Influence of Temperature and Pressure Stress On Compactness of Lunar Regolith Simulant

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Introduction

The Moon's magma oceans and volcanic activity formed lunar bedrock, from which regolith is formed. Meteor bombardment eroded exposed bedrock, forming a thin layer of regolith that subsequent impacts could penetrate, eroding more bedrock. As the regolith layer thickened, additional impact events caused shock waves to pass through this layer of regolith, pulverizing and compressing material [2,6]. Frictional heat from impacts melted and welded material together. These two outcomes resulted in a highly compacted layer of regolith dust and the formation of regolith breccia. We have studied how impact-induced heat and compression affected lunar regolith by characterizing the effects of heat and compression on lunar simulant and terrestrial regolith (clay from Aurora, UT). [5]

Definitions

Lunar regolith - fragmental rock material covering the bedrock found onn the Moon's lifeless and airless surface. Regolith is produced by a multitude of processes, which mainly include bombardment of the lunar surface by meteorites and charged solar atomic particles

Terrestrial regolith - fragmental rock material covering bedrock created by effects of wind and water, activities of life, and affected by the existence of oxygen

Figure 1. Terrestrial regolith soil on left [1] and lunar regolith on right [4].

Regolith breccia - compacted particulate material consisting of crushed debris and solidified magma produced by meteorite bombardment on the lunar surface

Figure 2. Regolith breccia [3]

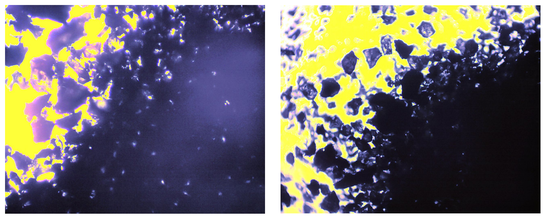

Figure 3: On the right is an image of the control lunar regolith at 400x magnification. On left, with reduced cavity size and number, is a sample of lunar regolith simulant after exposed to a heat-cool cycle.

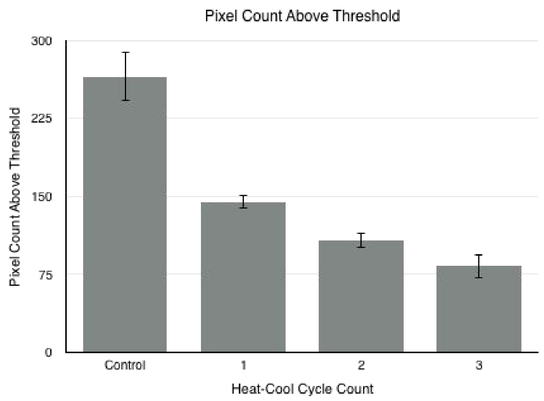

Figure 4: Pixels above a pre-set light threshold were counted. This is a measure of the amount of light allowed through the sample of regolith simulant. Higher pixel count means more and larger cavities as more light is allowed through and able to light up more pixels

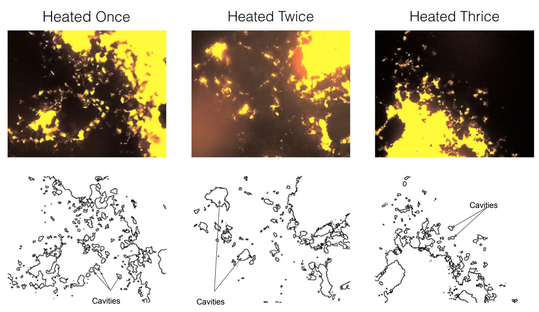

Figure 5: Above is a representation of lunar regolith simulant samples with their cavities isolated and outlined. Note that both cavity size and number decline as heat-cool cycle count increases. This is a visual representation of the effect in **Figure 4**.

