

CHARACTERIZATION AND MAPPING OF LIGHT-TONED, LAYERED DEPOSITS ON THE PLATEAUS OF WESTERN VALLES MARINERIS WITH SHARAD AND HIGH-RESOLUTION IMAGERY. I. Mishev (imishev@my.yorku.ca)¹ and I. B. Smith^{1,2}, ¹York University, Toronto, ON, Canada, ²Planetary Science Institute.

Introduction: Light-toned layered deposits (LLD) are found across the plateaus and near to the rim of western Valles Marineris (VM), situated on top of Hesperian aged terrain [1-3]. These deposits exhibit fine scale layering, visible down to 1 m resolution with the High Resolution Imaging Science Experiment (HiRISE, Fig 1).

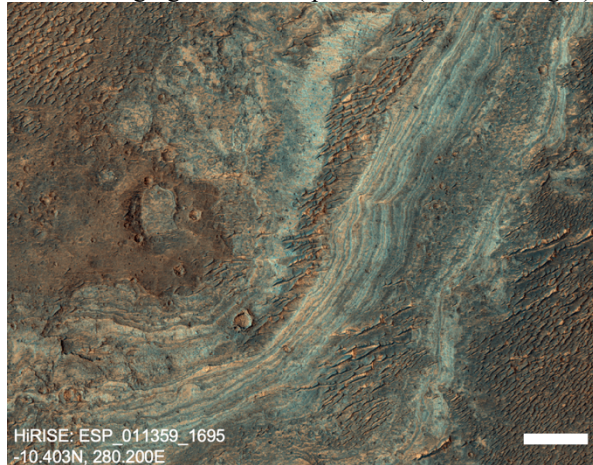


Figure 1: LLD outcrop displaying fine scale, complex layering with bedforms onlapping the horizontal surfaces. Located on the southern plateau of Ius Chasma (yellow star in Fig. 4). White = 50 meters.

The LLD are thought to be composed of pyroclastic ash that was emplaced during volcanic eruptions and then modified by water, either in lacustrine or fluvial sedimentary deposition [1-2, 6]. Characterizing LLD is essential to testing the hypothesis of their formation and may constrain the timing and duration of water activity in this region. Using instruments onboard the Mars Reconnaissance Orbiter such as The Context Camera (CTX), Mars Shallow Radar Sounder (SHARAD), and HiRISE, we mapped the extent of the LLD and other units over the western region of VM.

Previous examination of LLD was accomplished mainly through the use of visual imagery and spectroscopy [1-3]. Due to limitations of surface exposure (deposits are buried by dust and dunes), extent could not be fully determined using imagery alone. To remedy this, we analyzed SHARAD data to confirm the presence of LLD and massive deposits in areas where outcrops were unavailable, extending the boundaries beyond what was already mapped and discovering new deposits. The flat, high elevation topography of the plateaus are ideal candidates for radar investigations because off-nadir reflections (clutter) is rarer and does not interfere with interpretation of potential subsurface reflections.

SHARAD Mapping: Regions with LLD outcrops are found to have ubiquitous basal reflections. Using SHARAD data, and commercially available geophysical software (Seisware), all radar tracks (to orbit 49500) present in western VM were analyzed. The distinction between clutter and basal reflection was required to ensure accuracy. Clutter simulations based on topographic data from the Mars Orbital Laser Altimeter (MOLA) [4] were used to avoid erroneous reflections being present in our final map.

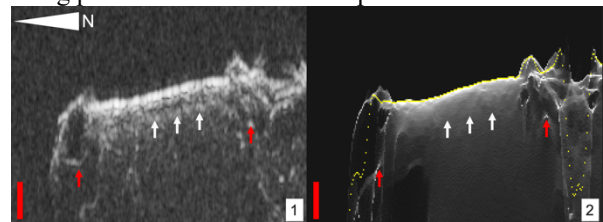


Figure 2: Radargram (1) and clutter simulation image (2) of SHARAD radar track 4828801 (black box in Fig. 4). White arrows indicate location of basal reflection, red arrows highlight clutter. Red bar = $1.00\mu\text{s}$ two way travel time, approximately 80 m.

Working with DTMs and MOLA topography, the thickness of the units across the three plateaus ranges from ~30-70 m. To date, we've been able to measure time delay with SHARAD in two places with DTMs and find that the bulk dielectric permittivity (ϵ) average is ~3.2, consistent with a low-density material [4].

Imagery Investigation: We analyzed HiRISE imagery to characterize the different morphological regions associated with large concentrations of basal reflections. Hundreds of images of western VM were cataloged, and three distinct regions were identified.

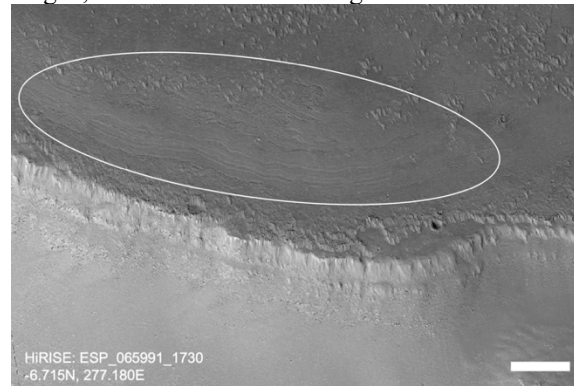


Figure 3: Massive unit with isolated, layers/pseudo-layers on the northern plateau of Ius Chasma (blue star in Fig. 4). Layering near to the rim is circled for emphasis. White = 300 meters.

