Artemis III EVA Opportunities on the Rim of de Gerlache Crater

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Introduction. The rim of de Gerlache crater is within 1° of the lunar south pole. The undulating crater rim contains a topographic high point, a lighthouse of sorts, with an average solar illumination of 84% [1]. The point, site 011 of [1] and *NASA's Plan for Sustainable Lunar Exploration and Development*, is on the nearside rim of de Gerlache crater (Fig. 1). Solar power at such sites may provide an important lunar surface resource if a distribution system can be established. Adjacent to that point of illumination are several permanently shadowed regions (PSRs) that may harbor icy regolith deposits, another resource, for crew consumables, radiation shielding, and propellant. Large PSRs reside within de Gerlache crater and neighboring Shackleton crater (Fig. 1). Intermediate size PSRs are distributed among secondary craters produced by Orientale basin ejecta. Small PSRs (below the resolution of Fig. 1) also occur along the rim of de Gerlache crater. Ice stabilized in the PSRs may be accessible within 1 m of the surface (Fig. 1; [2]). Calculated resource potential in area craters are of order 10^9 to 10^{10} kg within that 1 m-deep interval [2]. Water ice may be mixed with dry ice and other volatile constituents in colder cores of the PSRs (e.g., as in Cabeus [3]).

Surface conditions. Because the sun circumnavigates the pole a few degrees above the horizon, passing behind crater rims and massif summits, the terrain is covered with a complex web of shadows that are constantly varying (Fig. 2). In the immediate vicinity of site 011, the boulder density (~5 boulders per 250,000 m^2) and slope (~5°) are modest and may be able to accommodate a lander. Boulder density is a little lower on the ejecta blanket beyond the rim of de Gerlache crater, but the slope increases.

Geologic context. Plains material and crater de Gerlache represent the oldest geologic units (pre-Nectarian) in the area (Fig. 1) [4]. The crater has an estimated age of $3.9^{+0.01}_{-0.01}$ Ga [5]. Nectarian-, Imbrian-, and Eratosthenian-age crater materials were superimposed on the pre-Nectarian units. Among those materials are secondary craters produced when the Orientale impact ejected debris across the lunar surface, including blocks a few hundred meters in size, that landed with speeds of about 1 km/s. At that low speed, potentially rocky samples from the Orientale region survive in the secondary crater and its ejecta. If any impact melt was produced, the age of Orientale can potentially be determined, which would mark the end of the basin-forming epoch on the Moon. We have so little experience with secondary craters, however, it is difficult to evaluate the probability of Orientale debris and/or impact melt being recoverable.

EVA options. If crew do not have a rover, their excursions may be limited to a 2 km radial distance from a lander (Fig. 2). If

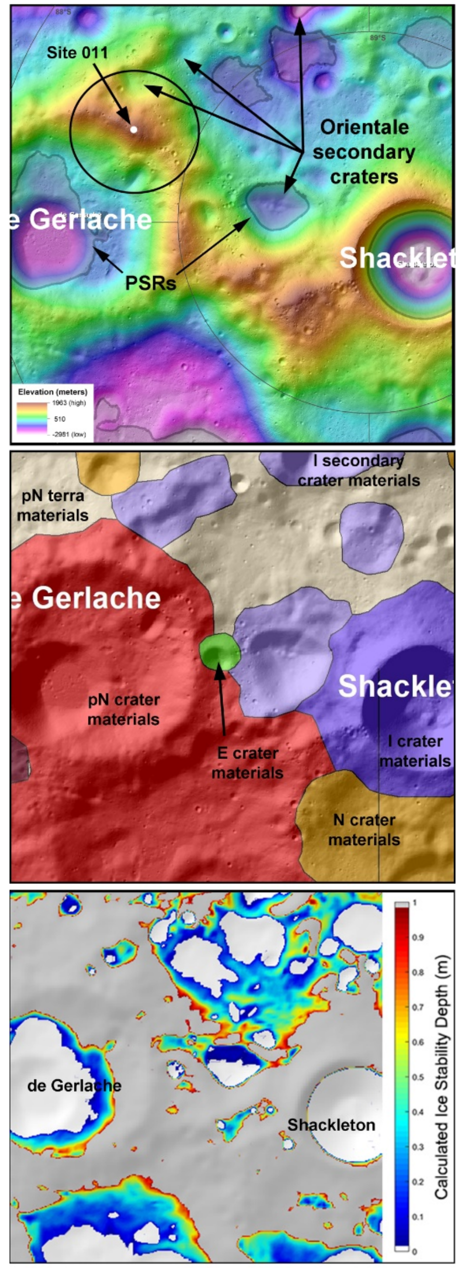

Figure 1. (top) Shaded relief topography around de Gerlache and Shackleton craters with a 10 km radius exploration zone (black circle), PSRs (gray boundary lines), and secondary craters; detail from [9]. (middle) Geologic map with pre-Nectarian- (pN), Nectarian- (N), Imbrian- (I), and Eratosthenian-age (E) materials; after [4]. Although Shackleton is mapped as Imbrian, it may be Eratosthenian in age. (bottom) Calculated stability depth of water ice from the surface to 1 m below the surface; extracted from [2].

