VARIATIONS IN SLOPES AMONG SMALL SOUTH POLAR IMPACT CRATERS: DEGRADATION BY VOLATILES? Ariel N. Deutsch[1], Michael K. Barker[2], Caleb I. Fassett[3], Jennifer L. Heldmann[1], Anthony Colaprete[1], and James W. Head[4], [1]NASA Ames Research Center, Moffett Field, CA 94035 (ariel_deutsch@nasa.gov), [2]NASA Goddard Space Flight Center, Greenbelt, MD 20771, [3]NASA Marshall Space Flight Center, Huntsville, AL 35804, [4]Brown University, Providence, RI 02912.

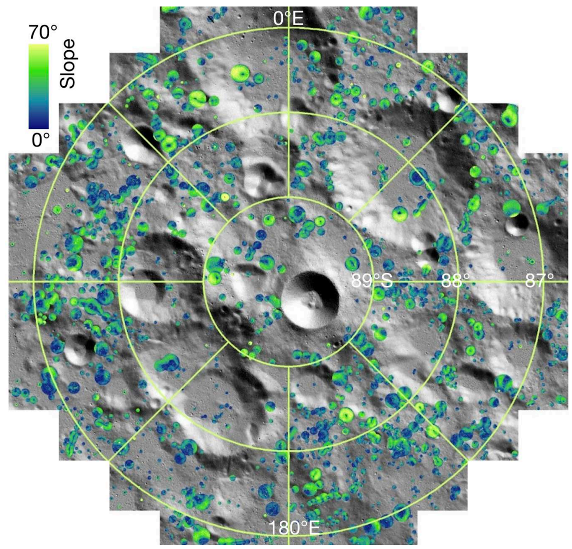
Introduction: The lunar poles are a dynamic and complex thermal environment. Some locations experience temperature variations >150 K on diurnal and seasonal timescales, and the surface area of below-freezing terrain more than doubles from summer to winter [1]. While this dynamic thermal environment has important implications for the activity of the lunar volatile cycle [2], it may also have important implications for the degradation of the landscape.

Thermal stress weathering can contribute to the degradation of impact craters as thermal cycling enhances rock breakdown and regolith mobilization, particularly on airless bodies like the Moon [3]. Thermal cycling has a particularly large amplitude at the lunar poles [1]. **Here we are interested in how thermal stresses possibly influence the degradation of small polar craters,** using slope as a morphometric measure of crater degradation.

Various other factors besides thermal stresses can influence crater slopes, such as the presence of cold-trapped volatiles. Previous works observed a shallowing of lunar polar craters with latitude that may be related to the accumulation of ice [4, 5]. If ice accumulations are indeed influencing crater morphometries, their influence on crater slope is expected to be greatest on (typically colder) pole-facing (PF) slopes [5], and thus here we analyze equator-facing (EF) and PF slopes separately.

Methods: Starting with a comprehensive lunar crater database [6], we identified all impact craters that (i) are unambiguously craters, (ii) are located between 87 and 90°S (where the highest-resolution topographic measurements exist) [7], (iii) have diameters <7 km (to mitigate scale-dependent crater degradation effects), (iv) are not located on the walls of larger craters (to mitigate effects of impacts into sloped terrain), and (v) are not superposed by other small craters (to mitigate influences of imprinting topography). This resulted in a study population of 1,337 craters, with an average diameter of 2.15 km. (**Fig. 1**).

For each crater, we extracted slope and azimuth measurements using new Lunar Orbiter Laser Altimeter (LOLA) topography models, which have a pixel scale of 5 m and uncertainties with typical root-mean-squared values of ~2° [7, 8]. Azimuth (i.e., direction of slope) is important because it heavily influences the amount of incident solar radiation [9, 10]. We define EF slopes by azimuths of 180°E ± 30° and PF slopes by azimuths of 0°E ± 30°.



For the PF and EF walls of each crater, we extracted (i) the median seasonal thermal amplitudes (K) from Diviner (240 mpp [1]), which is the difference between the maximum and minimum temperatures for each season, and (ii) the average illumination from LOLA (60 mpp [9]), a value between 0 (permanent shadow) and 1 (complete illumination) that indicates the average visible fraction of the Sun's disk over a lunar precession cycle.

Initial Results and Discussion:

Individual craters: Comparison of PF and EF slopes. We find that the PF slope is typically shallower than the EF slope of a given small (diameter <7 km) south polar crater located between 87 and 90°S (**Fig. 2**). While two-sample Kolmogorov–Smirnov (K-S) tests indicate that the slopes of PF and EF crater walls are not from the same continuous distribution (α=0.05), there is substantial statistical noise in the data, attributable to the natural and complicated topographic variation of the landscape. Similarly, Rubanenko et al. found that the median of PF slopes is ~5% lower than the median of EF slopes for shallow craters (depth-to-diameter ratios <0.08) located between 75 and 90°S, but this difference was not statistically significant [5].

