REMNANTS OF CLASTIC/VOLCANOCLASTIC DEPOSITS IN WESTERN ELYSIUM PLANITIA, MARS: IMPLICATIONS FOR THE STRATIGRAPHY BENEATH THE INSIGHT LANDER.

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Introduction: The Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) spacecraft landed in western Elysium Planitia at 4.502°N, 135.623°E on an Early Amazonian basaltic lava plain [1] (Fig. 1). The lander is also located ~500 km north of the planetary dichotomy and ~200 km west of Aeolis Planum, a large remnant of the Medusae Fossae Formation (MFF) [2,3].

Multiple investigations, ranging from shallow seismic experiments [4,5] to in-situ and remote geological analyses [6], have described the shallow stratigraphy (cm to 100-m-scale) beneath the lander. The general consensus from these studies is that InSight rests on ~3 m of loosely-consolidated, impact-generated sand that overlies up to ~10 m of coarser regolith consisting of fractured basaltic rocks. Beneath the regolith, are ~200 m of Early Amazonian to Hesperian basaltic lava. The Amazonian-Hesperian sequence overlies aqueously-altered Noachian-age clastic rocks that are interlayered with ejecta and volcanics [7].

While the seismic investigations generally agree with the geological analysis, a low seismic velocity zone was identified in the Amazonian to Hesperian-age sequence that suggests an interruption of effusive volcanic activity on the northern plains by an episode of clastic/volcanoclastic deposition [4]. The upper contact of the low velocity zone occurs at a depth of ~30 m, either beneath or inter-layered with the Early Amazonian lavas. The estimated maximum thickness of this unit is 50 m [4], although more recent analysis of the seismic data suggests a relatively thin (~15 to 25 m) unit [5].

There is currently no surficial geologic evidence of a unit corresponding to the low velocity zone in the immediate vicinity (i.e., the landing ellipse) of the lander [7,8]. It also remains unclear if this material is the product of late-stage, aqueous sedimentation on the northern plains or another non-aqueous mechanism (e.g., volcanic, eolian). Regional geological mapping prior to landing identified remnants of possible clastic/volcanoclastic rocks hundreds of kilometers south and east of the InSight lander, including layered materials in the transitional highland terrains and the MFF (Aeolis Planum) [7,8]. But, the relative age relationships of these materials to the Early Amazonian-age basaltic plains beneath InSight, and the possible connection to this low velocity unit, are poorly understood.

Here, we expand on earlier mapping efforts south of InSight (Fig. 1). We constrain the distribution, morphology, and relative age of possible clastic/volcanoclastic units relative to the lava plains. We posit that layered, easily erodible terrains to the south and east of InSight, including possible Hesperian to Early Amazonian-age remnants of the MFF, are representative of a more regionally extensive clastic/volcanoclastic unit that is thinly covered by Early Amazonian lava plains.

Methods: A 6 m/pixel Context Camera (CTX) image mosaic was constructed across a region from 4° S to 5° N and 131° E to 142° E. The images were overlain and co-registered to Thermal Emission Imaging System (THEMIS) daytime and nighttime 100 m/pixel mosaics. The Mars Orbiter Laser Altimeter (MOLA) gridded DEM at 463 m/pixel was also used.

Geological mapping was conducted using ArcGIS Pro. Terrain units were identified based on their albedo, topography, surface texture, crater abundance, and relative stratigraphic relationships. Contacts were mapped at a scale of 1:50,000. Once the contacts were placed, polygons were constructed and units classified.

While all terrain variations were identified and mapped, particular attention was paid to lava plains and materials that may be clastic/volcanoclastic. Units of possible clastic/volcanoclastic origin were distinguished in CTX images based upon: (1) poor retention of 10 to 100-m-scale craters, (2) evidence of meter-scale layering, (3) fluted, fretted, or grooved textures with a preferred orientation (i.e., yardangs), and (4) a higher albedo [9]. In contrast, lava plains are noted in CTX images by: (1) their smooth texture, (2) retention of small impact craters (including abundant rocky ejecta craters), (3) relatively moderate albedo, (4) wrinkle ridges, and (5) lobate landforms [8].

Results and Discussion: Figure 1 is a preliminary map of the region displaying all identified terrain units. The Smooth Plains unit dominates the region and is morphologically consistent and indistinguishable from, aside from local variations in bedform and rock abundance, the Early Amazonian lava plains beneath InSight (i.e., Smooth Terrain). This unit embays highland remnants as well as some relatively young impact crater ejecta blankets.

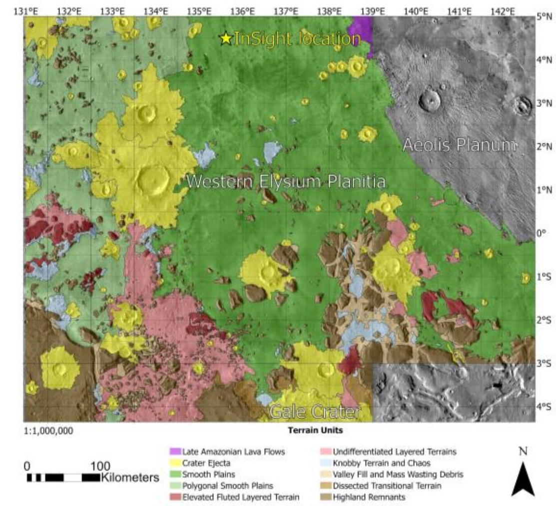

Figure 1: Geologic map of Western Elysium Planitia.

