

## Artemis III EVA Opportunities along a Ridge Extending from Shackleton Crater towards de Gerlache Crater

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**Introduction.** The 3.15 Ga [1], 21-km-diameter [2] Shackleton crater penetrated a 1900-m-high massif [3] along the margin of the 2,400-km-diameter [4] South Pole-Aitken (SPA) basin. Although the origin of massifs is still uncertain due to insufficient *in situ* field studies, massifs are thought to be blocks of crystalline crust – solidified portions of the lunar magma ocean and subsequent intrusive magmas – that were mobilized by basin-size impact events and covered with ejecta from those impact events and younger impact events. The surface of the massif will be dominated by reworked ejecta from the Shackleton crater. Hydrocode simulations of the impact that produced Shackleton [5] suggest the ejecta is ~150 m thick and covers target material uplifted >1 km to form the crater rim. That ejecta layer thins with radial distance from the point of impact, but should have covered the entire length of a ridge in the massif that extends from the rim of Shackleton crater (Fig. 1, left panel) towards de Gerlache crater.

**Points of illumination.** Two topographically high points in the area receive an unusually large amount of solar illumination (Fig. 1, center panel). An ~1700 m-high point on the rim of Shackleton crater has an average solar illumination of 85% [6] or greater [7] and an ~1900 m-high point on a massif ridge has an average solar illumination of 89% [6].

**Permanently shadowed regions (PSRs).** Permanently shadowed sites a few meters to ~100 m in size occur along the rim of Shackleton crater and the adjacent ridge (Fig. 1, center panel). Also, a PSR ~1 km in size occurs at the base of the ridge. Ice may be thermally stable in several locations from the surface to accessible depths <2.5 m (Fig. 1, right panel; [8]).

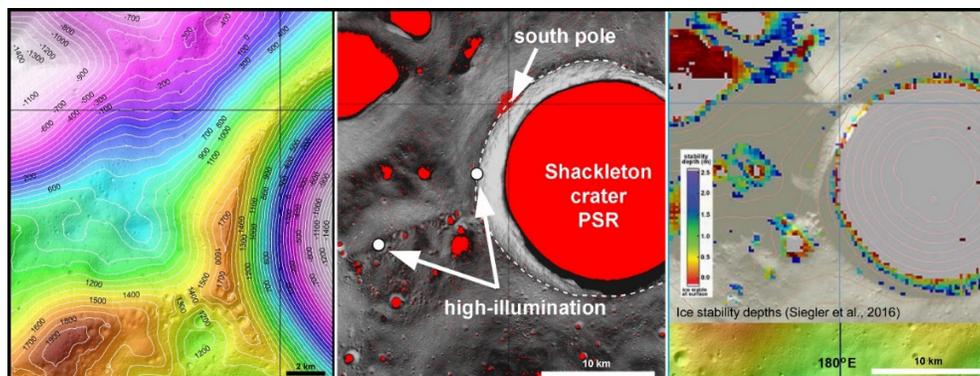


Figure 1. Location maps. (left) Topography with 100 m contours and 2 km scale bar in the vicinity of the south pole, a portion of Shackleton crater, and a massif ridge crosscut by Shackleton crater; reproduced from [13]. (center) NAC mosaic image with the locations of the south pole (crosshair), two points with high solar illumination (white dots), and LOLA-derived permanently shadowed regions (PSRs – red color) with 10 km scale bar; after [11]. (right) Same area as the center panel, showing locations where water ice may be stable at the surface (white – which may appear gray on overlay) to depths of 2.5 m (deepest blue) [8].

**EVAs – geologic sampling.** The Artemis III astronauts may or may not have a rover to traverse the region. For the purposes of this discussion, we assume they will be limited to walking EVAs within 2 km of a lander. The primary geologic samples available to them will be Shackleton ejecta [9]. Potentially, that will include Shackleton impact melts, from which the remotely estimated 3.15 Ga age can be tested. That age is important, because it represents the point in time after which volatiles may have accumulated within the crater's >15 km-diameter central PSR. The impact event penetrated and excavated debris from a crystalline terrain that is composed, in part, of nearly pure anorthosite [5,10,11]. It is important to note that the area contains rock exposures up to 100 m in size [11], which are far larger than anything sampled

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during Apollo and may provide new evidence of magmatic processes that shaped the lunar crust. The Shackleton crater wall, where it crosscuts the massif ridge, is not obviously composed of the same anorthosite assemblage [11] and may indicate other lithologies were ejected from that portion of the crater. The massif was covered by ejecta from several craters prior to the Shackleton impact event, producing a layered terrain evident on one side of Shackleton crater [11]. Thus, collected samples of Shackleton ejecta may also contain impact melt from the SPA basin and other pre-Nectarian and Nectarian-age impacts, plus cryptomaria from SPA. Collectively, samples of Shackleton ejecta may provide a 1.5 billion-year-long record that includes information regarding the bombardment that produced the Moon's giant impact basins and at least one period of intense volcanism. Small, recently-formed craters will provide samples from which their ages can be determined, too. Regolith sampling can be augmented with several mechanical property tests, such as lander and footstep penetration, stability of trench walls, cone penetrometer measurements, and vane shear device measurements. A seismic station, plus a meteoroid detector that can also be used to evaluate dust pluming by the Artemis III ascent vehicle and future descent vehicles, can also be deployed during EVA.

**EVAs – volatile element sampling.** Shadowed areas adjacent to ridges and boulders may have regolith sufficiently cold to stabilize ice [8]. Trenching or coring to test those model calculations will be valuable. Because craters hosting PSRs in the area were excavated from Shackleton crater ejecta, they will be younger than Shackleton and, thus, younger than 3.15 Ga [1]. Because they are small, they must also be much younger than that: of order 10 to 100 million years. Thus, they will not have trapped volatiles delivered by early impact bombardment or indigenous ancient volcanism. Rather, any volatiles trapped in these PSRs are likely to be dominated by solar wind with a micrometeoritic component. The volatiles may have a composition similar to those in Apollo regolith samples, albeit in greater concentration. Whereas science objectives require rock and soil samples be returned to Earth, significant measurements of volatile constituents can be made *in situ*. Mass spectrometers and evolved gas analyzers are two potentially deployable instruments. The largest PSR in the area is at an elevation of ~1200 m, well below the ~1700 and ~1900 m-high illumination points and may not be accessible during a walking EVA. Potentially, crew could instead deploy a tethered device that is lowered or freely descends into the PSR. Alternatively, the crew may deploy a rover that is teleoperated by additional crew on Gateway or by science operations staff in Houston, either during the mission or after surface crew ascent.

**Relevance.** EVAs in this location can begin to address science objectives 1c, 2a, 3a, 3b, 3d, 4a, 4d, 6c, and 7b, and potentially address objectives 1a, 1b, 4b, 5a-b, and 7d [12]. EVAs can also help address 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.

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