EXPOSED AND BRIGHT - CONTRAST SIGNATURES AT THE PERMANENTLY SHADOWED WALLS OF SHACKLETON CRATER  

P. Mahanti 1, S. Li 2, M.S. Robinson 1, E. Mazarico 3, B. Jolliff 4, ShadowCam Team 

1 School of Earth and Space Exploration, Arizona State University, Tempe, AZ; 2 Hawaii Institute of Geophysics and Planetology, University of Hawaii; HI; 3 NASA Goddard Space Flight Center, MD; 4 Washington University at St. Louis, MO; (pmahanti@asu.edu)

Introduction: Considering its age (3.5 to 3.7 billion years [1, 2]), the Shackleton crater (20 km diameter) is an unusually well-preserved simple bowl-shaped crater. Much of its interior lies in a permanently shadowed region (PSR); hence, details about the existent morphology and albedo that may indicate mineralogy and/or the presence of cold-trapped volatiles are scarce. Here, we use recently acquired ShadowCam [3] radiance-calibrated images [4] to investigate the albedo variations found on the walls of Shackleton crater.

Shackleton crater formed on the rim of the South Pole-Aitken (SPA) basin, implying that its pre-impact surface was primarily SPA ejecta, although likely complicated by material ejected from other neighboring, more recent impacts (e.g., impacts forming Haworth, Shoemaker, Faustini, de Gerlache, and Sverdrup craters). Consequently, the pre-impact target likely is comprised of ancient crustal material (pure anorthosite [5]), blocks of which might be exposed near the crater rim or as outcrops on the crater walls. Multiband Imager [6] spectra and photo-geologic inference from LROC NAC [7] indicate the presence of pure anorthosite along the sunlit portions of the crater rim and wall [8, 9]. But inside the PSR boundary, which starts 600m to 1400m below the rim, illumination is insufficient to allow spectral compositional determinations. With high-SNR ShadowCam images, we can now identify and locate high radiance contrast outcrops on the permanently shadowed walls, and spatially correlate these with spectral identifications of pure anorthosite at the sunlit portions. In the following text, bright indicates higher relative radiance ($W m^{-2} sr^{-1} \mu m^{-1}$) or irradiance ($W m^{-2}$) and does not necessarily indicate higher reflectivity, or albedo.

Methods: We use crystalline plagioclase as a proxy for pure anorthosite, and determine the mineralogy of the sunlit morphology of Shackleton from $M^3$ spectral reflectance and integrated band depth parameters around $1 \mu m$, $1.25 \mu m$, and $2 \mu m$ absorptions [10]. Strong absorptions near $1.25 \mu m$ indicate the presence of crystalline plagioclase, which has higher reflectance over basaltic components and mature regolith and leads to strong contrast differences in radiance images. In addition to Shackleton wall images (2m/px) acquired by ShadowCam, our analysis includes topography (20m, LOLA DEM [11]) to compare local morphology at apparent albedo boundaries and also to model the secondary illumination irradiance (magnitude and direction) for the ShadowCam images.

Figure 1: (A) ShadowCam image M014524048S of the leading wall (near to south pole) of Shackleton showing exposed bright units. $M^3$ data (red dots) overlayed indicates crystalline plagioclase at locations of PAN (purest anorthosite [6]) identification in earlier work [8, 9]. (B) $M^3$ spectra of crystalline plagioclase-rich region on the rim of Shackleton crater. A spectrum of terrestrial pure crystalline plagioclase is plotted to indicate the unique absorption near 1.25 $\mu m$ seen (red arrow) in terrestrial and lunar crystalline plagioclase.

Results and Discussion: Previous work correlating the locations of crystalline plagioclase in LROC NAC images noted high albedo rocky exposures (~20m to ~200m, at the interior walls below the crater rim) down to a depth of approximately 1 km [8, 9]. Boulders with similar albedo contrasts were also mapped in the Shackleton ejecta to infer ejected blocks [9] of crystalline plagioclase. Overlying the $M^3$ data over ShadowCam images (Figure 1, temporarily shadowed areas) allows us to follow a spectral detection of crystalline
plagioclase from the sunlit area into the permanently shaded wall towards the floor (Figure 1). ShadowCam images show bright exposures down to at least 2 km below the rim.

Contrasts within ShadowCam images vary (Figure 2B) with the direction of the secondary illumination [12]. The exposed units are brighter than the surroundings even after accounting for seasonal and diurnal variations. On average, the bright exposures (Figure 2A, trailing wall) have \( \sim 20\% \) higher radiance than the darker background [12] but at some subsolar longitudes, the radiance’s are \( \sim 90\% \) higher. At the same subset of subsolar longitudes, modeling results show \( \sim 15\% \) higher irradiance, suggesting the presence of subtle variations in topography [12] at the exposures.

Preliminary analysis suggests that the brighter exposures may be ridge-like (locally elevated) compared to the adjacent gully-like (locally subdued) relatively darker areas. Downslope mass wasting occurs predominantly within the darker areas (numerous boulder tracks visible) between the exposed bright outcrops which are more cohesive and remain in place. It is possible that the existing crustal ejecta fragmented from the Shackleton impact and affected a gully-like formation at the walls. Darker mature regolith from the more recent layers emplaced on the crustal ejecta then naturally infills the crater fractures due to gravity. Alternatively, the darker material was interstitial in the pre-impact target, indicating a second lithological component in a megabreccia [9]. Along with relative maturity, lighting can also moderate the appearance in secondary illuminated images - granularity and location (collecting in gully-like regions) causing an even darker/ shadowed appearance.

**Conclusion:** ShadowCam observations of Shackleton’s interior walls show distinct bright units down to \(< 2\text{km}\) from the crater floor. In combination with \(\mathbf{M3}\) spectral data and LROC NAC observations, our preliminary hypothesis is that the bright units are exposed crystalline plagioclase outcrops from the crustal material present in the preimpact surface up to a depth of 2 km, possibly originating from the SPA basin impact. The exposed units are relatively brighter than the surroundings even after accounting for variation due to secondary illumination direction.

**References:**