REVIEW OF PROCESSES INFLUENCING THE FORM AND MORPHOLOGY OF ICE ON THE MOON.

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Introduction: As our closest cosmic neighbour, the Moon has become one of the primary destinations of interest for space exploration. Water derived from ices mined at the polar regions of the Moon has the potential to be used for various proceses both on the lunar surface and in cis-lunar space [1, 2]. To achieve these goals, outstanding gaps in our knowledge on the physical properties and spatial distribution of frozen lunar volatiles at and below the lunar surface must first be addressed. The present work reviews the observed spatial distribution of water-ice on the Moon, the history of accumulation within persistently shadowed regions (PSR) at the lunar poles, and the various mechansism which might control its current state in icy lunar regolith.

Space weathering: A conceptual model summarizing the possible cycling of water-ice across several possible polymorphs and physical textures with lunar regolith is being developed, building on prior work describing possible textures of icy regolith [3–5]. The theoretical framework for this model is based on experimental work describing the polymorphic structures of water-ice [6, 7], together with in-situ and remote observations of space weathering processes on the Moon which control the production and evolution of lunar regolith. These include thermal cycling [8], solar wind [9], micrometeorites [10, 11] dialectric breakdown [12, 13] and seasonal changes in lunar water [14–16]. To validate this model, we provide several testable predictions which can be addressed by upcoming robotic missions to lunar PSRs including the Polar Resources Ice Mining Experiment-1 (PRIME-1) and Volatiles Investigating Polar Exploration Rover (VIPER) [17] or crewed missions as part of Artemis. These include the detection and presence of amorphous and stacking disordered ice or the microstructure of secondary growth fabrics of ice as icy regoloth undergoes lithification to hardened material like that observed by the LCROSS impact in Cabeus crater [18]

Extraterrestrial ice: The fundamental mechanisms that control the formation and evolution of ice on the Moon are not well known, and may differ significantly to Earth. Under the airless and cryogenic environmental conditions of the polar cold traps, the formation of ice occurs via vapor deposition in the absence of the bulk liquid phase which can result in a variety of ice forms and morphologies. Under sufficiently large thermal gradients, the effect of temperature on water vapor pressure gradients may exceed that of grain curvature, causing preferential ice nucleation on a grain, rather than at grain contacts resulting in unique ice structures [19]. The frequent churning of regolith via metoerite gardening [11] may preclude these fragile structures from forming from heat inudced vaporization of preexisting ice, which could either be permanantly lost or redeposited on lithic grains forming an iceglutinate - a process identical to agglutination [10]. In addition, water-ice may be in its amorphous form rather than a crystalline solid due to cryogenic deposition temperatures [20, 21]. Conversely, the low flux rate on the lunar surface may instead result in crystalline ice predominantly occuring [22]. This process is further complicated as icy regolith undergo burial and lithification via pressure-induced sintering [23] or thermal annealing with increasing temperature with depth due to the geothermal gradient. In short, it is not known which form or texture of water-ice predominantly occurs as on the Moon, nor if distinct types of ice deposits occur laterally or with depth.

Conclusions: This work aims to consolidate various experimental findings and theoretical models on the formation and evolution of ice on the Moon, together with remote observations from lunar orbiters to provide a framework to better describe different types icy lunar regolith.

References [1] Kornuta D. et al. (2019) *Reach*, 13(November 2018):100026. [2] ISECG , The Global Exploration Roadmap What is New in The Global Exploration Roadmap, Technical Report January ISECG (2018). [3] Cannon K. M., Physical textures of lunar ice (2023). [4] Johnson D. K. et al. (2023) *Icarus*, 115885. [5] Ricardo D. et al. (2023) *Advances in Space Research*. [6] Amann-Winkel K. et al. (2016) *Reviews of Modern Physics*, 88(1):1–20. [7] Chaplin M. F. (2019) *Encyclopedia of Water*, 1–19. [8] Byron B. D. et al. (2019) *Journal of Geophysical Research: Planets*, 124(3):823–836. [9] Jones B. M. et al. (2018) *Geophysical Research Letters*, 45(20). [10] Zhao R. et al. (2023) *National Science Review*, 10(12). [11] Speyerer E. J. et al. (2016) *Nature*, 538(7624):215–218. [12] Jordan A. P. et al. (2022) *Icarus*, 383. [13] Jordan A. et al. (2023) *Icarus*, 395:115477. [14] Luchsinger K. M. (2022). [15] Reiss P. et al. (2021) *Journal of Geophysical Research: Planets*, 126(5):1–14. [16] Schorghofer N. and Taylor G. J. (2007) *Jour-*

nal of Geophysical Research E: Planets, 112(2):1–11. [17] Zacny K. et al. (2022) *53rd Lunar and Planetary Science Conference*. [18] Luchsinger K. M. et al. (2021) *Icarus*, 354(August 2020):114089. [19] Siegler M. A. et al. (2012) *Journal of Geophysical Research E: Planets*, 117(3):1–24. [20] Cocks F. (2002) *Icarus*, 160(2):386–397. [21] Cartwright J. H. E. et al. (2008) *The Astrophysical Journal*, 687(2):1406–1414. [22] Kouchi A. et al. (1994) *Astronomy and Astrophysics -Berlin-*, 290(3):1009–1009. [23] Blackford J. R. (2007) *Journal of Physics D: Applied Physics*, 40(21).