**INSIGHT LANDING SITE: SUBSURFACE STRATIGRAPHY AND IMPLICATIONS FOR FORMATION PROCESSES.** V. Ansan[1], E. Hauber[2], M. Golombek[3], N. Warner[4], J. Grant[5], J. Maki[3], R. Deen[3], F. Calef[3], C. Weitz[6], J. Garvin[3], S. Wilson[5], N. Williams[3], C. Charalambous[7], T. Pike[7], H. Lethcoe[3], M. Kopp[4], A. De Mott[4], S. Smrekar[3], B. Banerdt[3], and R. Lorenz[8]
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**Introduction:** On November 26, 2018, the InSight lander touched down at 4.50°N/135.62°E within Homestead hollow, a subdued and filled depression on Late Hesperian, highly cratered volcanic plains of western Elysium Planitia, Mars [1,2,3,4].

**Surface Terrain:** Images from the lander-mounted Instrument Context Camera (ICC) and the robotic arm-mounted Instrument Deployment Camera (IDC) [5] show a smooth, sandy surface with additional >cm scale clasts, ranging from pebbles to very few cobbles [6,7,8] within ~20 m of the lander (Fig. 1). Close to the lander, pebbles and cobbles show two types of materials: one is dark-toned, grey aphanitic, probably corresponding to a basaltic composition, and the other one is light-toned with unknown composition.

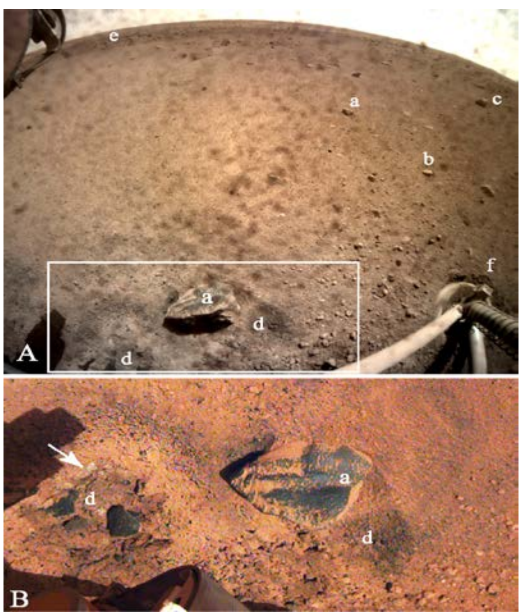


**Fig. 1:** A. South view of Homestead hollow, showing the flat sandy terrain covered by sparse sub-angular, pebbles and cobbles (a,b,c), and boulders (e) over the hollow. The right lander footpad (f) is partially buried in cohesionless, dark-toned, fine material. The ~20 cm long, "Turtle" cobble (a) consisting of dark-toned material (probably basalt), is eroded by wind (ventifacts, flutes) at its top surface and may have been pushed away by rockets during landing, leaving a shallow depression (d) composed of <cm scale dark particles (Fig. 1B). B. Detailed view in front of lander marked by white box in A, obtained by IDC, showing a few cm-deep left pit whose steep edges are irregular, composed of few mm- to cm thick, indurated, light-toned, fine-grained material (white arrow), and covering a material composed of dark-toned, angular to sub-rounded pebbles poorly sorted in a very fine grained matrix.

**Sub-surface terrain (~10 cm deep):** The texture and near surface structure of regolith have been exposed by landing rocket-induced excavations beneath the lander (Fig. 2), showing a variety of clast sizes, arrangements and texture at meter-scale. Note that measured grain size is greater than 0.5 mm due to the best resolution of IDC in near field.

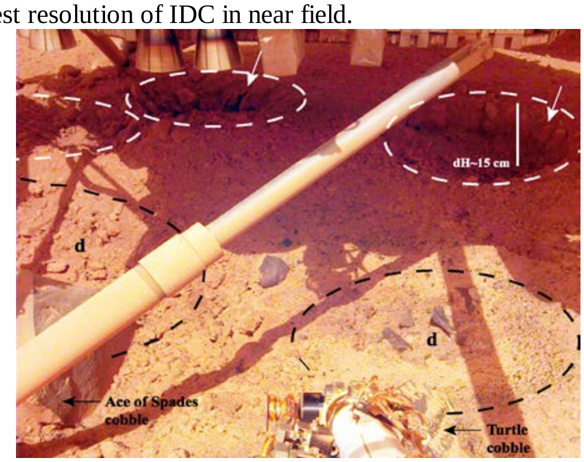


**Fig. 2:** IDC image showing the rough terrain beneath the lander: two cobbles in front of and near the western lander foot, two shallow depressions (black circles, <10 cm deep) and three deeper pits (white circles, <15 cm deep) showing a ~5 cm high micro-cliff composed of indurated soils, small angular gravels and pebbles. Within the indurated layer, there are locally sub-vertically fractured pebbles (white arrows). Below, a finer, cohesionless material is mixed with granules and small pebbles, some of which may be broken up from indurated layer.

