GEOLOGIC MAPPING AND RADAR SOUNDING IN HEBRUS VALLES AND HEPHAESTUS FOSSAE, MARS.

S. Nerozzi[1], R. Spurling[1], M.R. Ortiz[2], L. Panzarella[1], J.W. Holt[1]. [1]Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ (nerozzi@arizona.edu), [2]Jackson School of Geosciences, University of Texas at Austin.

Introduction: Hebrus Valles (HV) and Hephaestus Fossae (HF) are well-preserved examples of Early Amazonian outflow channel systems carved into bedrock in SE Utopia Planitia, Mars (17-25 °N, 118-129 °E, Fig. 1). They exhibit a diverse set of morphologies indicative of formation by one or more liquid water outflow events, possibly initiated by magmatic intrusion, melting and cracking of the cryosphere [1-4]. However, little is known about their history, including both the origin and ultimate fate of the water and resulting sediments. This represents a significant gap in our understanding of geologic processes occurring in the Amazonian Period. Thanks to extensive coverage by recent datasets, it is now feasible to study the evolution of the HV-HF outflow channel systems with an integrated analysis of diverse, complementary data. These include high-resolution visible imagery, multispectral infrared datasets, surface and subsurface radar sounding, and stereo-derived digital terrain models (DTMs).

Methods: The initial task of this study is chronostratigraphic geologic mapping of the HV-HF region (Fig. 1). We integrate the analysis of a context camera (CTX, [5]) mosaic basemap with stereo-derived CTX DTMs, Shallow Radar (SHARAD) surface reflectivity, and Thermal Emission Imaging Spectrometer (THEMIS) decorrelation stretches. This task is followed by the detailed reconstruction of the sequence of geological processes and events based on the identification of morphological and thermophysical facies in a subset of the study region. We employ impact crater statistical analysis to determine geologic unit ages (and thus maximum ages of outflow channels), and history of subsurface water exposed in the ejecta of large impacts.

We analyzed over 300 Shallow Radar (SHARAD, [6]) 2D profiles over the entire study area, and traced subsurface reflectors. Clutter simulations based on high resolution DTMs allowed us to distinguish returns that appear in the subsurface but originate from off-nadir surface relief [7]. In addition to subsurface mapping, numerous studies have demonstrated the ability of reflectivity analysis to provide quantitative descriptions of scattering properties and dielectric permittivity of the surface and the shallow subsurface in SHARAD data [e.g., 8]. We applied similar techniques to a subset of SHARAD profiles crossing HV to obtain a quantitative description of near-surface reflectivity.

Results: *Geologic mapping.* We have delineated the contacts between 8 geologic units, not including impact craters and the materials inside the outflow channels. The oldest unit in the study area is the *Nepenthes flow unit*, a complex layered volcanic and sedimentary unit that was previously identified with the same name by [9] in the adjacent Nepenthes Planum region. On top of it lies the *Utopia lower unit*, which corresponds to a unit identified with different names in older geologic maps [e.g., 9]. Moving up in the stratigraphic column, we found three additional lowland units: the *Utopia lowland unit*, the *Utopia lumpy unit*, and the *Utopia lobate unit*. We are currently testing hypotheses on the stratigraphic and genetic relationship between these units: (1) they represent two or three separate chronostratigraphic units, (2) they are three different morphological facies of the same chronostratigraphic unit, (3) they are three separate resurfacing stages of the same unit. This hypothesis testing exercise consists of refining of CTX image analysis and impact crater statistical analysis. Three younger units overlie the Utopia units. In the NE corner of the geologic map lies the *Elysium volcanic unit*, which consists of volcanic flows related to Elysium Mons volcanic activity. To the south, we identified two additional units: the *Elysium platy unit*, which we interpreted to be volcanic in origin but distinct from the *Elysium volcanic unit*; the *Elysium chaos unit*, which we interpreted to be a tectonic break up of the *Elysium Platy unit*.

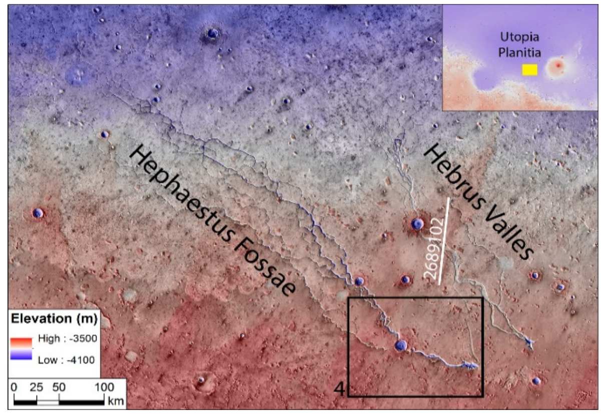

Figure 1: THEMIS IR Day mosaic overview of the study region in the broader context of Utopia. The white line indicates the radar profile ground track in Fig. 3.

The outflow channels of Hebrus Valles and Hephaestus Fossae are carved exclusively on the *Utopia units*, which allows us to place a maximum age constraint of their formation at 2.4 ± 0.2 Ga (i.e., the age of the *Utopia units*). However, the head depressions from where the channels originate may reach a lower unit that underlies the Utopia lower unit, perhaps the *Nepenthes flow unit*.