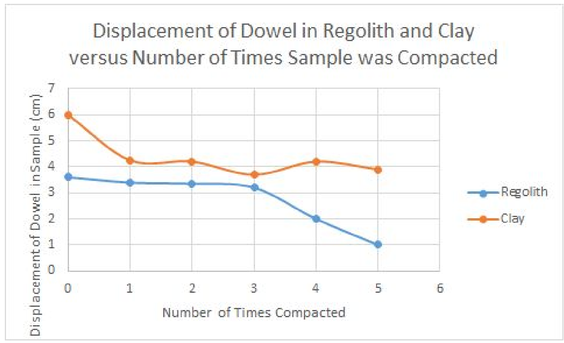

Figure 6: Dowel displacement decreased a greater amount for lunar regolith with increasing times compacted.

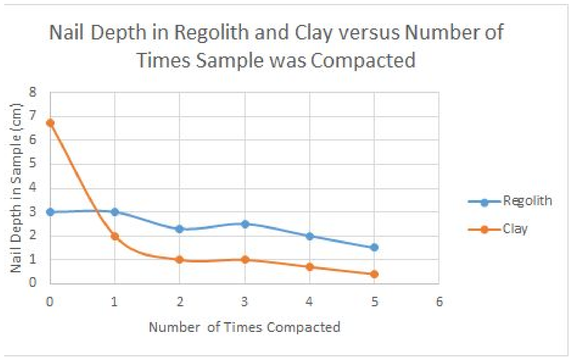

Figure 7: Nail did not penetrate as deep into clay as it did into regolith.

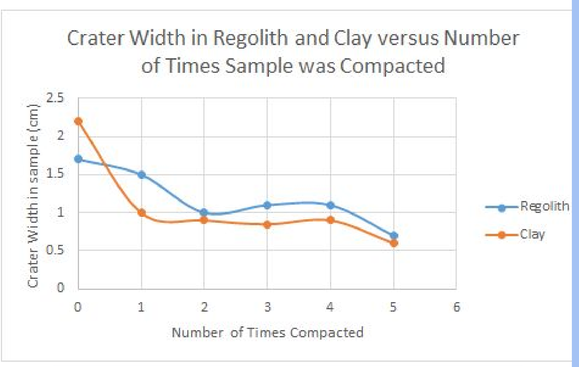

Figure 8: Crater width was larger in regolith.

Materials and Methods

I. Heat

1. Samples were subjected to several cycles of heating and cooling with a bunsen burner
2. Thin layers of regolith were examined under a light microscope (400x).
3. The number of pixels with a light intensity above a pre-set threshold were identified with ImageJ64 as a means for quantifying both the number and size of cavities in a sample.

II. Compression:

We compacted lunar regolith simulant and terrestrial clay in beakers with a piston and performed three tests to measure compressibility as a function of times compacted:

a. Dowel was compressed with a force of 40 lbs into beaker
b. Nail was dropped from 30 cm into the samples
c. Marble was dropped into sample to form a crater

Discussion

I. Heat

As shown in **Figure 3**, cavity size and number were visibly reduced in thin layers of lunar regolith simulant. This effect was quantified by counting the number of pixels in a sample image that were above a pre-set light threshold. Larger pixel counts indicated more light penetration in the sample. **Figure 4** demonstrates that additional heat-cool cycles decrease pixel count. Lower pixel counts mean that samples allow less light to penetrate through them, becoming denser. From this data we can conclude that density increases as heat-cool cycle number increases. This suggests that repeated meteorite impacts on the lunar surface may increase surrounding lunar dust density, without directly applying pressure to the surface, due to creating a large temperature change in the surrounding area. This effect may explain the formation of regolith breccia, a rock-like substance, far away from direct meteorite impacts as thousands of heat-cool cycles may induce solid rock formation from otherwise loose dust.

II. Compression:

Lunar regolith compacted very readily, sticking to the walls and bottom of the beaker it was stored in. With an increasing number of times compacted, displacement of the dowel in the regolith decreased by a greater amount than it did in the clay. However, when a nail was dropped onto the regolith it went deeper than it did into the clay. This may indicate that the regolith is less compact than the clay since the nail goes deeper, but when the dowel is pushed into the clay slowly, the clay flows out of the way, so the dowel goes deeper. The width of the crater formed in the regolith was greater than that in the clay, demonstrating that the clay was more compact than the regolith since fewer of its particles were displaced by the marble.

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