1:2500 GEOMORPHOLOGICAL MAP OF THE INTERCRATER REGION BETWEEN SHACKLETON CRATER AND SHOEMAKER CRATER OF THE LUNAR SOUTH POLE. F. B. Wróblewski[1], K. R. Frizzell[2], G. R. L. Kodikara[3], M. Kopp[4], K. M. Luchsinger[5], A. Madera[2], M. L. Meier[1], T. G. Paladino[6], R. V. Patterson[7], C. J. Tai Udovicic[8], and D. A. Kring[9,10]. [1]University of Idaho (Email: frankw@uidaho.edu), [2]Rutgers University, [3]University of Wisconsin-Milwaukee, [4]Boston College, [5]New Mexico State University, [6]Idaho State University, [7]University of Houston, [8]Northern Arizona University, [9]Lunar and Planetary Institute, Universities Space Research Association, [10]NASA Solar System Exploration Research Virtual Institute.

Introduction: Shackleton crater (21 km diameter, 4 km deep [1], 3.43 +0.04/-0.05 Ga [2], 131°E 89.6°S) is a deep Late Imbrian impact crater at the lunar south pole along the margin of the South Pole-Aitken (SPA) basin [1]. Shackleton is separated from Shoemaker crater (50 km diameter, 2.1 km deep [1], 4.15 +0.02/-0.02 Ga [3], 50°E 88°S) by an intercrater plain. Both Shackleton and Shoemaker craters host large permanently shadowed regions (PSRs) which contain volatile elements [4,5] that may be used to trace the evolution of volatiles on the Moon and provide *in situ* resources [6,7]. In addition, the rims of both craters are illuminated topographic highs feasible for solar power [8,9]. Despite those favorable conditions, crater wall slopes >25° make it difficult to access the large PSRs. We note, however, that smaller and potentially more accessible PSRs occur on the intercrater plain (Fig. 1). The intercrater plain is a topographic depression spanning the nearside-farside transition and is composed mostly of Shoemaker and Shackleton ejecta with thinner intervening contributions from Faustini crater. Here, we present a new morphological map spanning 1600 km^2 between Shackleton and Shoemaker craters to highlight the units of the intercrater region and explore the area's potential for meeting Artemis objectives.

Methods: Morphological classification and boulder identification were developed using individual ~50 km-long, 0.5m/pixel, LRO Narrow Angle Camera (NAC) image swaths and an averaged NAC mosaic distributed by MoonTrek [10]. Topographic analysis used LRO Lunar Orbiter Laser Altimeter (LOLA) digital elevation models (DEMs) at ~5m/pixel. Water-ice detection used Moon Mineralogy Mapper (M^3) data at 280m/pixel [4]. NAC image swaths were processed using the USGS Integrated Software for Imagers and Spectrometers (ISIS) 5.0.1. ArcGIS Pro 2.8.3 was used for visualization and mapping. Geospatial Data Abstraction Library (GDAL) was used for spatial calculation.

Morphology Evaluation: Morphological units are defined using geographic location, elevation, slope, NAC reflectance, and surface texture (Table 1). Average terrain roughness index (TRI) was calculated for each unit [11]. In this survey, we recognized four major morphological zones (Shackleton crater, Shoemaker crater, the intercrater plain, and ridges) with 21 morphological units (Fig. 2).

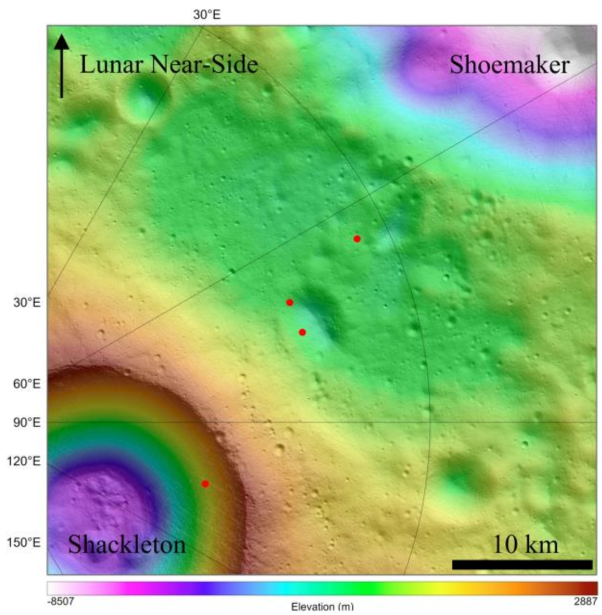

Figure 1: Topographic map of Shackleton, Shoemaker, and the intercrater region with overlain hillshade at 45° azimuth. Red points are M^3 water-ice detection [4].

Shackleton crater. Low-sloped circulate ridges along the rim of Shackleton contain high-reflectance blocky exposures that correlate to purest anorthosite (PAN) deposits [12]. Units are circumferentially distributed around Shackleton with lesser abundances of blocky features found outward and downslope from Shackleton's rim (units *ShRp* and *ShRtS*). Most of Shackleton's interior is permanently shadowed; however, portions of the upper crater walls are sunlit and composed of high-reflectance blocks that slump downward into the crater.

Shoemaker crater. The mapped area contains a portion of Shoemaker crater. Shoemaker's ejecta blanket, and regolith covering it, is divided into sloped units from the crater rim to the intercrater region.

