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Regolith thickness estimation over Sinus Iridum using morphology of small craters from LROC images

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Abstract

Regolith thickness over Sinus Iridum region is estimated using morphology and size–frequency distribution of small craters that are counted from Lunar Reconnaissance Orbiter Camera (LROC) Narrow Angle Cameras (NACs) images. Results show that regolith thickness for Sinus Iridum is from 2 m to more than 10 m, with a medium value between 4.1 m and 6.1 m.

1. Introduction

Lunar regolith thickness provides important information for scientific questions about lunar geology and engineering constrains for lunar explorations. Regolith thickness can be estimated using in situ geophysical measurements [1], morphology and size frequency distribution of small fresh craters [2], and microwave remote sensing techniques [3, 4]. Based on these techniques, a consensus has been reached that regolith thickness is about 4-5 m for maria and 10-15 m for highlands [3]. With the recent released high resolution optical images from LROC [5], it is possible to estimate regional regolith thickness using morphology and size–frequency distribution of small fresh craters. In this study, regolith thickness in Sinus Iridum region, the potential landing site for Chang-E 3 rover, is estimated using LROC images. Regolith thickness distribution and statistical characteristics are presented, and compared with the inversion results from Earth–based 70 cm Arecibo radar data.

2. Thickness estimation approach

In high resolution optical images, small fresh craters (<250 m) that are widespread on the lunar surface can be classified into three morphological classes: normal, flat-bottomed, and concentric (Fig. 1). By impacting various projectiles against targets consisting of loose materials overlying more cohesive substrates, small craters with these morphologies could be reproduced in laboratory, suggesting that morphologies of small craters depend mainly on the thickness of the surficial layer [2]. Experimental results show that normal craters form when the surficial layer has a thickness greater than a value between D/5.7 and D/4.8, and concentric craters form when the surficial layer has a thickness less than a value between D/10 and D/8, where D is the apparent crater diameter [2]. If crater morphology can be identified in high resolution optical images, regolith thickness can be estimated using this relation. It should be noted that only small fresh craters can be utilized in this approach, and degraded craters should be excluded.

In our study, Crater Helper Tools toolkit extension to ArcGIS is used for crater counting and morphology identification [6]. To identify a crater, 3 points are selected on the rim of a crater and then define a circle that is used to determine crater diameter. The morphologies of the craters are further identified by its shape and shadow patterns: normal craters usually have spherical shapes and arcuate shadows, flat-bottomed craters have distinct flat floor, and concentric craters have double annular arcuate shadow patterns (Fig.1). Then, location, diameter and morphology of the crater are recorded automatically by this toolkit.

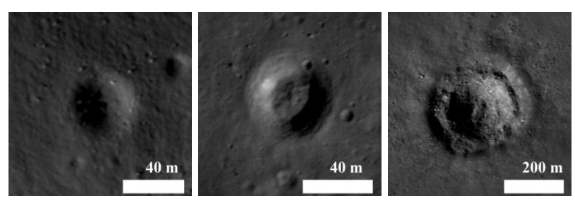

Figure 1: Three types of small craters: normal (left), flat–bottomed (middle), and concentric (right).

3. Results

Fig. 2 shows a LROC wide angle camera (WAC) image for Sinus Iridum (44.1°N, 31.5°W; diameter 259 km), which is a bay of basaltic lava in the northwest of Mare Iridium. The northwest of Sinus Iridum is surrounded by Montes Jura, and the northeast and southwest capes are Promontorium Laplace and Heraclides [7]. There are totally 379214 craters with diameters between 4.2 m and 250 m. Size–frequency distributions show that the diameters of normal craters

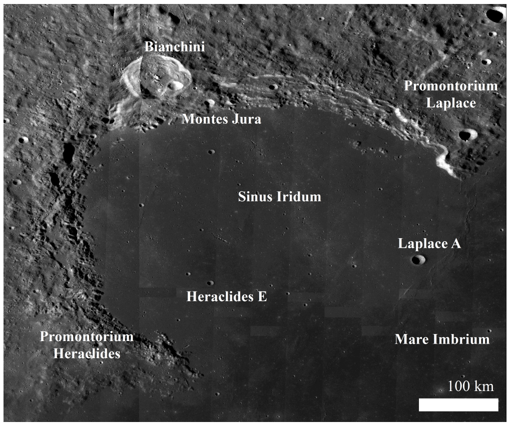

Figure 2: A LROC WAC image for Sinus Iridum region.

(275090) are usually smaller than 50 m with a medium value about 18.5 m, diameters of flat-bottomed craters (19156) vary from 9.5 m to 234.5 m with a medium value of 34.5 m, and diameters of concentric craters (84968) are from 7 m to 250 m with a medium value of 30.5 m. Almost all the fresh craters with diameters between 150 m and 250 m are concentric.

Using the relations between regolith thickness and crater diameter, regolith thickness for Sinus Iridum is estimated. Fig. 3 shows the cumulative distribution of regolith thickness (percentage of area with regolith thickness smaller than a given value), where the black line indicates the estimation from normal craters, and the red line is the result from concentric craters. As can be seen, the medium regolith thickness is between 4.1 m (from normal crater) and 6.1 m (from concentric crater). From the normal craters, regolith thickness for 75% of the area is larger than 3 m, and that of 25% region is larger than 6.5 m.

4. Conclusions

In this study, small fresh craters in Sinus Iridum region are counted and their morphologies are identified from high resolution LROC images. Using their morphology and size–frequency distribution, regolith thickness over this region is estimated. Our results show that regolith thickness in Sinus Iridum varies from 2 m to more than 10 m, with a medium value between 4.1 m and 6.1 m. The results can help to analyze the received ground penetrating radar echoes for Chang-E 3 mission.

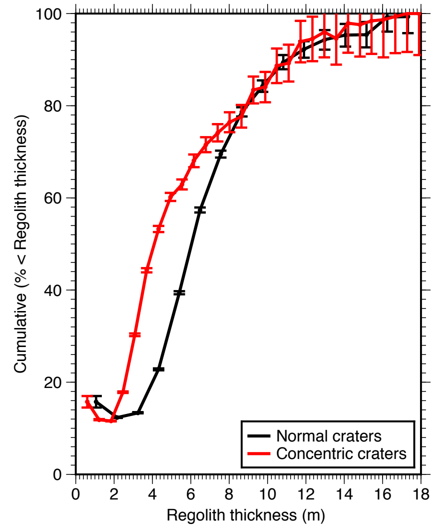

Figure 3: Cumulative distribution of regolith thickness for Sinum Iridum region that are estimated from normal craters (black) and concentric craters (red).

Acknowledgements

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