Approximately 300 km south of the lander (Fig. 1), the Smooth Plains unit contacts layered terrains of possible clastic/volcanoclastic origin, including the Undifferentiated Layered Terrain and the Elevated Fluted Layered Terrain (Fig. 2). These terrains are spatially and stratigraphically related and may have a similar origin. The elevated variant rests hundreds of meters above the surrounding plains and is characterized by km-scale yardangs. This unit is texturally and topographically similar to the Aeolis Planum remnant of the MFF and overlies Noachian-age highland remnants. The Undifferentiated Layered Terrain rests at a lower elevation relative to the elevated remnants and is also younger than the Noachian highland remnants. The unit is dubbed "undifferentiated" here due to complexity in surface textures and differential weathering patterns. Figure 2a displays low-albedo, crater-retaining, lobate material in the undifferentiated unit south and west of InSight. This material has a similar texture to the Smooth Plains (lava plains) beneath InSight. Lava plains-like units exist throughout the undifferentiated unit, but are relatively rare compared to higher albedo, layered materials (Fig. 2b). The layered materials in the undifferentiated unit are extensively eroded, exhibiting yardang-like features, mesa/butte morphology, and lack small craters, indicating a possible clastic/volcanoclastic origin. Smooth plains materials in the undifferentiated unit consistently embay the higher albedo layered materials. The Undifferentiated Layered Terrain unit, at the transition with the highlands, represents the largest remnant (by area) of possible clastic materials in western Elysium Planitia. It extends south to north from the dichotomy to 0.9° N. Its western extent has yet to be mapped at this scale, but remnants span the width of the map.

Similar stratigraphic relationships are observed south and east of InSight, proximal to Aeolis Planum. At 1.417° S, 140.190° E (Fig. 2c), an elevated remnant of likely Aeolis Planum material (the MFF) is surrounded by Smooth Plains. CTX images reveal that Smooth Plains were emplaced, likely as lava, within troughs in the previously eroded and grooved landscape of the layered stack. The stack has since backwasted, leaving a mold of its original extent. The Smooth Plains material forms long, tongue-like casts where it was emplaced in the troughs. Molds in the MFF and casts of lavas occur at contacts between the easily eroded MFF and more resistant Hesperian to Amazonian-age lavas elsewhere on Mars [2]. The Smooth Plains unit embays remnant stacks of layered materials everywhere in this region (Fig. 2c, d).

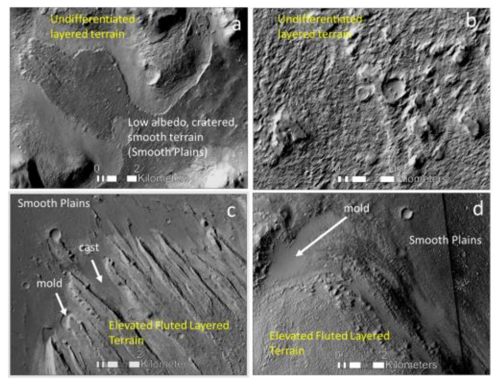

Figure 2: CTX images showing: (a) low albedo smooth unit embaying layered terrains in the Undifferentiated Layered Terrains unit, (b) mesa/butte morphology with poor crater retention in the Undifferentiated Layered Terrains unit, and (c, d) contacts between the Smooth Plains and Elevated Fluted Layered Terrain (MFF remnants) unit showing mold and cast morphology.

Conclusions: Our preliminary results suggest that the Early Amazonian-age Smooth Plains unit that underlies the InSight lander post-dates clastic/volcanoclastic materials that occur further south of the landing site. The clastic/volcaniclastic units identified here are more extensively distributed across the region than previously considered and potentially extend beneath InSight as the low velocity zone that is below or within Early Amazonian lavas. These layered terrains share similar physical characteristics to Aeolis Planum and may represent remnants of the MFF.

References: [1] Golombek, M.P. et al., (2020), *Nat. Comm.*, 11. [2] Kerber, L. & Head, J., (2010), *Icarus*, 206. [3] Bradley, B. et al., (2002), *JGR*, 107. [4] Hobiger, M., et al., (2021), *Nat. Comm.*, 12. [5] Carrasco, S. et al., (2023), *Geo. J. Intern.*, 232. [6] Warner, N. et al., (2022), *JGR*, 127. [7] Pan, L. (2020), *Icarus*, 338. [8] Golombek, M.P. et al., (2018), *Space Sci. Rev.*, 214. [9] Rogers, A.D., (2018), *GRL*, 45.