A RASCALLY RIM AT NORTH RAY CRATER AND ITS RELEVANCE TO ASTRONAUT OPERATIONS AT THE SOUTH POLE. C. H. van der Bogert[1], W. Iqbal[1], T. Gebbing[1], H. Hiesinger[1], D. A. Kring[2], J. M. Hurtado[3], T. M. Hunning[4], M. Lemelin[5], C. A. Looper[4], G. Osinski[6], L. Gaddis[2], and K. Joy[7], [1]Institut für Planetologie, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany (vanderbogert@uni-muenster.de); [2]Lunar and Planetary Institute, Houston, Texas, USA; [3]University of Texas at El Paso, El Paso, TX; [4]Johnson Space Center, Houston, TX, USA; [5]Université de Sherbrooke, Québec, Canada; [6]University of Western Ontario, London, Ontario, Canada; [7]University of Manchester, UK.

Summary: In this work, we examined the slopes along the rim of North Ray crater (Apollo 16, Station 11 and House Rock) to compare with slopes around proposed south polar landing sites 001 and 004. Our goal is to inform and improve astronaut training and mission planning for operations on a massif ridge and along the rim of Shackleton crater (see also [3]).

Conditions at Station 11 and House Rock: When Apollo 16 astronaut John Young parked the rover near the North Ray crater rim at Station 11 (Figs. 1, 2), he exclaimed, "*Man, does this thing have steep walls.*" Charlie Duke responded, "*Yeah, they said 60 degrees.*" The slope of the crater wall is actually ~30-35 degrees, but both astronauts clearly perceived the slope as remarkably steep. Young continued, "*Now, I tell you, I can't see to the bottom of it, and I'm just as close to the edge as I'm going to get*" [1].

Later during the EVA, as Young was describing the crater rim to Mission Control, he noted, "*The unfortunate thing about it, Houston, is that rascally rim... It goes down... It slopes into it about, say, 10 or 15 degrees, which is the kind of slope I'm standing on right now; and then, all of a sudden, in order to see to the bottom, I've got to walk another 100 yards down a 25- to 30-degree slope, and I don't think I'd better*" [1].

As they continued investigating the rim, they went northeast towards House Rock, down a gradual slope, descending ~10 m in elevation. Just before House Rock, they encountered a small depression with much steeper slopes as they moved to the eastern side of House Rock (Fig. 2). Here, Young warns Duke, "*Charlie, don't get too near the edge of that thing, it falls off. Look over at your right; it falls off pretty good.*" Likely, Young was referring to the steep flank of the crater ejecta to the east of House Rock, with local slopes of >25° (Fig. 2c). After Duke took a sequence of stereo photos at the base of House Rock, Young said, "*Okay, now we had to come down a pretty good slope to get to this rock, so we may have to leave early to get back*" [2].

After the mission was over, Duke commented that the North Ray crater wall was about as steep as at Meteor Crater, but "*it was really scary, getting up too close. We kidded about it, but we weren't about to get too close*" [1]. Indeed, these highly trained astronauts had been to Meteor Crater (1.2 km diameter) as part of their training, which is similar in size to North Ray (1.0 x 1.1 km in diameter), but their perception of the danger of the slopes at North Ray was likely augmented by factors affecting their perception of distance and slope.

Perception of Distance and Slope: During work between Station 11 and House Rock, Young was not confident he was robustly estimating the distance from the rover to House Rock. In fact, [2] notes that the difficulty of estimating distances in the wild Chilean Andes had previously been described by Charles Darwin in *The Voyage of the Beagle* (1835), where he noted that it is hard to judge distances "in the absence of objects of comparison". Similar challenges were echoed by coauthor KJ, who collected meteorites in Antarctica with ANSMET. Here, distance and surface roughness were strangely difficult to estimate particularly on cloudy days, likely due to an absence of shadows.

The lunar landscape also offers no objects of comparison, but depending on the time of the month, shadows can be particularly long, and the shadows of boulders on slopes are cast even longer producing a particularly rugged appearance. The inability to accurately estimate distance likely causes slopes to also be perceived as steeper.

Thus, we investigated the slopes at North Ray to gain insight into whether the slopes in the targeted regions 001/004 at the South Pole may also invoke

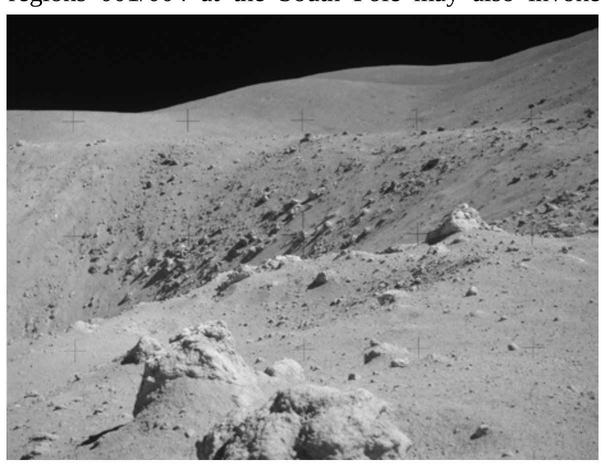

Figure 1. *First frame of a polarimetry pan taken by Duke at Station 11 looking NE along the North Ray crater rim (AS16-106-17305). The crater wall slopes steeply to the left, with the closest part of the crater wall hidden behind a swell of rim material and perched blocks in the foreground.*

