A NEW LOOK AT SURVEYOR VII FROM THE LUNAR RECONNAISSANCE ORBITER CAMERA. H. M. Meyer[1], M. S. Robinson[1], and J. D. Stopar[2], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85281 USA, [2]Lunar and Planetary Institute, USRA, Houston, TX.

Introduction: Of the five successful Surveyor missions, Surveyor VII (January, 1968) was the only one targeted primarily based on science and to land in a highlands location. It was equipped with a TV camera, alpha-scattering surface analyzer, and a soil mechanics surface sampler [**1,2**]. As such, it provided key information about the composition and structure of the highlands regolith, specifically that the highlands were richer in Al_2O_3 and poorer in FeO than the maria [**2**]. New data from the Lunar Reconnaissance Orbiter Camera (LROC) provides a means to constrain the geologic context of the Surveyor VII landing site at the meter scale, which also entails a fresh look at the lander observations and subsequent interpretations.

Landing Site: Tycho crater was chosen as the landing site for Surveyor VII because of its location in the southern highlands, providing a terrain distinct from previous Surveyor missions. A landing ellipse ~18 miles (~29 km) north of the crater on the continuous ejecta of Tycho (**Fig. 1**) was selected because it was expected to be covered in debris excavated from depth [**1**].

Surveyor VII Observations. The best estimate of the location of Surveyor VII was 40.95°S 11.41°W within the dark halo, or second ring, of Tycho's ejecta based on Lunar Orbiter V images [**1**]. Surveyor VII sits on top of the patterned flow unit (Cpf in **Fig. 2a**) near its margin with the patterned debris unit (Cpd in **Fig. 2a**) as identified by [**1,2**]. Patterned debris was interpreted as relatively high standing Tycho ejecta [**1,2**]. The patterned flow was thought to be a lobe of the same ejecta that was remobilized later during the formation of Tycho, leading to a slightly smoother appearance with fewer craters [**1,2**]. However, the patterned flow was also described as having swarms of north- and northwest-trending fissures to the south of the landing site. Interpretations of in-situ observations compared the patterned flow material to suevite, a melt-bearing breccia found at the Ries impact crater on Earth [**3**]. Closed depressions with dark, smooth interiors with branching grooves were called "lunar playas" due to the fact that they are flat floored depressions similar to terrestrial playas (Clp in **Fig. 2a**); however, they were interpreted as melted ejecta from Tycho [**1,2**]. Relatively low reflectance, smooth (rougher than Clp) units occurring on level benches and lacking branching grooves were identified as smooth patch material (Csp in **Fig. 2a**), interpreted to be the same, albeit thinner, material as the melt ponds (Clp) [**1, 2**].

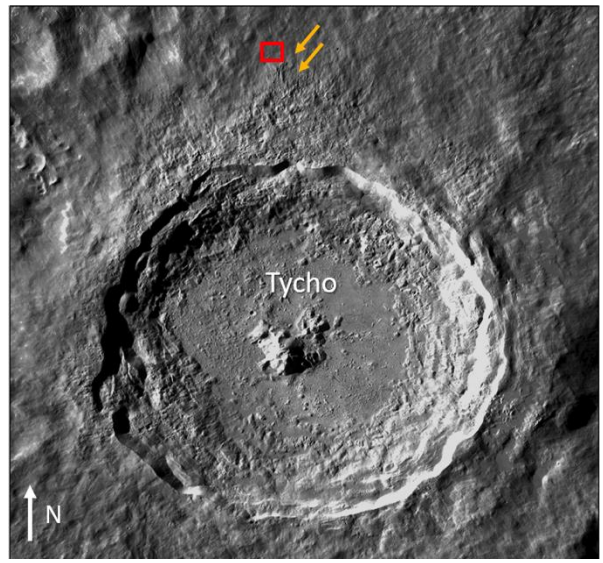

Fig. 1: LRO Wide Angle Camera image of Tycho crater (~85 km in diameter) located at 43.2958°S 11.2153°W. The red box denotes the Surveyor VII landing site. Yellow arrows denote large impact melt flows extending from Tycho near the landing site.

LROC Observations. The Surveyor VII lander was located using Narrow Angle Camera (NAC) images at 40.9812°S 11.5127°W [**4**]. The gradational contacts between the units defined by [**1,2**] appear even less distinct and in some cases disappear. The large impact melt pond (Clp in **Fig. 2a**) to the northeast occupies a topographic low (**Fig. 2b**) and thins along the southern margin, becoming a less continuous smooth unit in its southern half (**Fig. 2c)**. It is continuous with the slightly higher-standing terrain upon which Surveyor sits (**Fig. 2b**) and the high-standing bench of smooth patch material (Csp), and it is thin enough that the underlying topography shows through. This smooth unit, which is comparable to Csp material [**1, 2**], coats the Surveyor VII site and much of Tycho ejecta. It is likely a major contributor to the well known dark halo, interpreted as hosting impact melt glass, veneers, and ponds [e.g., **5-7**]. Further, the fissures identified by [**1,2**] as part of the patterned flow occur within this smooth unit (**Fig. 2c**). They become less distinctive with increasing distance from impact melt ponds and patches, likely indicative of decreasing thickness of the deposit. These fissures or fractures closely resemble those found within impact melt ponds at Copernican craters [**8**].

