ENHANCED TOPOGRAPHIC DIFFUSION IN ANCIENT LARGE COMPLEX CRATERS NEAR THE LUNAR SOUTHERN POLE PROMOTES VOLATILE REWORKING.

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Major Objective: To quantify the effects of topographic diffusion on 16 complex craters found near the Lunar southern pole. How the different degradation processes (impact mixing, ejecta blanketing, topographic diffusion, and internal heat) effect the existence or preservation of ancient water ice found in the PSRs. Full manuscript available: Talkington, C. L., Hirabayashi, M.., Montalvo, P. E., Deutsch, A. N., Fassett, C. I., Siegler, M. A., et al. (2022). Survival of ancient water affected by topographic degradation of old, large complex craters. Geophysical Research Letters, 49, e2022GL099241. https://doi.org/10.1029/2022GL099241

Contribution of multiple mixing processes and thermal conditions to water distribution on the Moon: We propose how mixing processes and thermal conditions interact together to effect water distribution on the Moon (Figure 1).

Water is deposited within permanently shadowed regions (PSRs) on the floors of complex craters (panel a). Impact events on the walls create mass movement events towards the floor which disturb previous deposited water (panel b), followed by large scale ejecta blanketing and topographic diffusion (panel c) and mixing as well as internal heat (panel d). Over time, this continued effect redistributes the water distribution, protecting water in the subsurface at meters in depth. Below, we describe our approach to explain this mechanism.

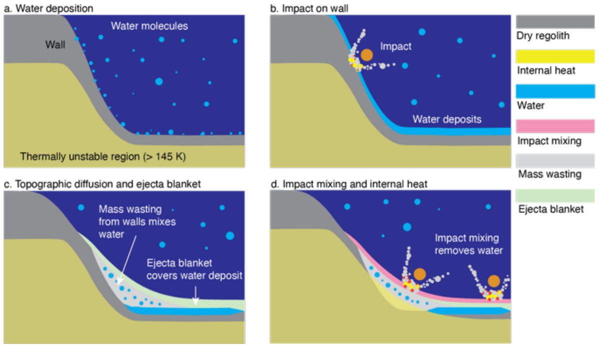

Figure 1: Schematic illustrating multiple geologic processes and their interactions with lunar water in the subsurface.

Connections between existing issues and the motivations & objectives: The existing issue before this work was that there was not any work done to quantify the effects of topographic diffusion on large complex craters. This article connects research previously completed by [1] to analyze topographic diffusion of complex craters found near the lunar southern pole, while they researched simple craters on the Maria regions. We used previous work done by: [2] Deutsch et al., (2020), [3] Cannon et al., (2020), and [4] Tye et al., (2015) to study crater populations on the floors of craters found near the lunar southern pole. Our study is unique in that we looked only at crater populations found on the complex crater walls. Our motivation was to quantify topographic diffusion of these craters and analyze the cumulative effects of other degradation processes on the preservation of ancient water found in these regions.

Approaches: We took the difference between the observed crater populations on the walls and the expected crater populations using the Neukum (2001) production function [5] (Figure 2). This difference gave us the number of craters erased on the walls due to mass movement events. We characterized the volume of material removed by these impact events and accumulated on the floor as the effects due to topographic diffusion and ejecta blanketing [3]. We developed a thermal model to investigate the effects of internal heat from the regolith on the preservation of previously delivered ancient water in these regions.

Findings: We found that the resurfacing rate of Imbrian complex craters is comparable to similarly aged simple craters. Additionally, older craters experience significantly higher degradation than those formed during the Imbrian, however, the effects of topographic diffusion on these craters is an inefficient process, and it is likely that their significantly degraded state is due to the combination of ongoing geologic processes (cookie cutting, ejecta blanketing, and impact mixing). Next, we find that topographic diffusion and ejecta blanketing yields the mixing of water deposited during or before the Imbrian. This allows us to calculate a water mass fraction of ~ 0.2 - 1 wt %. However, it is important to note, that impact mixing and internal heat limit the survival of water at a range of 10s of m (particularly below areas of impact mixing) and on surfaces younger than 3.9 Ga.

Interpretations: We interpret that Late Imbrian complex craters have a similar degradation rate to those of similarly aged simple craters. Meanwhile, older complex craters are significantly more degraded, though topographic diffusion is an inefficient process in their degradation. Impact delivered water may be found anywhere from a few meters to 10s of meters limited by the effects of impact mixing and internal heat.

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References: [1] Fassett and Thomson (2014), *Journal of Geophysical Research Planets*, 119, 2255-2271, [2] Deutsch et al., (2020), *Icarus*, 336, 113455, [3] Cannon et al., (2020), *Geophysical Research Letters*, 46, 21, e2020GL088920, [4] Tye et al., (2015), *Icarus*, 225, 70-77, [5] Neukum et al., (2001), *Chronology and Evolution of Mars*, 96, 55-86, [6] Costello et al., (2021), *Journal of Geophysical Research*, 126, 9.

