurface ice below the surface flows [8,9], but people doubt the hypothesis since the maximum depth of the reflectors is less than the thickness of entire volcanic stack and the reflectors were interrupted as the contact between Smooth Lobate Unit and VBF [9]. Though the range of permittivity value has been estimated[10], however, the composition of the detected subsurface layer is unclear without the exact permittivity value inferred from radar results.

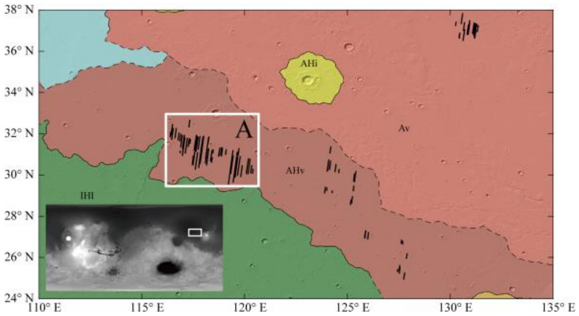

Fig. 1 MOLA topography and geologic map of Elysium-Utopia region. Black lines indicate locations where SHARAD detected subsurface reflections. Av and AHv are volcanic units, while IHI is lowland unit [11]. Area A is outlined by white frame.

SHARAD data: We checked over 300 radargrams individually and get 69 radargrams with clear subsurface reflections in the Elysium-Utopia region (Fig. 1). Ground Penetrating Radar (GPR) processing software, Reflexw, is used to generate time delay data for the surface and subsurface echoes. No subsurface interface was found from MARSIS data in the same region. The reason may be that the resolution of MARSIS in this region is larger than the thickness of surface flows.

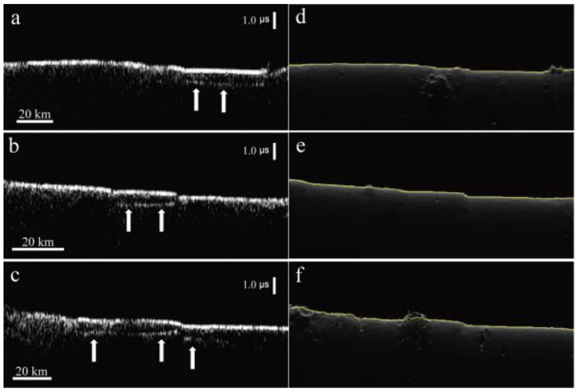

Fig. 2 Examples of subsurface reflectors in the Elysium-Utopia region. The orbit number from top to bottom is 0467301, 0509501 and 1822801, respectively. White arrows denote subsurface reflectors in the radargram (a, b, and c) which can't be found in the cluttergrams (d, e, and f).

Three types of the radargrams with clear subsurface reflections were observed: (1) single subsurface reflector (Fig. 2a); (2) subsurface reflector gradually extends to the surface (Fig. 2b); (3) combination of the former two (Fig. 2c). The depth of the reflector of type 1 is unknown, which results the difficulty of estimation of permittivity, while the layer thickness is used in the remaining two types to calculate permittivity of the surface layer.

Measurement of the permittivity: The elevation profile shows the surrounding region of reflectors is not flat and rises from north to south, hence, the elevation of the bottom of the surface layer is generated with extrapolated method.

The value of ε' of the surface layer in area A is 8.2 with a standard deviation of 2.2 (Fig. 3). This is close to basaltic flows as most terrestrial and lunar basalts that have ε' value between 7 and 11. Therefore, the surface materials was interpreted as lava flow.

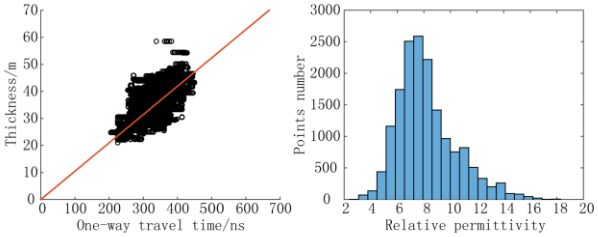

Fig. 3 Plot of surface layer thickness versus one-way travel time. The red line stands for the mean value of permittivity (left). The distribution of relative permittivity performs a normal distribution (right).

Disscussion: Several factors may affect the detection of subsurface interfaces. Surface roughness is an important factor because the reflectors occur almost exclusively beneath the smooth surface [6,9]. The thicknesses of surface flows may be another factor. Radar wave may not be able to penetrate thick layers or detect thin layers with thickness less than its resolution. The thicknesses of surface flows in area A range from 26m to 45m, most of them appear in magmatic front with relatively shallow thickness. Other factors such as loss tangent and permittivity contrast also influence the subsurface reflections.

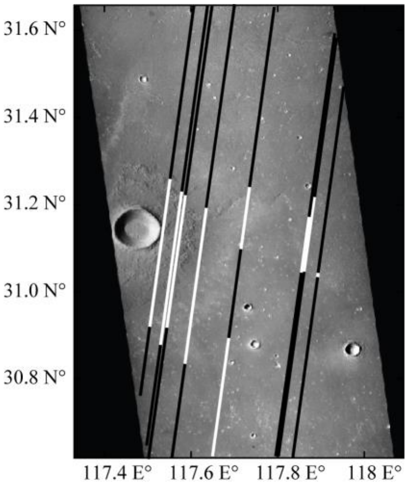

Fig. 4 Context image B20_017325_2122_XN_32N242W. The lines are ground tracks. The black lines indicate location where SHARAD detected subsurface reflectors.

In Fig. 4, the color change of the black lines to white ones denoting the disappearance of subsurface reflectors happens along the end of the surface lava flow, where the lower layer exposes. Both layers show similar characteristic in CTX images, THEMIS daytime and nighttime infrared images cross the lava front, indicating their similar composition or permittivity. Hence, the reflector is caused by the interface between lava flows erupted in different periods, which could be the regolith layer formed by the erosion of the beneath basalt layer, while a volatile-rich dust layer can't be ruled out [7].

In the study of lava flows in Tharsis region, the ε' values of lava flows range from 7.6 to 11.6, with an average of 9.6 [6]. The relative low ε' value in Elysium-Utopia region may be caused by thicker dust layer, higher porosity or the presence of water ice in the flows. Based on the results of OMEGA and TES, dust covers the surface of both Elysium-Utopia and Tharsis regions. The brightness of radar signal at 12.6 cm wavelength could be the indicator of thickness of dust layer [14]. However, no clear difference of the earth-based radar measurements in these two regions could provide the conclusion on dust thickness. The impact processes may also affect the porosity of the surface material. The model age of area A is about 1.66 to 3.08 Ga [15], while the age of Tharsis region where SHARAD detected subsurface interfaces is several millions of years [16]. Generally, the aged surface experiences more impact events and long-time erosion, which contribute relatively high porosity and can explain the low value of permittivity.

Acknowledgements: This research was supported by project of the Science and Technology Development Fund (FDCT) of Macau (Grant No. 107/2014/A3 and 039/2013/A2).

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