Introduction: Water ice presence at the lunar poles is now firmly established [e.g., 1-4]. The ice is expected to be largely cold-trapped in the subsurface [1-3]; however, detections of ice exposed at the surface [4] have also been made (Fig. 1). But what is the origin and age of such ice? Ice could be ‘young’ if surface ice was delivered after the formation of their host cold traps (generally, \( \leq 3.5 \) Ga simple impact craters). 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.

This work models the formation of simple (\( D < -20 \) km) impact craters at the lunar poles to: determine how (near) surface ice is redistributed by cratering events and study the conditions under which these layers can be excavated to, and preserved at, the lunar surface. 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.

Methods: The iSALE shock physics code [e.g., 5] was used to numerically model simple crater formation. Typical lunar impact velocities (10-20 km/s) were used; impactor diameters were varied between 0.5 and 2 km. Impactor, crust, and water-saturated proxy ice layers were represented by dunite [6], gabbroic anorthosite [7], and wet tuff [8], respectively. The ice proxy layer was interspersed within the anorthosite at various depths (e.g., 0.5 km, 1 km) and with various thicknesses (up to 1 km - representing an upper boundary of ‘gigaton’ thick ice deposits [9]).

Results: Models demonstrate that initially buried ice can be excavated or exposed at the lunar surface while being subjected to low peak shock pressures (Fig. 2). This work, therefore, suggests that some lunar ice deposits could be ‘old’ - ice exposures in smaller craters are the remnants of ancient ices, exposed during the impact cratering process. This would be consistent with Monte Carlo ice deposition modeling [9] and regolith gardening processes [10] which predict most ice is from relatively ancient, episodic deliveries. However, this is heavily dependent on the impact and target parameters, as briefly shown in Figure 2. Ice must be at a great enough depth to not be vaporized (or else submitted to high peak shock pressures) and not too deep to prevent excavation or exposure during crater formation.

Fig. 1. Distribution of surface ice detections [4] at the lunar south pole. Examples of small (\( D < 10 \) km) craters that host ice exposures are denoted by an X. PSRs: Permanently shadowed regions. (LOLA WAC image.)

Fig. 2. Material (a) and ice peak shock pressure (b) distribution for the impact of a 1 km diameter body at 10 km/s. The ice layer was originally at a depth of 1 km, with a thickness of 1 km.