The relatively shallow PF slopes in comparison to EF slopes of individual craters is consistent with the hypothesis of Rubanenko et al. that buried volatiles influence the shapes of south polar craters on the Moon [5]. On Mars, PF slopes have also been shown to be systematically gentler than EF slopes in particular latitudinal belts where ground ice is expected [11].

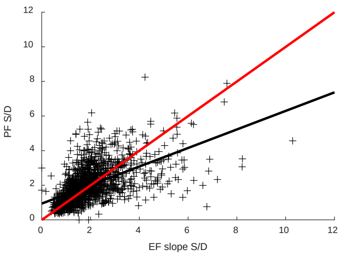


Fig. 2. Mean slope-diameter (S/D) ratios of pole-facing (PF) and equator-facing (EF) walls of the 1,337 study craters. A crater whose PF slope is equal to its EF slope would plot on the red 1:1 line.

Crater populations: Correlations between crater slope, thermal amplitude, and average illumination. We measure the slopes, thermal amplitudes, and average illuminations of all EF slopes (180°E ± 30°) and, separately, of all PF slopes (0°E ± 30°).

Thermal amplitude. We measure statistical variation in the population of PF slopes with respect to thermal amplitude, but not in EF slopes (**Fig. 3**). PF slopes that experience seasonal thermal amplitudes >~120 K are relatively lower than PF slopes of similarly sized and similarly located craters that experience lower thermal amplitudes. It is possible that high thermal amplitudes have contributed to slope reductions as a result of freeze-thaw cycles and/or creep (no melting) causing downslope movement of ice, as has been suggested for some ice-bearing craters on Mars [11]. Furthermore, slope reduction at high thermal amplitudes may be related to the presence of volatiles because it is observed at PF slopes (where ice is predominantly predicted to be cold-trapped [e.g., 5, 9,10]), but not at warmer EF slopes (**Fig. 3**).

Intriguingly, we also find that the slopes are relatively high for EF walls that experience seasonal thermal amplitudes >160 K. Work is ongoing to investigate these specific craters, their regional environment, and their age.

Average illumination. It is possible that the average illumination (or integrated thermal pressure) also influences crater degradation. We do not find any statistically significant difference in the slopes of crater walls between slopes that receive higher vs. lower levels of average illumination (**Fig. 3, bottom row**), suggesting that the temperature swing, as opposed to average illumination conditions, is a driving factor in the reduced slopes of particular PF walls.

Conclusions: Crater slopes can be influenced by a myriad of factors, including the crater-forming conditions (e.g., impact angle, target composition, target slope) as well as modification processes (e.g., regolith gardening, impact bombardment and emplacement of distal ejecta, thermal cycling) and the crater's age (i.e., exposure time to modification processes). Here we use population statistics of 1,337 similarly sized and similarly located craters to provide insight into the possible influences of volatiles and thermal degradation on crater slopes at the lunar south pole.

Initial results suggest PF walls of south polar impact craters subject to larger thermal amplitudes (>~120 K) generally have lower slopes than PF slopes subject to smaller thermal amplitudes (**Fig. 3**). This effect is not clearly observed at EF slopes. We are currently testing the hypothesis that this asymmetry may be due to degradation processes associated with preferential volatile deposition on PF slopes [5], consistent with the finding that the PF wall of a given crater in this region is typically shallower than the EF wall.

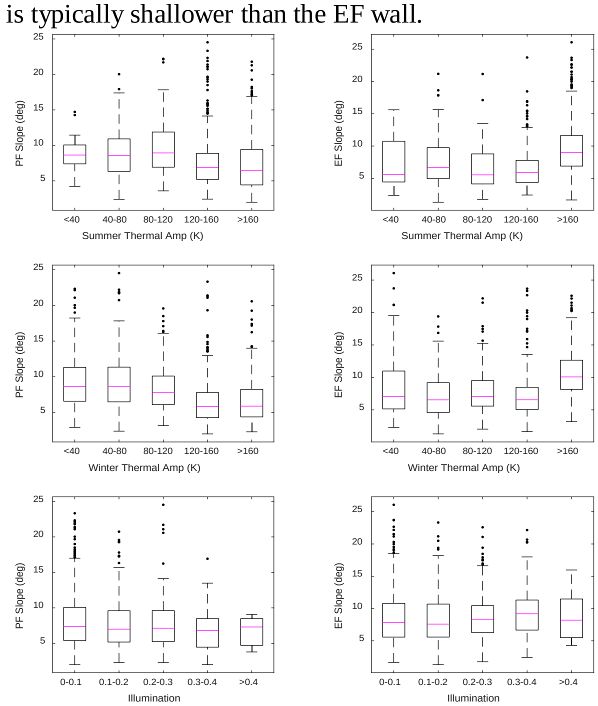


Fig. 3. Box plots depict mean slopes of (left) pole-facing (PF) and (right) equator-facing (EF) crater walls, for population bins defined by (top) summer and (center) winter thermal amplitudes and (bottom) average illumination. Median values are noted by pink line and statistical outliers plot as black dots.

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