Radar sounding. Radar subsurface mapping reveals

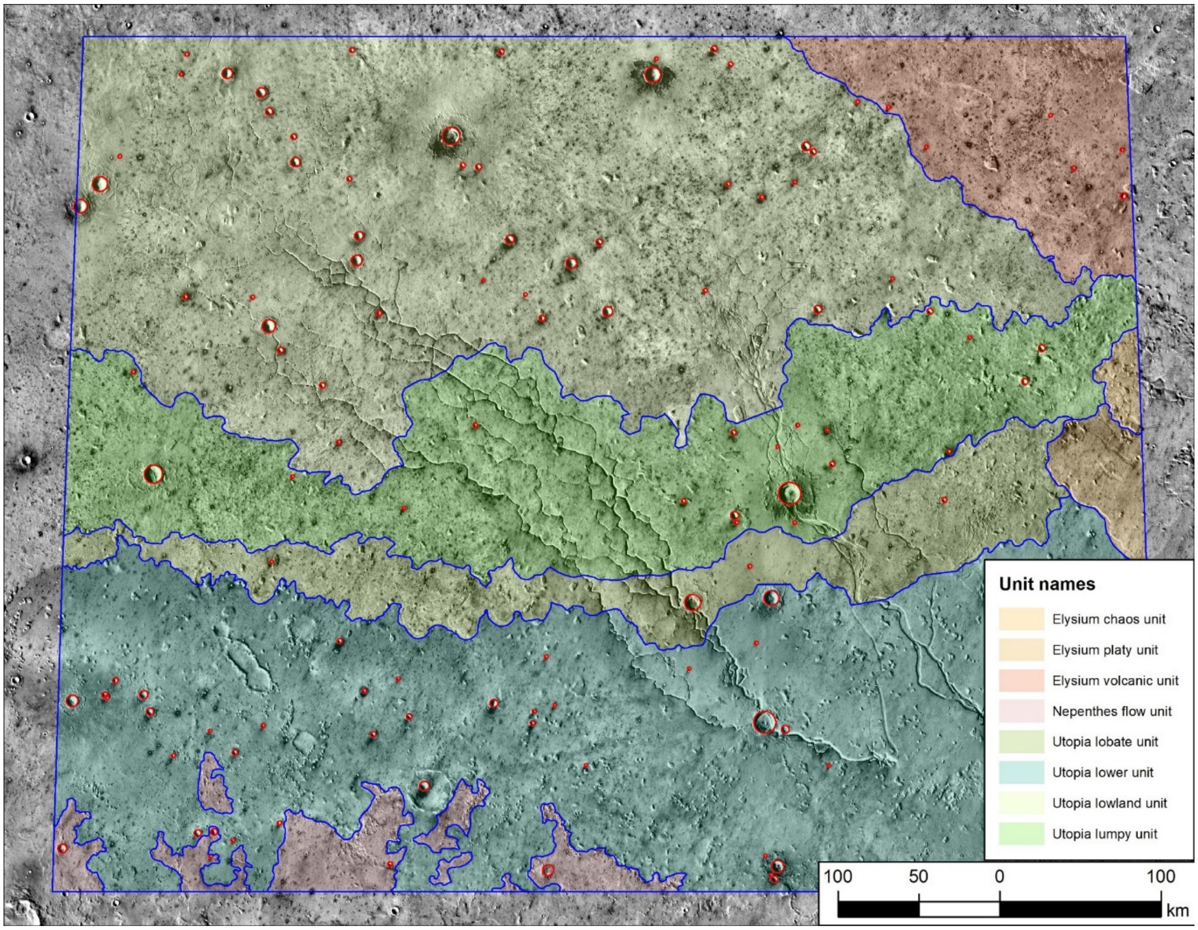

Figure 2: Preliminary chronostratigraphic map of the Hebrus Valles and Hephaestus Fossae region. The red circles delineate impact craters with diameters >2 km used for crater size-frequency distribution analysis.

numerous clusters of shallow reflectors, which we divide into three categories based on their location. One large cluster of reflectors is associated with terrains of Hyblaeus Fossae and Granicus Valles, and corresponds to the *Elysium volcanic unit*. A second cluster, smaller in extent, is located to the SE of HV. The third group comprises reflectors near the outflow channels of HV, with a depth ranging from ~45 m assuming a basaltic subsurface composition (ε'=8.8, [10]) to ~60 m assuming pure water ice (ε'=3.1 [e.g., 8]). These depths are not compatible with the detection of the base of the resistant layer seen in nearby outcrops at <30 m depth. Moreover, reflectors appear to pinch-out or vary in depth considerably, and are all located within the topographic expression of a wrinkle ridge, suggesting a structural, rather than stratigraphic, origin.

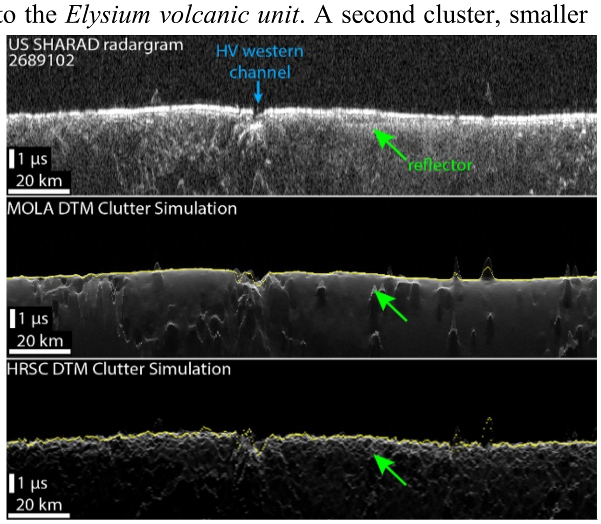

Figure 3: Sample of SHARAD profile showing a subsurface reflector. Clutter simulations below shows that only diffuse scattering is present at that location.

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