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Character of the Lunar Regolith: The View from LROC

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Abstract

Regolith is the fragmental layer of debris covering most of the lunar surface formed by meteorite bombardment over billions of years. High resolution images being acquired by the Lunar Reconnaissance Orbiter Camera (LROC) are providing a view of the surface in exquisite detail. Regolith thickness varies significantly over short distances as evidenced by the morphology of small craters and the presence and distribution of excavated rocks. Down-slope regolith movement results in the development of an "elephant hide" morphology and removes of small diameter craters.

1. Introduction

Regolith is the fragmental debris layer that covers most of the lunar surface **[1-2];** the thickness and maturity being a function of age. The regolith has been formed by bombardment by meteorites over billions of years. High resolution images being acquired by the LROC are providing a view of the surface in exquisite detail **[3]** that allows detailed study of its formation and evolution.

2. Regolith Morphology

On level surfaces (slopes of only a few degrees or less) the surface undulates due to the presence of impact craters with morphology ranging from crisp and young, to ancient and highly subdued. Fresh craters exhibit sharp raised rims, steep interior slopes and bright ejecta and ray deposits. With time, the craters degrade, bright rays disappear, rims become rounded and the interior fills becoming shallower. Eventually the topography of the crater is completely lost. Boulders and rocks that are excavated by the impact and distributed around the crater are worn away by micrometeorite abrasion.

On sloping surfaces, a unique texture, referred to as "elephant hide," is observed (Figure 1). The down-slope movement of the regolith, driven by micrometeorite impact, removes small impact craters at a rapid rate such that the observed crater frequency is not indicative of the actual surface age.

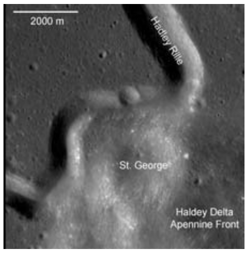

Figure 1. Apollo 15 landing site. Note that slopes of Hadley Delta / St. George crater are less cratered than the mare plains. The flanks of Hadley Delta exhibit an "elephant hide" texture caused by the down-slope movement of regolith. LROC image M104490494L.

3. Crater Morphology

Small crater morphology provides an indication of the regolith structure and thickness. **[4-5]** developed a model relating crater morphology to regolith thickness. This type of morphology is well observed using the LROC images (Figure 2). Crater morphology is highly variable over small spatial scales indicating that the regolith is not a simple layer-cake model but rather has variable thickness, complex structure and different material properties.

4. Surface Rock Distributions

Rocks and boulders associated with impact craters have two sources; (a) bedrock excavated during impact, and (b) regolith impact-breccia formation at the time of the impact event. Van Serg crater at the

Apollo 17 site (Figure 3) is an example of a small crater exhibiting blocks around the rim. These blocks are regolith breccias, not excavated bedrock **[6].**

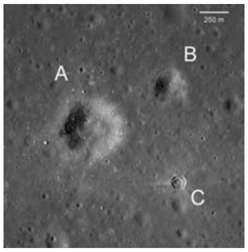

Figure 2. Mare area near Apollo 12 landing site. Crater A (525 m) and has a hummocky mounded floor with excavated boulders, Crater B (300 m) and degraded, Crater C (130 m) is very fresh with bright rays and concentric floor.

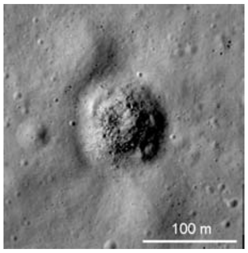

Figure 3. Van Serg crater. 95 m diameter at the Apollo 17 site. Most rocks around the crater are regolith breccias formed during the impact. LROC image M101949648R.

Numerous boulders are observed to have rolled down slopes leaving a linear track (Figure 4). A particularly good example is the boulder at Station 6 at Apollo 17. This boulder, 6 x 10 x 18 m across, rolled ~500 m down the North Massif. Analysis of the regolith deformation by the boulder **[8-9]** provides information on regolith geotechnical properties such as the cohesion and friction angle. The ability to observe examples like these across the Moon provides information about the physical properties of the regolith in many additional locations.

6. Summary and Conclusions

LROC images can be used to understand various properties of the regolith to better understand how it forms and evolves. Data provided by other instruments when combined with LROC images provides important insight in regolith processes. Regolith thickness varies over small spatial scales. The high image resolution allows for detailed study of the size-frequency distribution of impact craters to relatively small diameters (few meters). This, in turn, allows for a better understanding of the surface morphology and allows for more detailed estimates of relatively and absolute ages.

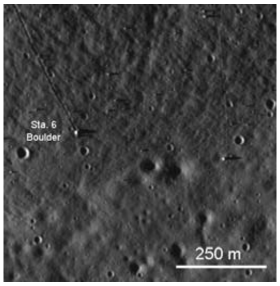

Figure 4. Large boulder that rolled down the North Massif at the Apollo 17 site. The trail behind the boulder is about 10 m wide. LROC image M101949648R.

References:

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