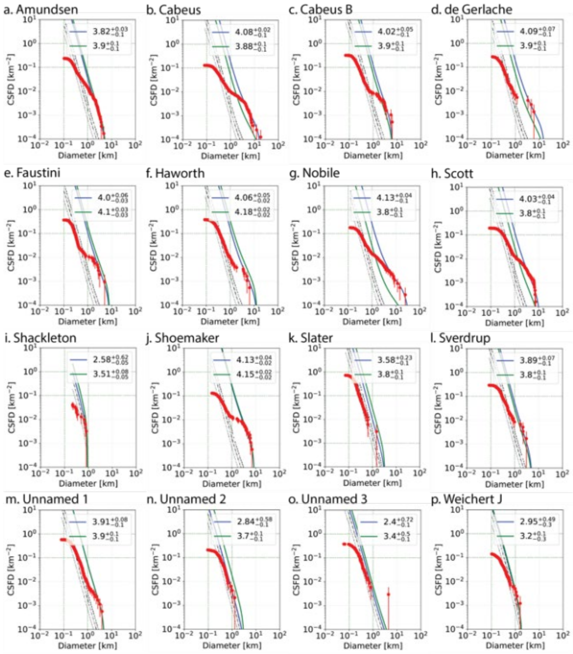

Figure 2: Cumulative crater size-frequency distributions (CSFDs) of 16 complex craters. The x axis shows the diameter of counted craters on the wall, and the y axis shows the CSFD. Red dots with uncertainties show empirically derived data samples from this study, while white solid lines show the Neukum-based [5] chronology models. The blue lines are derived based on our analysis, green lines are based on earlier work [2,3,4]. Three isochrons are also added to panels, dotted lines are 0.5 Ga, dot-dashed lines are 1.25 Ga, and dashed lines are 2.5 Ga.

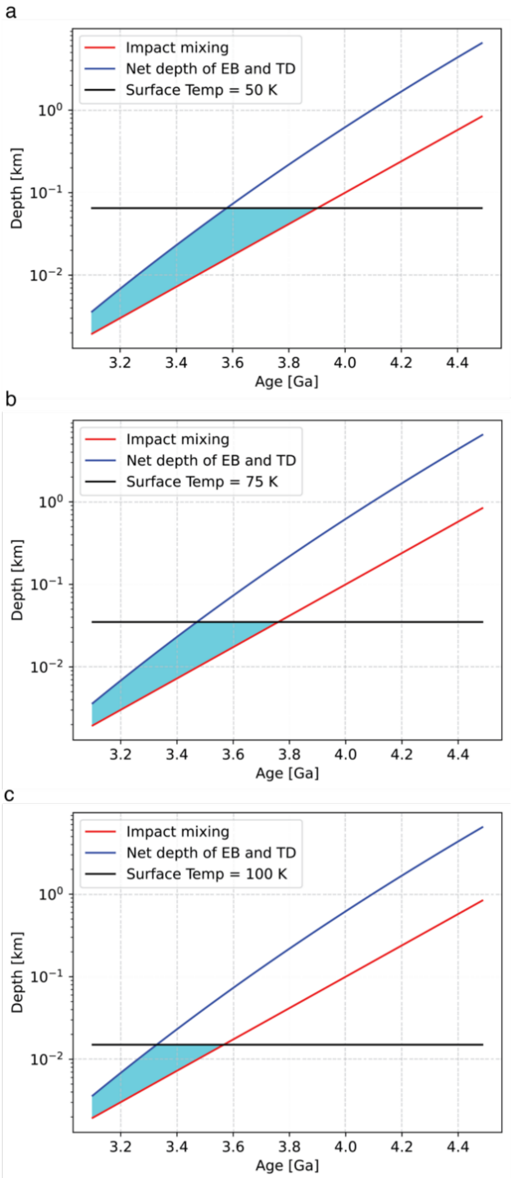

Figure 3: Existence of ancient water affected by material accumulation from ejecta blanketing [3] and topographic diffusion, as well as two disturbing factors: impact mixing and internal heat. For all the panels, the red lines illustrate the depth affected by impact mixing [6], while the blue lines describe the net depth driven by ejecta blankets [3] and topographic diffusion. EB stands for ejecta blankets, while TD means topographic diffusion. The black lines describe the 16 m W/m-2 thermal threshold. The cyan regions are areas where ancient water may be preserved. Panels a, b, and c show cases when the surface temperatures are 50 K, 75 K, and 100 K, respectively.