REGOLITH THICKNESS IN WESTERN ELYSIUM PLANITIA: CONSTRAINTS FOR THE INSIGHT MISSION. N.H. Warner[1], M.P. Golombek[1], C. Bloom[1,2], N. Wigton[3], C. Schwartz[4], Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, [2]Occidental College, Los Angeles, CA 90041, [3]University of Tennessee, Knoxvlle, TN 37996, [4]Mount Holyoke College, South Hadley, MA 01075.

Introduction: One of the primary science objectives of the InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) mission is to constrain the geothermal flux of the interior of Mars [1]. The Heat Flow and Physical Properties Package (HP^3), a percussive "mole", is designed to acquire this measurement from a depth of up to 5 m, with a requirement of 3 m. To achieve this depth, the surface materials at the landing site must be a regolith that is composed of loosely consolidated material without tabular flat rocks larger than ~10 cm diameter. Given these parameters, constraining the thickness of the regolith in the landing site region [2] in western Elysium Planitia is important to assess the success potential of HP^3.

Here, we provide constraints for the regolith thickness across the Hesperian to Early Amazonian-aged ridged plains of western Elysium Planitia [3] at the location of the finalist landing ellipses. Martian regolith is generated through multiple processes, including impact cratering, aqueous weathering, volcanism, aeolian erosion and deposition. However, for the majority of Martian history, comminution of surface material by impact gardening was likely the dominant process [4]. Using impact production rates, Hartmann et al. [4] estimated that Late Hesperian to Early Amazonian surfaces experienced 3 to 14 m of impact gardening. By comparison, the Spirit rover at Gusev crater identified regolith around 10 m thick on Early Hesperian-age basaltic terrains [5]. The ridged plains at the InSight landing site are of similar-age and morphology to the basaltic plains of Gusev crater and should therefore, in the absence of processes that may have stripped the regolith, also exhibit loose surface material that is adequate for HP^3 penetration.

Methods: Due to the lack of in-situ observations at Elysium Planitia our analysis relies on 25 cm pixel^{-1} High Resolution Imaging Science Experiment (HiRISE) images to indirectly estimate regolith thickness. HiRISE to date has acquired 22 images across four finalist landing ellipses.

Here, we utilize observations of rocky ejecta craters across the landing region to constrain possible regolith thicknesses. Rocky ejecta craters are defined as relatively fresh impact structures that exhibit boulder-sized rocks in their contiuous ejecta blanket, within an annulus of 1 crater diameter from the rim. This ejecta is sourced from a depth that is approximately 10% of the crater diameter [6]. Using this principle, Catling et al. (2011) [7] mapped rocky ejecta craters across the northern plains, Vastitas Borealis Formation to constrain near surface stratigraphy. They identified the presence of a regionally-extensive shallow, 100 m to 200 m thick basalt unit. They also demonstrated that small craters with diameters <200 m do not exhibit rocks in their ejecta and interpreted this to indicate the presence of a 10 to 20 m-thick surface regolith on top of the bedrock unit.

Figure 1 displays a unique cross-sectional view of the stratigraphy of Utopia Planitia, visible along fracture walls of Hephaestus Fossae, that illustrates the shallow northern plains stratigraphy [7]. A massive, strong, fractured, unit occurs at the base of the exposure and is likely a basaltic lava flow. A ~5-m-thick, massive, lighter toned unit rests on top of the bedrock. This unit shows no obvious bedding structure and its bulk clast size is below the resolution limit of HiRISE. We interpret the upper unit as a surface regolith. Rocky ejecta craters occur only at the >50 m diameter range across the plains surface surrounding the Hephaestus Fossae exposures, confirming the methodology for estimating regolith thickness by [7].

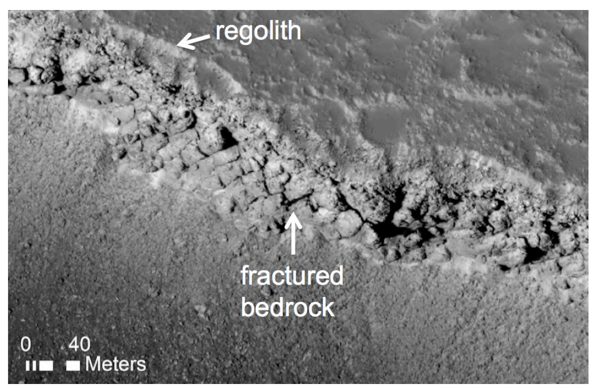

Figure 1: HiRISE image showing a cross section of northern plains stratigraphy along Hephaestus Fossae.

Results and Discussion: Across western Elysium Planitia, similar rocky ejecta craters are present that confirm a regionally extensive shallow bedrock unit. We also observe a cutoff diameter at which rocks no longer exist within the continuous ejecta blanket of small craters, consistent with Catling et al. (2011) [7] observations of a regionally-extensive northern plains regolith. Here, we estimate regolith thickness in the landing region by recording the onset diameter of rocky ejecta craters using the available HiRISE imagery. The minimum onset diameter of rocky ejecta craters in the InSight landing site region of western Elysium Planitia is ~40 m. While all craters smaller than this size do not exhibit blocks in their ejecta at HiRISE resolution, some craters larger than 40 m also do not have rocks in their ejecta. Figure 1 highlights example craters in one of the finalist landing ellipses (E05) [2]. The crater cluster in this image represents a swarm of secondaries, a portion of a ray from Corinto crater. Corinto crater is a 14 km impact structure located ~1000 km north of the landing region. Within this secondary cluster, only the largest crater, at ~40 m diameter, has excavated rocks. Recent mapping of Corinto secondary rays suggests that the Corinto impact occurred between 0.1-1 and 2.8±0.5 Ma [2]. Therefore, the Corinto secondaries excavated material that had comparable stratigraphic characteristics to what is present today and thus measures the thickness of the regolith produced since the Hesperian.