Intercrater region. The intercrater region contains a diverse suite of rock exposures, boulders ejected from several locations, and underlying lineations of the lunar regolith. Contrasting reflectance units appear within areas of similar topography, possibly from newly exposed regolith or creep-like processes (units *PS* and *PmS)*. Bright-reflectance rock exposures are observed near the contact with Shackleton and smaller primary craters (1-5 km diameter). Primary and secondary crater walls and floors are mapped individually (units *CtW* and *CtF*), with smaller craters perched along primary and secondary crater walls (unit *PCtW*). Primary craters, secondary clusters, and perched craters (<1 km diameter) dominate the topography. Eroded crater walls or isolated steep slopes are defined as ridges. Smooth slopes with distinct reflectance from ridges are identified as plains.

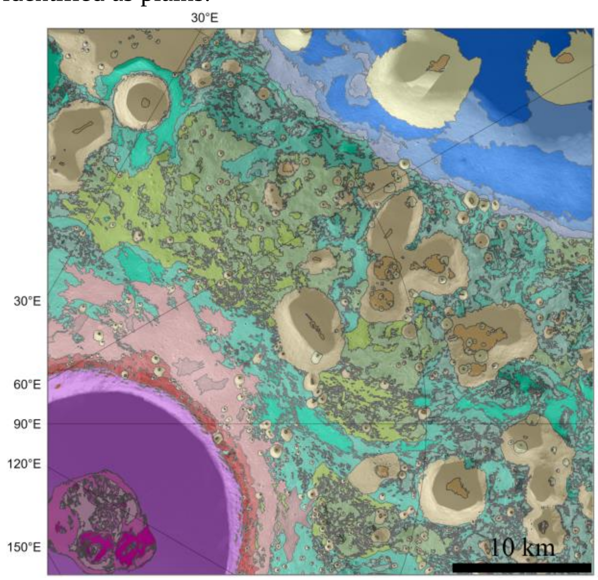

Figure 2: Geomorphic map of Shackleton crater, Shoemaker crater, and the intercrater region overlain on a NAC mosaic [10] and hillshade. Units are grouped by colour; Shackleton in red, Shoemaker in blue, intercrater plains in green, and cratered ridges in teal and yellow. Unit legend is described in Table 1.

Geomorphic Map: The most distinct geomorphic contacts are near the margin of Shackleton, where exposures of bright material appear mechanically transported from the slopes. Further distinction is found within the plains units, where trends of high-slope, high NAC reflectance, and *vice versa*, are found intermixed with slight differences in crater density (units *PmS* and *PS*). Ridges are orientated radially from Shackleton and Shoemaker near the unit zone margins and are generally less slumped with fewer effects of regolith creep toward Shoemaker. Craters 1-5 km diameter are positioned towards higher elevations, and provide areas of winter temperatures ~<110 k. The most central primary craters (~5 km diameter, 600 m deep) within the plain are smoothly sloped (<15°) to their floors and contain M^3 water-ice detection with rock exposures straddled along the rims. These 1-5 km diameter craters may also have excavated Shoemaker ejecta and massif material from beneath Shackleton ejecta.

Summary: Morphological units were mapped as a function of topography, NAC reflectance, and surface texture. The intercrater plains are mostly covered by Shackleton ejecta, but ridge exposures and ejecta from penetrating craters may have exposed Shoemaker ejecta and other lithologies from SPA impact melts or pre-Nectarian and Nectarian impacts [13]. Most blocky exposures are near the margins of Shackleton's units, which due to the proximity to Shackleton, may then contain lithologies of the original highland crust, the lunar magma ocean, and the cryptomare [13]. Units upon Shackleton contain blocky exposures, with some corresponding to previously identified PAN deposits. Units within the intercrater plain contain further blocky exposures and accessible areas (<15° slope) which may contain water-ice. Further investigation of these blocky exposures and of the overall accessibility within the intercrater region may provide a useful tool for Artemis exploration and for understanding the material and resource distribution on the lunar south pole [e.g., 14].

Table 1: Legend and classification of morphological units by slope, NAC reflectance, and TRI.

Map Unit	Unit Description	Slope (Degrees)	NAC Reflectance	TRI
CtW	Crater Wall	> 30	120	2.75
PCtW	Perched Crater Wall	> 30	186	> 10
CtF	Crater Floor	≤ 20	2	0.375
PmS	Plain Moderately Hummocky	≤ 20	99	1.125
PS	Plain Hummocky	≤ 10	23	0.125
RhS	Ridge Highly Slumped	> 25	110	2
RmS	Ridge Moderately Slumped	≤ 25	56	0.75
RS	Ridge Slumped	≤ 10	35	0.125
SohS	Shoemaker High Slope	> 30	160	3.2
SotS	Shoemaker Transition Slope	≤ 30	110	2
SolS	Shoemaker Low Slope	≤ 15	64	1.3
ShRp	Shackleton Perched Rim	≤ 15	96	3.1
ShRhS	Shackleton Rim High Slope	> 30	166	4.75
ShRtS	Shackleton Rim Transition Slope	≤ 30	86	2.5
ShRlS	Shackleton Rim Low Slope	≤ 15	36	0.375
ShW	Shackleton Wall	> 45	0	> 10
ShFhS	Shackleton Floor High Slope	> 30	0	4
ShFmS	Shackleton Floor Moderate Slope	≤ 30	0	1.25
ShFlS	Shackleton Floor Low Slope	≤ 15	0	0.125
ShFPF	Shackleton Floor Perched Floor	≤ 10	0	0.25
ShacFF	Shackleton Floor	≤ 10	0	0

Acknowledgments: This work was supported by CLSE, LPI, USRA, and NASA-SSERVI to the 2021 Exploration Science Summer Intern Program.

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