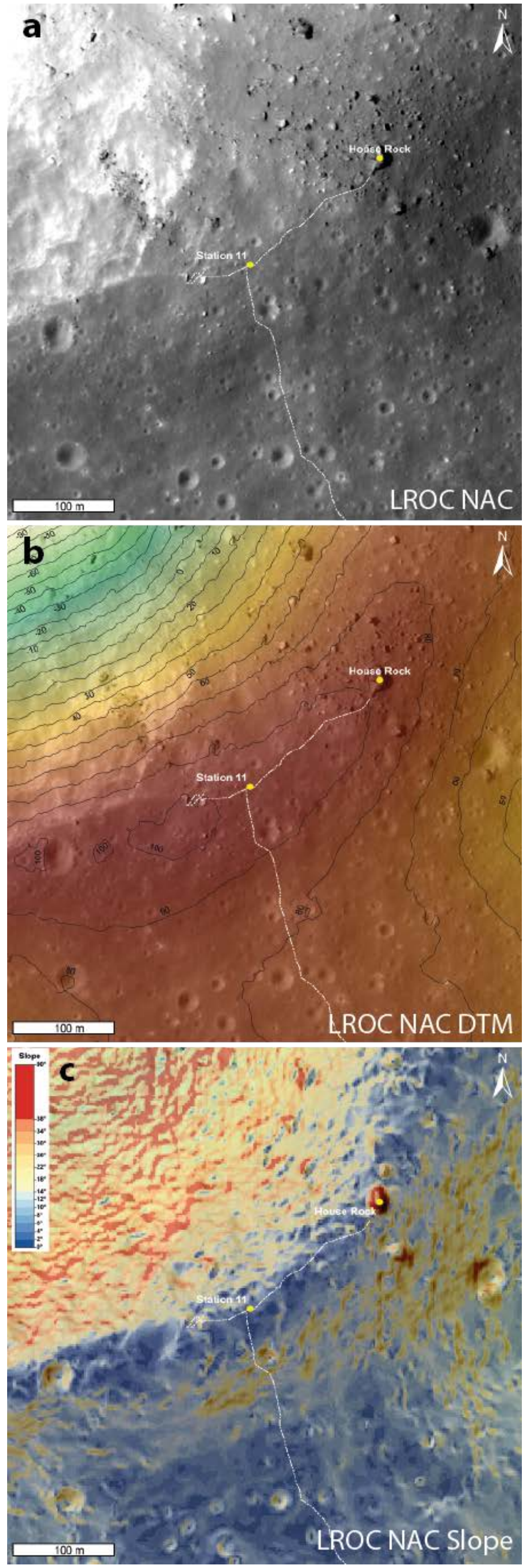

Figure 2. *The southeastern rim of North Ray crater showing the path of the Apollo 16 EVA. (a) LROC NAC orthophoto mosaic (0.5 m/p), (b) LROC NAC DTM (2 m/p), and (c) LROC NAC DTM-derived slope map.*

enhanced perception of danger during traverses along the massif ridge and Shackleton crater rim (e.g., [4]).

Data and Observations: We used the Lunar Reconnaissance Orbiter (LRO) Narrow Angle Camera (NAC) 2 m/pixel Digital Terrain Model (DTM), slope map, and 50 cm/pixel orthophoto mosaic to examine the elevations, slopes, and morphological features around Station 11 and House Rock in ArcGIS (Fig. 2) [5, 6].

The slopes on rover approach to Station 11 were <~15°, except for a short segment with slopes of ~20-25°. The rim crest is 40-50 m wide and exhibits slopes of <~14° between Station 11 and House Rock (Fig. 2).

Discussion: Based on examination of the Apollo 16 transcripts and films, we find that slopes of ~>20° were perceived by the astronauts to require enhanced caution compared to shallower slopes. The gradual long downslope between the rover at Station 11 and House Rock was noted to potentially require extra time for the return trip, in addition to the short, steeper descent in the last 10's of meters as they approached House Rock.

Mitigation of the real and perceived hazards associated with slopes could take a variety of forms. In the context of traverse planning, it is important to allow for slower traverse speeds at particularly challenging sections, and to select paths that minimize time spent on narrow ridges between slopes of >~20°. The astronauts' perception of the slopes and ability to confidently move along narrow ridges will also depend on the effects of reduced peripheral vision and mobility due to their suits and equipment. Additional strategies, such as the installation of fixed ropes or tethering/belaying could reduce psychological stress associated with the slopes. Luckily, the next lunar astronauts will also have the benefit of rich remote-sensing datasets for high-resolution maps and modern range-finding tools to help measure distances and slopes.

Implications for Artemis: The terrain at the south pole is more rugged than at the Apollo 16 landing site, exhibiting larger craters with steep walls, as well as steep flanks along the massif ridges (e.g., [3, 4]). Thus, the next step of our work is to examine high resolution DTMs and slope maps for proposed Artemis sites 001/004 and propose traverses with these factors in mind.

References: [1] Jones (1996a) Ap16 Lunar Surface J, Station 11, [2] Jones (1996b) Ap16 Lunar Surface J, House Rock, [3] Kring et al. (2022) LPSC 53, this conference, [4] Speyerer et al. (2016) Icarus 273, 337-345, [5] NAC_DTM_APOLLO16, [6] Henriksen et al. (2016) Icarus 283, 122-137.