A) Widespread Layering. These regions exhibit complex layering (Fig. 1, orange in Fig. 4) that extends across vast unbroken stretches, and are accompanied by the largest concentration of radar reflections. Additional evidence of fluvial morphologies and overland flow exists in these regions [3].

B) Massive Unit with Isolated Layers/Pseudolayers. Regions with intermittent or occasional layering, often concentrated directly adjacent to the rims of the plateaus (Fig. 3, green in Fig. 4). Layers appear less pronounced and discontinuous, but radar reflections are contiguous throughout and into neighboring units.

C) Unlayered Massive Unit. These units are bland on the surface and are only identified by the density of SHARAD reflections found within them (yellow in Fig. 4). Radar investigations show that the massive unit is contiguous with the LLD.

Formation Hypothesis: The formation mechanism and history of the LLD is currently under question. One hypothesis that we are investigating is that the LLD are thought to be composed of pyroclastic ash fall. The relative proximity to multiple large volcanos suggests that nearby eruptions emplaced material in vast amounts, consistent with other locations on Mars [5-6].

Morphological Map of Western VM:

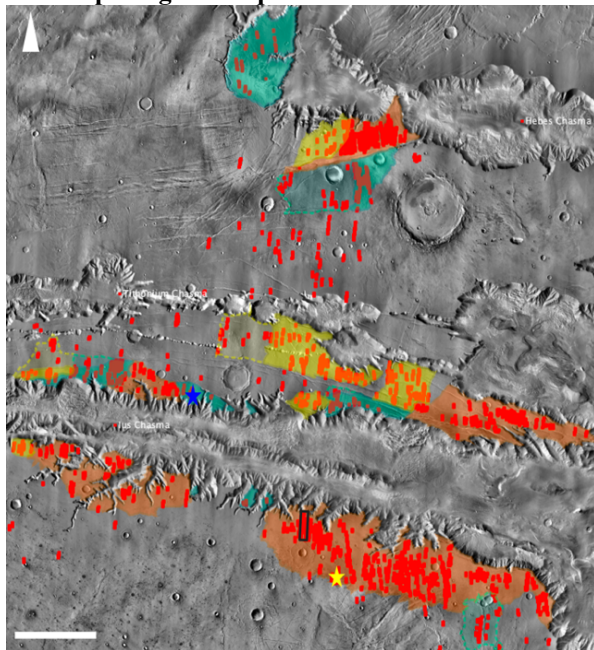


Figure 4: THEMIS-Daytime image of Western VM. Red lines show SHARAD basal reflections. Widespread layering displayed (A) in orange. Massive unit with Isolated Layers/Pseudo layers (B) shown in green. Unlayered massive unit (C) shown in yellow. Dashed lines indicate regions where extent of unit boundaries are not defined. Yellow Star = Fig. 1, Black Box = Fig. 2, Blue Star = Fig. 3. White = 100 km.

Widespread evidence of fluvial and lacustrine settings [1-3] correspond spatially to the LLD, where geochemical alteration products are also present. Thus, after and during emplacement, the material interacted with water to form layers, channels, and alteration minerals. We hypothesize that the difference between regions A, B, and C, is access to water: areas with widespread layering formed in ponded water, whereas regions with moderate layering experienced intermittent or one-time water. Regions absent of layers were dry.

We combined the findings from the radar and imagery investigations to create a map of Western VM that shows the relationship between the LLD, the massive units, and the basal reflections (Fig. 4).

The fully mapped plateaus give larger context to the geology of VM rim. The appearance of a potential relationship between the morphology of the plateaus on either side of Ius Chasma is noteworthy because it suggests the widening of Ius Chasma played a role in the modification of the LLD and the accompanying layered and unlayered massive units.

Ongoing Work: Along with parallel work to map alteration minerals and thermophysical properties, we are comparing SHARAD time delay of the reflections to HiRISE and CTX DTMs to determine the dielectric constant of the units to help constrain the density composition of the material. Surface feature analysis of the plateau is currently ongoing. The abundance of bedform and aeolian ridge-like surface structures covering all units may suggest that they were eroded out of the pyroclastic material after it was emplaced. The effort to create a deep learning neural network to map and analyze the geomorphology of these surface features is underway and in the early stages of development. Our current hypothesis of formation needs further investigation for testing. Our maps are continually updated as new data from the MRO becomes available.

Acknowledgments: We acknowledge NASA Mars Data Analysis Program Grant 80NSSC17K0437 and a Canada Research Chair grant in Planetary Science to Isaac B. Smith.

References: [1] Le Deit et al. (2010) *Icarus*, 208, 2, 684–703. [2] Weitz et al. (2008) *GRL*, 35, L19202. [3] Weitz et al. (2010) *Icarus*, 205, 1, 73–102. [4] Smith et al (2019) *LPSC L, Abstract #2713* [5] Kerber et al. (2012) *Icarus*, 219, 1, 358–381. [6] Runyon et al. (2020) *LPSC LI, Abstract #1083*