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the landing occurs along the rim of de Gerlache crater, crew might deploy a solar power station on a point of high illumination. The rim would be composed of rock uplifted by the de Gerlache impact event, covered by de Gerlache impact ejecta. Reworking of that material by younger, smaller impact events may have produced surface deposits of pre-Nectarian crustal components excavated from both de Gerlache and Shackleton craters, including nearly pure anorthosite [6-8], de Gerlache impact melt, and Shackleton impact melt. Boulder fields occur along the rim of de Gerlache (Fig. 2), but are beyond a 2 km EVA limit if the landing occurs at the point of maximum illumination. Boulders are attractive geologic targets, so adjusting the landing site to access them is a trade to consider.

A few PSRs occur within one of the boulder fields and seem to occur in the bottoms of three small (250 to 390 m diameter) impact craters. These features are young and, for that reason, volatiles in them will likely be dominated by solar wind with an additional micrometeorite component. Accessing those sites would, however, require a dramatic descent of 1 km elevation, which is not possible in a walking EVA. Older deposits of volatile elements, derived from impactors during the late heavy bombardment or from volcanic outgassing, may occur on the floor of de Gerlache, but that, too, occurs beyond the accessibility of a walking EVA from the crater rim.

If landing at the point of maximum illumination, then a descent of 1.6 km over 9 km is required to reach an Orientale secondary crater where water ice may be stable. If one landed closer to the secondary craters, and if a sufficiently long period (>7 days) of illumination exists, then the craters may be within reach of a walking EVA. Such an EVA may, however, be a complex choreography of shadows and light. Alternatively, a rover can be deployed that crew on Gateway or mission specialists in Houston can tele-operate into the secondary craters to measure ice *in situ* via mass spectrometry or other techniques. If the rover has ground penetrating radar and neutron spectrometer systems, then it can also conduct subsurface surveys of ice deposits throughout the area. Other instruments can potentially be deployed: a seismic station; a meteoroid detector that can also be used to evaluate dust pluming by the Artemis III ascent vehicle and future descent vehicles; and a low-light imaging system, potentially with a spectrometer, that can produce a mosaic of the de Gerlache PSR during or after the mission.

Relevance. Sampling geologic materials, assessing potential ice deposits, and making the measurements described above will address science objectives 1a, 1e, 3a, 3b, 3d, 4a-d, 6d, 7b-c and potentially address 1a, 1b, 4e, and 7d [NRC (2007)], while also addressing strategic knowledge gaps (SKGs) I-D, I-G, II-D-3, III-C-2, III-D-1, III-D-2, III-D-4, and III-J-4.

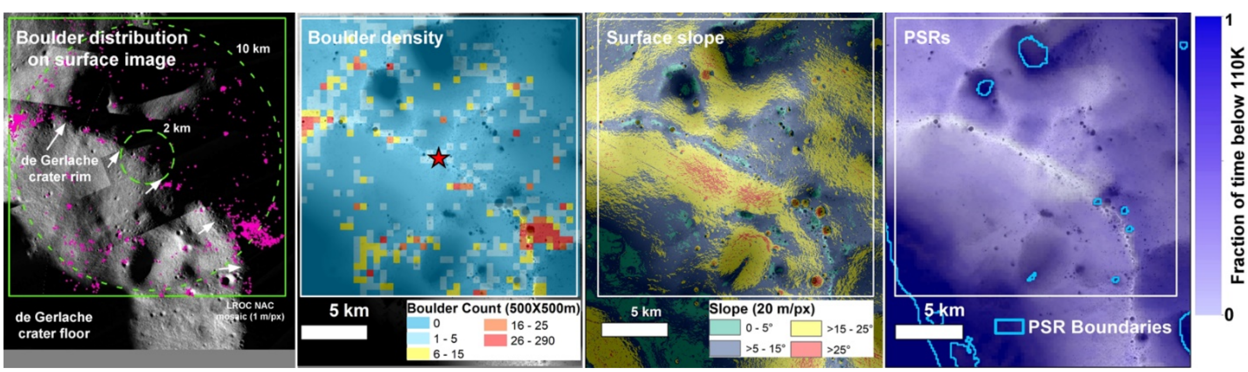

Figure 2. (from left to right) Boulder distribution mapped (pink) on a NAC mosaic surface image; the limits of 2 km walking EVAs and 10 km rover EVAs are shown with dashed lines. Boulder density map of same area, with 5 km scale bar. Surface slope of same area. PSR locations within the same area.

References: [1] Mazarico, E. et al. (2011) *Icarus 211*, 1066–1081. [2] Kring, D. A. et al. (2020) *Lunar Planet. Sci. LI*, Abstract #1933. [3] Colaprete, A. et al. (2010) *Science 330*, 463-468. [4] Spudis P. D. et al. (2008) *Geophys. Res. Lett. 35*, 5p., L14201. [5] Deutsch, A. N. et al. (2020) *Icarus 336*, 10p., 113455. [6] Yamamoto, S. et al. (2012) *Geophys. Res. Lett. 39*, L13201. [7] Gawronska. A. J. et al. (2020) *Adv. Space Res. 66*, 1247–1264. [8] Halim, S. H. et al. (2020) *Icarus 354*, 9p., 113992. [9] Stopar, J. & Meyer, H. (2019) *Topography and Permanently Shaded Regions (PSRs) of the Moon's South Polar Ridge.* LPI Contribution 2178, https://repository.hou.usra.edu/handle/20.500.11753/1263. [10] Allender E. J. et al. (2019) *Adv. Space Res., 63*, 692–727.

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