GEOLOGICAL DIVERSITY AT TWO POTENTIAL LANDING SITES IN THE LUNAR SOUTH POLE.

Nandita Kumari[1], I. Ganesh[2], A. Lang[3], J. M. Bretzfelder[4] and D. A. Kring[5]. (Nandita.kumari@stonybrook.edu) [1]Department of Geosciences, Stony Brook University, [2]Department of Planetary Sciences, University of Arizona, [3]University at Buffalo, [4]Department of Earth, Planetary, and Space Sciences, University of California, Los Angeles. [5]Center for Lunar Science and Exploration, Lunar and Planetary Institute.

Introduction: Several high-illumination sites [1] are being considered for Artemis missions with crew EVAs. An examination of two sites (Fig. 1) is complete [2]. Here we examine two additional sites (007 and 011) identified in NASA's Plan for Sustainable Lunar Exploration and Development [1] (Fig. 1). These sites are located on a summit between Shackleton and Slater craters and on the rim of de Gerlache crater, respectively.

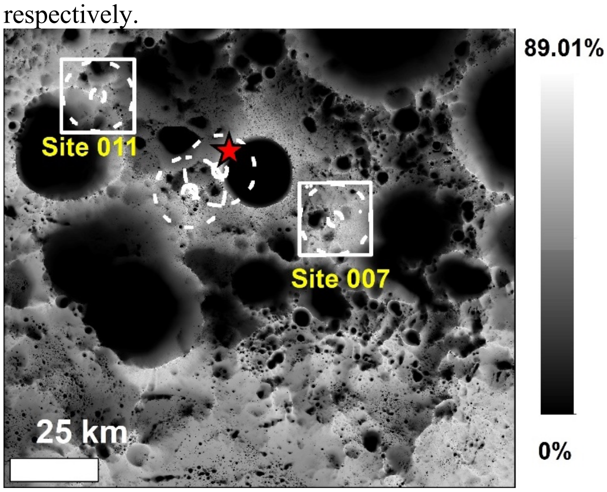

Fig1. Site 007 and Site 011 overlayed on average solar illumination map by [3]. The red star represents the south pole on the rim of Shackleton crater

Geologic Context: Site 007 is covered by pre-Nectarian, Nectarian and Shackleton crater ejecta which is of Imbrian age [4]. This site is located between Shackleton $(3.15^{+0.05}_{-0.08}\,Ga)$ and Slater $(3.18^{+0.1}_{-0.1}\,Ga)$ craters and blanketed by their ejecta [5]. Site 011 is located on the rim of de Gerlache crater blanketed by ejecta from several pre-Nectarian to Eratosthenian craters, including discontinuous debris from the Orientale impact basin [4]. The principal ejecta horizons are from de Gerlache $(3.9^{+0.1}_{-0.1}\,Ga)$, Cabeus $(3.5^{+0.1}_{-0.1}\,Ga)$, and Shackleton [6]. We have used the chronostratigraphic relationships of those ejecta horizons to identify (below) geologically diverse EVA targets at both the sites.

Boulder Distribution: Comprehensive boulder maps of sites 007 and 011 were created at a scale of 1:800 using high-resolution NAC images (0.4-0.8m/px) to evaluate the hazards they pose relative to experience around South and North Ray craters at the Apollo 16 landing site. Site 007 has 3204 visible boulders ranging from 0.7 to 14.4 m length while Site 011 has 3774 boulders 1 to 25 m in length (Fig. 2a, b). The identified boulders are primarily present in and around small craters in both sites. Most of the boulders in sites 007 and 011 are similar in size to the boulders found in South Ray crater [7] (Fig. 2c) and are bigger than the boulders around North Ray crater (Fig. 2d). To compare the distribution of these sites with South Ray and North Ray craters, K-S testing was done on both the sites with alpha of 0.001. The D-statistics for the tests with South Ray and North Ray craters are bigger than the critical value, indicating that though most of the boulders at 007 and 011 are of same length as those at South Ray crater, their distribution of sizes is very different.

