CHARACTERIZING POTENTIAL LANDING SITES FOR FUTURE EXPLORATION OF LUNAR SURFACE WATER ICE.

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Introduction: Surface exposed water ice at the lunar polar regions are among the highest priorities for future explorations of the Moon [e.g., 1, 2]. Lunar ice can be directly mined and used as drinking water and rocket propellant, which will be more economical than bringing it from the Earth [e.g., 3].

The ice content, minerology, surface roughness, geomorphology, and thermal environment are key factors for engineers to consider when designing rovers, landers, and other facilities for exploration. The temperature, slope, hydrogen, number of ice detections, depth to stability for water ice and dry ice, and mobility of 169 ice bearing PSRs near the lunar south pole have been examined to prioritize possible landing sites for exploring surface exposed ice [4]. Major mineral phases in the lunar polar regions were assessed using the LOLA and the Kaguya Spectral Profiler (SP) data [5].

Our work focuses on characterizing the ice content, mineralogy, geomorphology, and temperature variations of 9 (6 south and 3 north polar) PSRs showing high concentrations of ice exposures. The derived information may provide guidance for selecting landing sites to explore lunar ice and associated geological processes.

Data and Methods: We estimate the ice and mineral contents from the averaged M^3 spectra of ice exposures and the entire PSR, respectively. We use long exposure LROC NAC images (~20 m/pixel) [6] to interpret geomorphology of ice exposures. We use the LRO Diviner data to understand the local thermal environment and how the temperature varies within a lunar year. The surface roughness is examined with the LRO LOLA DEM data.

The ice and mineral contents at each PSR are estimated using Hapke's radiative transfer model [7] by assuming an intimate mixing scenario. The ice content is also estimated from the albedo variations near 700 nm of the NAC data and the absorption features near 1.5 and 2.0 μm of M^3 data. We are conducting lab and field tests of ice and regolith mixtures to validate our model.

Preliminary Results and Discussion: Here we show a case study at the Shoemaker PSR. Fig. 1. shows the averaged M^3 spectra at illuminated walls, the whole PSR, and ice exposures of the Shoemaker PSR. Our spectral unmixing results suggest that the dominant mineral phases are glasses, plagioclase, and pyroxene. The absorption near 2.2 μm of the averaged spectrum of ice bearing pixels may indicate the presence of hydrated minerals. Our results suggest ~10 wt.% ice in the ice bearing pixels in the Shoemaker PSR. We observe strong enhancement in the long exposure NAC data of those ice exposures. A model is developed to estimate the ice content from the albedo enhancement at 700 nm. ~5-10 wt.% ice is estimated from the NAC data. Diviner data at the Shoemaker PSR suggest that the highest temperature is <90 K and mostly between ~25 K and 70 K. Preliminary geomorphic mapping using the long exposure observations indicates that some ice exposures are associated with small craters and crater ejecta. Shoemaker Crater is dated to be 4.15±0.02 Ga old [8]. That can be used as the upper estimate of the age of observed surface ice in this PSR. However, a previous study suggest that the Moon spin axis may have been tilted ~77° at ~2 Ga ago [9], which means all PSRs and their hosted ice could be younger than ~2 Ga. The 5m/pixel DEM map suggests that the Shoemaker PSR is very smooth. The mean slope at this region is 8.6° ± 6.1° (1σ). Over 90% of it has a surface slope <16°, which makes the Shoemaker PSR highly traversable to examine patchily distributed ice exposures.

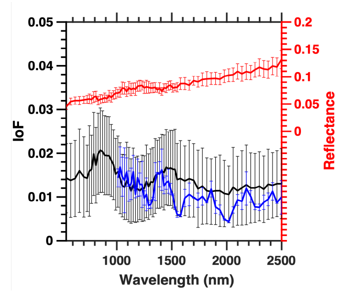

Fig. 1. The averaged spectra and standard deviations of M^3 data at the Shoemaker illuminated crater wall (red), the entire PSR (black) and all ice bearing pixels (blue).

Our estimations of ice content from radiative transfer modeling, the 700 nm albedo variation, and the absorptions near 1.5 and 2.0 μm show great consistency. The ongoing lab and field tests of ice and regolith mixtures will help to validate our modeling work. Our validated models will also be applicable to future missions, such as the Flashlight, Trailblazer, and VIPER missions that will examine the IR features near 1.5 and 2.0 μm and the ShadowCam onboard the KPLO mission that will map the 700 nm albedo. These missions will provide new insights and constraints on our current understanding about lunar surface ice, which is critical for ISRU of lunar ice.

References: [1]. Jawin, E.R., et al. *ESS*, 2018. [2]. Li, S., et al. *PNAS*, 2018. [3]. Blair, B.R., et al. *NASA Exploration Team Report*, 2002. [4]. Lemelin, M., et al. *PSJ*, 2021. [5]. Lemelin, M., et al. *LPSC*. 2021. [6]. Cisneros, E., et al. *LPSC*. 2017. [7]. Hapke, B. *JGR*, 1981. [8]. Deutsch, A.N., et al. *ICARUS*, 2020. [9]. Ward, W.R. *Science*, 1975.