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DETERMINING TRAFFICABILITY OF PYROCLASTIC DEPOSITS AND PERMANENTLY SHADED REGIONS OF THE MOON USING BOULDER TRACKS.

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Introduction: Lunar Pyroclastic deposits (LPDs) and Permanently Shaded Regions (PSRs) are areas of the Moon that have significant ISRU potential. LPDs can contain volatile- and ilmenite-rich glasses [1,2], whilst PSRs act as cold traps for stable water ice [3,4]. Although several proposed missions may explore these regions, little is known about trafficability of those terrains. Here we used boulder tracks to remotely determine the bearing capacity of regolith in representative sites within LPDs and PSRs.

Lunar boulder tracks: Rockfalls and their associated boulder tracks are abundant on the Moon. They are also classic tools for determining surface properties, having been used during Apollo to evaluate bearing capacities at the Apollo 17 landing site. The key input parameters are boulder and track dimensions, and those of their associated shadows, which can be evaluated as a function of slope and boulder shape using Hansen's formula [5].

Methods: Forty-eight boulder tracks in 10 large LPDs [6] and 13 boulder tracks in 5 PSRs [7] were identified. A baseline set of boulder tracks in highland and mare regions was also measured. Whilst measurements for boulders in LPDs, highland, and mare regions can be made directly from NAC imagery, that is not possible in PSRs. For those regions, NAC images were stretched by enhancing contrast and brightness to identify boulder tracks in shadowed areas. Only areas that experience secondary sunlight, diffusively reflected from crater walls into PSRs, could be used in this study as some secondary source of illumination was required to identify boulders.

After suitable images were selected, they were processed to remove excess noise. Boulder and track dimensions, and the associated shadows produced, were recorded. All measurements and complementary soil properties from the literature were then input into Hansen's formula to estimate bearing capacities.

Results: Qualitative analyses show that boulder tracks formed in LPDs and PSRs have similar morphologies to those formed in highland and mare regions. Bearing capacity decreases with increasing slope across all location types. Therefore, rover wheels and lander pads will sink more on steeper slopes [5]. LPDs and PSRs are significantly stronger than mare regions in almost all depth ranges of regolith with estimated bearing capacities of 131 ± 21 kNm^{-2} and 127 ± 29 kNm^{-2} respectively, compared to 85 ± 12 kNm^{-2} for mare regions (for upper 1 m on 0° inclines). There was insufficient data in the upper 1 m of highland regolith for comparison. It should be noted that this technique is limited by the minimum depth of measured boulder tracks ($\gtrsim$19 cm in LPDs), which is limited by the resolution of the available NAC imagery (~0.5 m/pixel).

Combining our results with data obtained from surface images of lunar rover tracks, and extrapolating to the upper few cm's of regolith, suggests that rovers and landers planning to explore LPDs should not sink as far into the regolith there as in highland and mare regions. The nature of the uppermost 28 cm of PSRs (the minimum track depth measured in PSRs) remain unclear as a result of special environmental conditions.

Conclusions: This initial study of boulder track analyses suggests the regolith in LPDs and PSRs is significantly stronger than mare regolith at equivalent depths of $\gtrsim$19 cm and 28 cm respectively. Trafficability should not be an unusually difficult impediment to ISRU within LPDs, meanwhile the trafficability of rovers in PSRs remains uncertain. To further reduce mission risk, the soil strengths calculated here for LPDs and PSRs should be tested in situ.

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