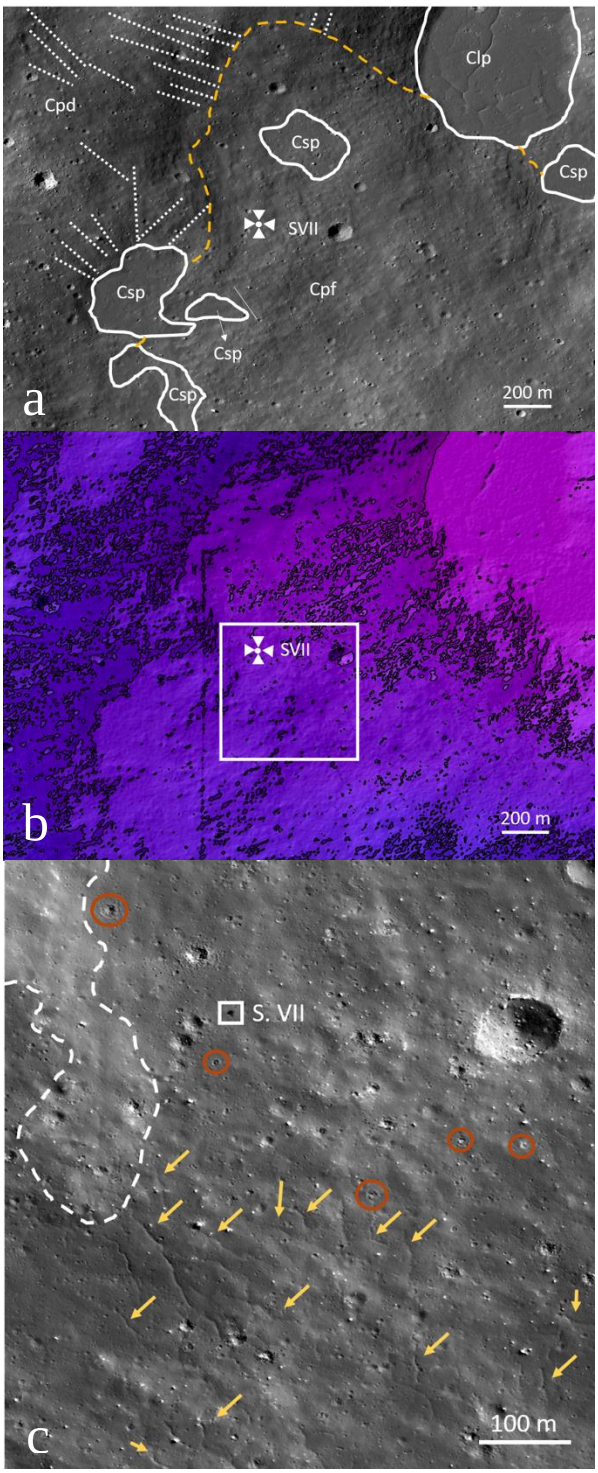

Fig. 2: (a) An LRO NAC image with the units and boundaries defined by [**2**] superposed. Dotted lines are faults, dashed yellow line is the approximate boundary between Cpf and Cpd. Image centered at 40.9820°S 11.5030°W. (b) LRO NAC DTM of the same location. Purple is high and pink is low, 50 m contours. Total relief for this area is ~120 m. The white box shows the location of panel c. (c) LRO NAC image M150598504R (56.22° incidence). The white dashed line shows the approximate boundary between the low-standing smooth unit and the high-standing debris unit. The orange circles indicate irregular craters. Yellow arrows designate clusters of N/NW trending fractures in the smooth unit.

Additionally, there are several small (few meters in diameter) irregularly shaped craters within the smooth unit beneath Surveyor that suggest that craters were forming while the unit was solidifying [**9**]. Small strength-regime crater morphologies, including benches, mounds, blocky ejecta, and relatively deep floors around the Surveyor VII landing site are consistent with a melt component in these deposits [**9,10**]. Kruger et al (2016) noted that the the greatest ejected melt at Tycho is concentrated on the NE to SE rims (postulated to be the result of an oblique impact) as a result of not only more ejected melt, but also favorable local topography [**11**].

Conclusions: Based on NAC observations, the geologic unit on which Suveyor VII sits, originally interpreted as remobilized ejecta [**1,2**], is interpreted as a melt veneer [**5,12**]. The appearance of fewer craters is likely due not to remobilization but to the late stage emplacement of melt and/or crater scaling effects [**13**]. The units defined by [**1,2**] as smooth patches and lunar playas are impact melt ponds (consistent with earlier interpretations [**1,2**]) that are continuous with the veneer on which Surveyor sits. Variations in the morphology of this unit are likely due to local differences in thickness. The morphology of the landing site, associated features, and the topography of the region suggest that the terrain is the product of impact melt flowing over the continuous ejecta of Tycho (and ponding locally). While much of the melt pooled in topographic lows, a thin veneer remained coating and subduing the terrain in the vicinity of the Surveyor VII lander.

References: [1] Shoemaker et al. (1968), Surveyor VII Prelim. Sci. Rep., NASA SP-173, [2] Shoemaker et al. (1968), Surveyor VII Mission Report Pt II Science Results, JPL Technical Report 32-1264, [3] Hörz et al. (1983), Rev. Geophys. Space Phys., 21, 1667-1725 , [4] Wagner et al. (2016), Icarus, 283, 92-103, [5] Hawke and Head (1977), Impact and Explosion Cratering, 815-841, [6] Smrekar and Pieters (1984), LPSC XV, P. 802-803, [7] Hawke et al. (1986), LPSC XVII, PP. 999-1000. [8] Stopar et al. (2014), Icarus, 243, 337-357. [9] Plescia (2015), LPSC XLVI, abstract #2054. [10] Stopar et al. (submitted) Icarus. [11] Kruger et al. (2016), [12] Howard and Wilshire (1975), J. Res. US Geol. Surv., 3, 237-251, [13] van der Bogert et al. (2017), Icarus, in press.