Understanding the Depositional Character of Lunar Ice

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Abstract

The key strategic prize on the moon is water in the form of ice. Water is essential for long-term human sustainability for drinking, breathing oxygen and hydrogen for fuel plus other chemical and infrastructure needs. Orbiter, lander and earth based sensors have verified a hydrogen signature to, and suspected to be water in the form of ice in a variety of lunar geographies but dominantly in the permanently shaded southern hemisphere polar regions. Although we now have defined areas where water-ice is likely, the actual nature, three-dimensional occurrence and depositional character of the ice as a mineable formation is relatively unknown. Models assume frozen sheets to large blocky crystalline water-ice potentially easily mined. However, assuming icy comet collision sourcing, the interaction of frozen crystalline ice in the absence of a frictional atmosphere on a cold surface with periodic exposure to lunar seismic shaking, other impacts and possibly solar winds, then a simple pool or ice-block model may be inadequate. For example, assuming a nominal icy comet, water-ice density, 5 km in diameter traveling 40 km/s, approaching at a 45 degree angle and with no atmosphere to disperse energy, would yield an approximate crater approximately 76 km in diameter and 1 km deep, displacing about 4,500km^3 of regolith (with a Richter magnitude of 9), while transferring approximately 65km^3 of water-ice to the surface (~75M gallons). Instantaneous impact heating and ice melting plus the chaotic presence of impact debris strongly suggests a process of regolith mixing with ice. If there is lunar geologic debris mixed with turbulent but changing to quiescent meltwater/ice slush, then earthlike depositional packages may form. In addition to primary blast debris, additional and ongoing impacts of various scales cause impact blast and seismic re-working with subsequent ground disturbance and loose sediment displacement suggesting ongoing depositional changes. This paper presents an early concept of lunar ice as blended with regolith debris in potential depositionally controlled patterns. Data from early thought experiments followed by a simplistic impact experiment are shown which suggest potential water -ice mixing, possibly in depositionally controlled patterns. Prior to potential experimentation in a lunar regolith bin, a simple benchtop setup was used to impact ice onto a simulated lunar surface. Crater size and depth and ice interaction was measured and post-impact patterns observed. These data suggest that although ice may occur in blocks or sheets there is evidence that instantaneous to near-term depositional mixing may occur. Tools and processes to map this possibility may be needed on the lunar surface prior to mining. Knowing the nature, three-dimensional occurrence and depositional character of the ice as a mineable formation is critical for planning sustainable lunar infrastructure.

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