THE ORIGIN OF ICE IN SIMPLE LUNAR POLAR CRATERS: NUMERICAL MODELING INSIGHTS.

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Introduction: The presence of water ice at the lunar poles is now firmly established [e.g., 1-4]. This ice is expected to be largely cold-trapped in the subsurface [1-3] but some water ice exposed directly at the surface has been detected [4] (Fig. 1). If surface ice was delivered after the formation of their host cold traps (generally, <~ 3.5 Ga simple impact craters), then the cold trap ages provide upper limits on the ice age; surface ice could therefore be 'young' (<~3.5 Gyr). Alternatively, ice could be 'old' if it existed prior to the formation of its host crater; surface ice exposures in smaller craters may then be remnants of ancient ices exposed during the impact cratering process.

Here, we model the formation of simple (D <~20 km) impact craters at the lunar poles to determine how (near) surface ice is redistributed by cratering events. This work has important implications for the stratigraphies of ice-bearing craters, and thus, the ages and sources of surface ice observed on the Moon today. It will also provide important insight into the influence of ice layers in the formation of simple craters, building upon the Shackleton crater investigation of [5].

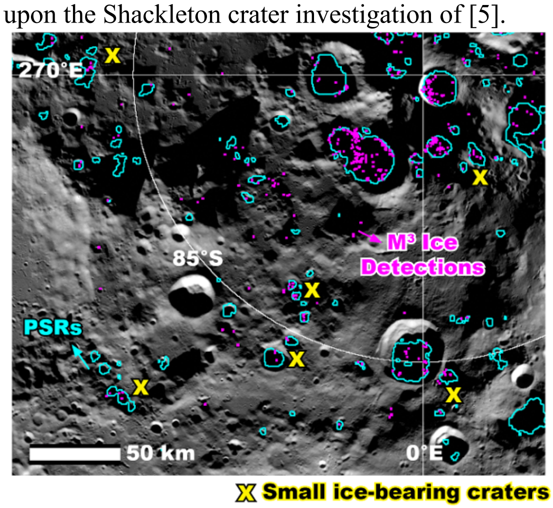

Fig 1. Surface ice detections [4] at the lunar south pole. 'X' denotes small (D <10 km) craters hosting ice exposures; PSRs: permanently shadowed regions. (LOLA WAC).

Methods: The 2D iSALE shock physics code [e.g., 6] was used to numerically model the formation of simple lunar impact craters covering an impact velocity range of ~10–20 km/s and impactor diameter range of ~0.3–2 km. Impactor, crust, and water-saturated proxy ice layers were represented by dunite [7], gabbroic anorthosite [8], and wet tuff [9], respectively. Surface temperature was 100 K; the ice layer was a constant 125 K. Cell size was 25 m. Ice layer thickness was varied between 0.1 and 1 km (representing an upper boundary of 'gigaton' thick ice deposits [10]) and placed either at the target surface, or at a depth of 0.1, 0.5 or 1 km.

Results: Simulations illustrate the effect of an ice layer buried at depth on simple crater formation. Instead of a smooth bowl-shape, the ice layer creates a platform on the crater wall (Fig. 2a). Peak shock pressures demonstrate that water-saturated material originally at depth is not significantly shocked (i.e., melted/vaporized) and can be found near or at the surface (Fig. 2b).

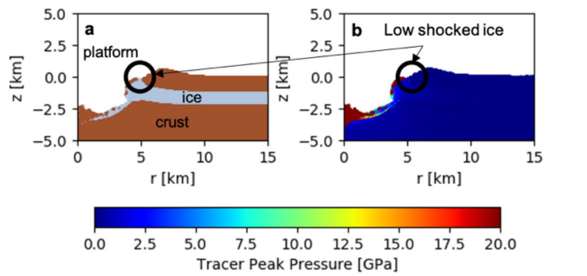

Fig 2. Crater with an ice platform on its wall (at ~5 km radius). The ice layer (light gray) was originally 1 km thick at a depth of 1 km. Ice exhumed at the surface at ~5 km radius (circled) remained solid. a) material; b) peak shock pressure. (impact velocity: 10 km/s; diameter: 1 km.)

Discussion: These preliminary models suggest that an ice layer, originally at depth, could survive (i.e., remain solid) a cratering event and be found near the crater floor. Some lunar ice deposits could, therefore, be 'old'; this would be consistent with Monte Carlo ice deposition modeling [10] and regolith gardening processes [11]. The presence of ice platforms along crater walls will be dependent on impact energy and ice depth/thickness, but nonetheless demonstrates that an ice layer could affect crater formation. Further modeling investigating additional impact velocities/diameters, and ice thicknesses/depths, is required to validate and augment these findings.

References: [1] Feldman W. C. et al. (2000) *JGRP*, 105, 4175–4195. [2] Rubanenko L. et al. (2019) *Nat Geo*, 12, 597–601. [3] Hayne P. O. et al. (2015) *Icarus*, 255, 58–69. [4] Li S. et al. (2018) *PNAS*, 115, 8907–8912. [5] Halim, S. H. et al. (2021) *Icarus*, 354, 113992. [6] Collins, G. S. et al. (2004) *MAPS*, 39, 217-231. [7] Benz, W. et al. (1989) *Icarus*, 81, 113-131.[8] Thompson, S. L. and Lauson, H. S. (1972) Sandia National Laboratory Report SC-RR-71 0714. [9] Allen, R. T. (1967). General Dynamics Report #GA MD-7834. [10] Cannon K. M. et al. (2020) *GRL*, 47, e2020GL088920. [11] Costello E. S. et al. (2020) *JGRP*, 125, e2019JE006172.