Near the $HP^3$ heat flow probe feet (Fig. 3), indentations show fine-grained (< mm in size) material with a cm-scale deep, steep slope (greater than the angle of repose), suggesting some degree of cohesion.

**Fig. 3.** Indentation from the $HP^3$ feet after hammering.

**Stratigraphy of regolith:** From these observations, the near-surface stratigraphy is from top to bottom (Fig. 4): i) a ~cm-thick layer consisting of light-toned, cohesionless, sand or smaller (<1 mm) grains. This material was sculpted into <cm deep troughs and ridges radial to the lander by the descent rockets [6,7];

ii) an indurated layer, called duricrust, showing lateral variations of thickness (ranging from a few mm in front of lander up to ~5 cm beneath the lander). In addition, the duricrust shows lateral variations of textures, from fine-grained (i.e. <mm) to coarse-grained material (i.e. composed of poorly-sorted, angular to sub-rounded dark-toned clasts, ranging from granules to pebbles contained in lighter-toned, finer-grained (i.e. <0.5 mm) matrix, which would favor induration.

iii) a ≥~5 cm-thick, cohesionless, granular material comprised of a likely sandy matrix with poorly sorted clasts of sub-angular, dark-toned pebbles.

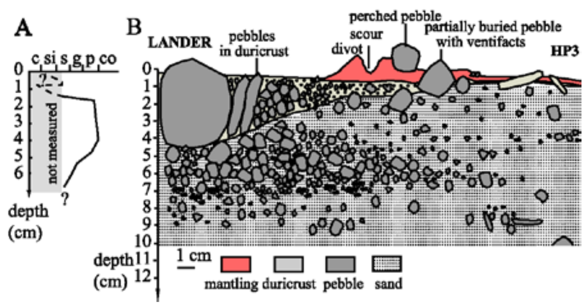


**Fig. 4:** A. Granulometry (c: clay, si: silt, s: sand, g: granule, p: pebble, co: cobble). B. synthetic cross-section of regolith near the InSight lander. Notice the variation of duricrust thickness and the change of grain size and texture.

If we extrapolate this at meter-scale, an idealized geologic cross-section would show the distribution of fragmented-rocks with depth (Fig. 5), due to impact gardening, before reaching Hesperian lava flows a few meters deep [9, 10, 11].

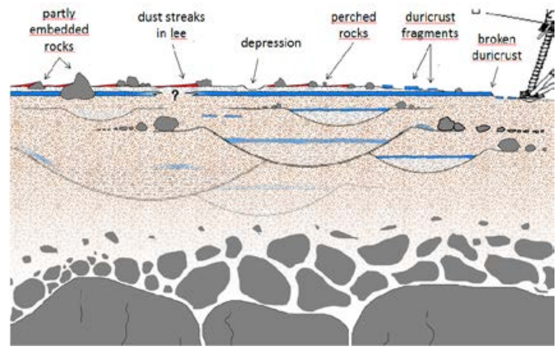


**Fig. 5:** Idealized geologic cross-section in Homestead hollow (not to scale). Lander foot at right side.

**Discussion:** This stratigraphy is generally similar to that at the Spirit landing site [12] and the Gusev cratered plains in which an impact-generated regolith up to 10 m thick overlies Hesperian basalt flows [13]. Although soils at the Gusev cratered plains have been cemented (<1 cm thick) [12,14], the duricrust at InSight shows a large variability in spatial occurrence and texture: It is both thicker and contains larger clasts in a matrix.

The near-surface stratigraphy of Homestead hollow suggests that several processes modified the Late Hesperian/Early Amazonian lava flows of western Elysium Planitia into this clastic regolith during the last 3 billion years: impact gardening to produce the angular clasts; aeolian erosion, transport and sedimentation, modifying clast shape and size, filling impact craters and intercratered plains, and weathering leading possibly to induration of sub-surface layer to form the duricrust.

**References:** [1] Golombek M. et al., (2019) *LPSC L*, Abstract #1694. [2] Golombek M. et al. (2018) SSR. [3] Warner, N. et al., *LPSC L*, Abstract #1184. [4] Parker, T., et al. (2019) *LPSC L*, Abstract #1948 [5] Maki, J., et al. (2019) *LPSC L*, Abstract #2176. [6] Grant et al. (2019) *LPSC L*, Abstract #1199. [7] Weitz, C. et al. (2019) *LPSC L*, Abstract #1694. [8] Charalambous C. et al. (2019) *LPSC L*, Abstract #2812. [9] Warner N., et al. (2017) SSR. [10] Golombek M. et al. (2017) SSR. [11] Ansan V. et al. (2019) *LPSC L*, Abstract #1310. [12] Arvidson et al. (2006) *JGR*, 111, E02S01. [13] Golombek M et al. (2006) *JGR* 111, E02S07. [14] Herkenhoff et al. (2008) The Martian Surface. Chp 20.