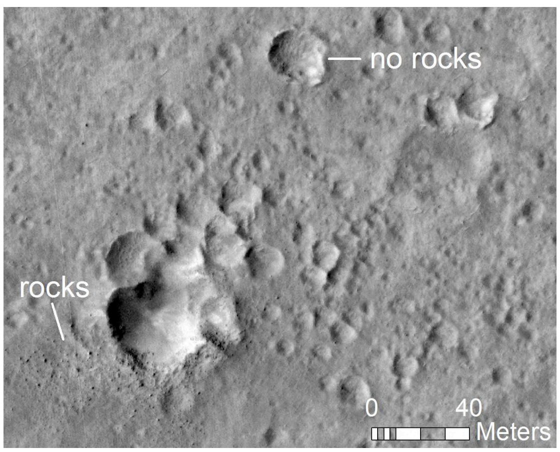

Figure 2: HiRISE image showing example Corinto crater secondaries. The 40-m-diameter crater in the lower left of the image has some rocks in its ejecta. The 15-m-diameter crater of the same age at the top has none.

Given the observed 40 m onset diameter of rocky ejecta craters, the regolith must be at least 4-m-thick across the region. Figure 2 displays a Hartmann root-2 binned crater frequency histogram that highlights important characteristics of regolith thickness and rocky ejecta crater preservation. The dark green data points represent the size-frequency distribution (SFD) for all craters larger than 1 km, measured from Context Camera (CTX) images across western Elysium Planitia. Using the chronology functions of [8], the model age of this population is ~3.5 Ga, confirming the Hesperian age of this surface. The lighter green data represent only the terrain that occurs within the four finalist landing ellipses, identified as Smooth Terrain [2]. The model age of this surface is ~3.1 Ga. The red data points represent crater counts that include only rocky ejecta craters, identified in the available HiRISE. At D >200 m the SFD follows the 0.5 Ga isochron, indicating that all craters of this size range that formed after 0.5 Ga accessed the competent bedrock layer below 20 m and have rocks preserved in their ejecta. However, a significant kink in the SFD occurs at diameters <200 m, indicating that there are less rocky ejecta craters of that size range than the 0.5 Ga production line requires. This indicates that while some <200 m-sized craters may have impacted into competent bedrock locally, many craters of this size did not. The cutoff diameter of where we observe no rocky ejecta craters anywhere on the landing site terrains is ~40 m. The blue data points represent our hypothesized projection of the 0.5 Ga production line for the rocky ejecta crater data if no regolith was present. In other words, if competent bedrock was present at the surface across the entire region, all of the <200 m diameter craters that formed after 0.5 Ga should exhibit rocky ejecta. Comparing the craters / root-2 bin km^{-2} values for the no regolith case (blue) to the actual rocky ejecta data (red) indicates that 99.75% of the entire area of the landing region should have a surface regolith that is at least ~5 m thick, fitting the depth requirement for the HP^3.

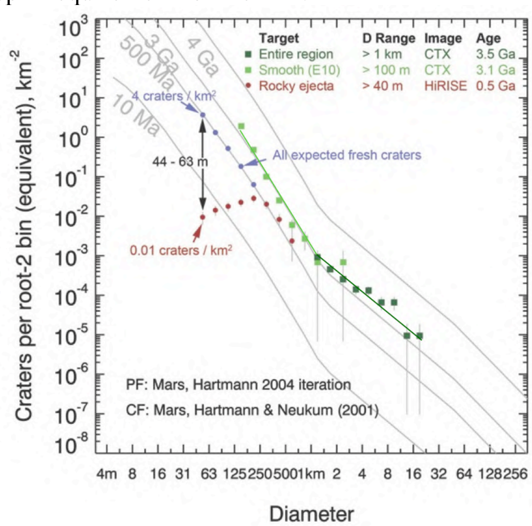

Figure 3: Hartmann crater plot for all craters in the landing region (dark green), craters in the four finalist landing ellipses (light green), and rocky ejecta craters in the landing region (red).

References: [1] Banerdt, W. et al. (2012) *43rd LPSC,* #2838. [2] Golombek, M. et al. (2013) *44th LPSC*, #1691. [3] Tanaka, K. et al. (2005) *USGS Map* 2888. [4] Hartmann, W.K. et al. (2001) *Icarus* 149, 37-53. [5] Golombek et al. (2006) *JGR* 111. [6] Melosh, J. (1996), in *Impact Cratering: a Geologic Process*, Oxford Univ. Press. [7] Catling et al. (2011) LPSC, #2529. [8] Hartmann, W.K. (2005) *Icarus* 174, 294-320.