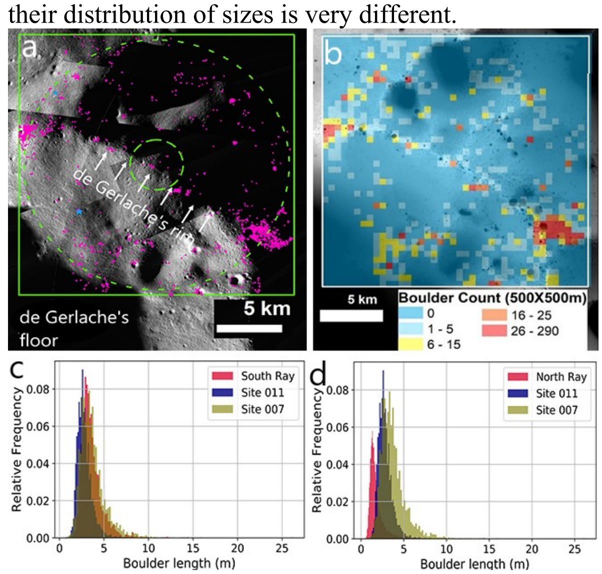

Fig 2. (a) Mapped boulders(pink) on a NAC mosaic (1m/px). (b) Boulder density distribution per 500m × 500m area. (c-d) Histogram displaying boulder lengths at site 007, site 011, and South Ray and North Ray craters.

Ejecta Thickness: The thicknesses of Slater and Shackleton ejecta at Site 007 were calculated using the equation of [8]. Shackleton ejecta thickness varies between ~250 m and ~10 m and that of Slater ejecta varies between ~3200 m and ~10 m (Fig. 3a). A 5 m/px LOLA DEM was used estimate the depths of subsequently formed smaller craters surrounded by boulders (Fig. 3b, d) to determine whether Shackleton or Slater ejecta horizons were being excavated by them. We also examined the geometry of underlying bedrock uplifted by the Shackleton impact event [9] to determine if it was penetrated by subsequently formed smaller craters. At least two craters at Site 007 may have excavated the bedrock that is potentially composed of pure anorthosite [10] (Fig. 3a, b).

Site 011 is blanketed by ~70 to 30m of ejecta from Cabeus crater (Fig. 3c) followed by ~20 to 5 m of ejecta from Shackleton crater (Fig. 3c). Those units are covered by a ~650 to 100 m thick ejecta layer from de Gerlache. Small, fresh craters on the rim of de Gerlache crater mostly excavated de Gerlache ejecta along with Cabeus ejecta in upper left portion of the site as shown in Fig. 3c and Shackleton ejecta in the upper-right portion of the region (Fig. 3d).

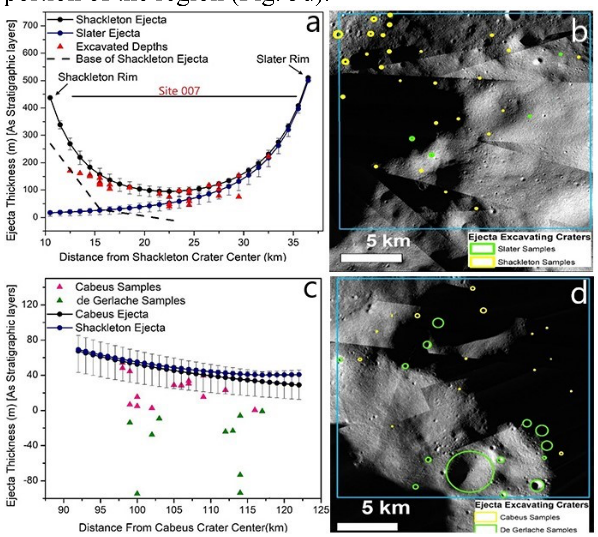

Fig3. (a) Shackleton and Slater ejecta thicknesses over Site 007. The red triangles represent the craters excavation depth w.r.t to ejecta thickness. (b) Craters excavating Slater ejecta (green) and Shackleton ejecta (yellow) (c) Cabeus and Shackleton ejecta thicknesses over Site 011. Green triangles represent craters excavating de Gerlache ejecta and pink triangles represent craters excavating Cabeus ejecta. (d) Craters excavating de Gerlache ejecta (green) and Cabeus ejecta (yellow).

EVA Targets in Site 011: Because the lower elevation portion of Site 011 lies on the walls of de Gerlache crater, most of this region has steep (>15°) slopes. In higher-elevation regions, however, slopes are less severe and conducive for traverses (Fig. 4a). Shallow slope and low boulder density within a 2-km radius might permit walking EVA for sample collection (Fig. 4a) of de Gerlache ejecta. Small PSRs within small craters may host volatiles that can be evaluated. If a rover extends the exploration zone to a 10 km radius, then at least 7 craters (Fig. 4b) can be used to sample relatively freshly exposed de Gerlache ejecta (Fig. 4c, d) and underlying Cabeus and Shackleton ejecta. In addition, it may be possible to collect Orientale ejecta at this site as well [4].

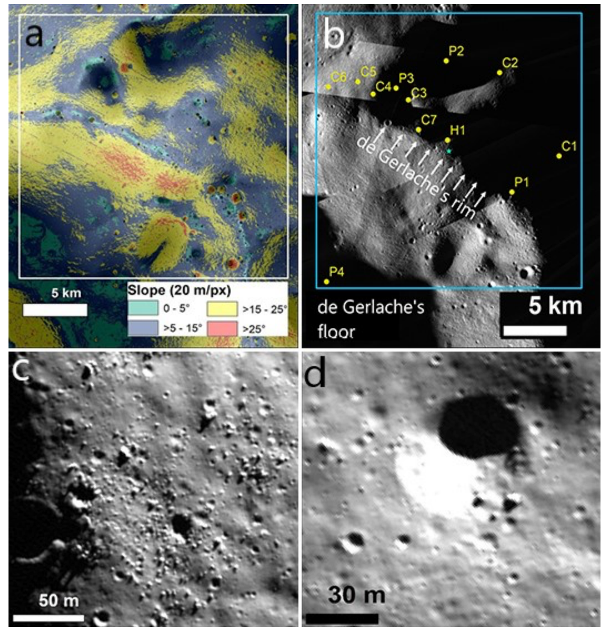

Fig. 4. (a) Slopes at Site 011 (b) Seven craters represented labeled C1-C7. (c) Boulders at the wall of de Gerlache crater marked in Fig. 2a as star (blue). (d) Close-up view of location C3.

Summary: Site 007 and Site 011 are geologically diverse regions with materials from pre-Nectarian to Eratosthenian era providing an opportunity to address strategic knowledge gaps [11] and several science goals [12] regarding bombardment history of the moon, impact processes, key planetary processes with diverse crustal rocks, regolith processes and weathering, dust environment and lunar volatiles.

Acknowledgement: The team thanks CLSE for the summer intern opportunity, V. Bickel and E. Mazarico S. Li, R. Miller, R. Klima, T.D. Glotch, J.P. Williams, A. Bramson and J. Kloos for helping with data processing &collection and Delia Enriquez for constant support. All the data used in the study is available at PDS.

References: [1] NASA's Plan for Sustainable Lunar Exploration and Development, 2020 [2] Gawronska A.J., et. al., 2020, *ASR, 66, 1247-1264* [3] Mazarico E. et al. (2011) *Icarus,* 211, 1066-1081 [4] Spudis P.D. et al., (2008), *GRL,* 35, 5p., L14201 [5]Bretzfelder J.M. et al.,2021, *LPSC Abstract # 1148* [6] Deutsch A. et al., (2020), *Icarus* 336, 113455 [7] Watkins R.C. et al., (2019), *JGR,* 124, 2754-2771 [8] Kring D.A.(1995), *JGR,* 100, 16979-16986 [9] Halim S.H. et al., (2021), *Icarus,* 354, 113992 [10] Yamamoto I. et al., (2012) *GRL*., L12101[11] Connolly J. (2014) SBAG meeting [12] National Research Council (NRC) (2007), Washington, DC