#2119 - Geologic Study of Unusually Deep Simple Craters in the Lunar Simple-to-Complex Transition

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Abstract

From a group of 117 well-preserved lunar simple craters in the 15-20 km diameter range that roughly spans the lunar simple-complex transition, and with the help of Lunar Orbiter Laser Altimeter (LOLA) topography data, we identified seven craters that are unusually deep (depth/diameter ratio > 0.20 plus standard deviation). These craters are in the regions around the mare-highlands boundaries, which are characterized as having the highest porosity on the lunar surface. To understand the cratering mechanics behind the formation of these craters, a geologic investigation of the terrains of these craters was performed. We evaluated the depth/diameter ratios of simpler craters surrounding several 15-20 km diameter craters, analyzed the morphometry of the craters, and visually examined the cavities using multiple data sets. We conclude that deep transient cavities were formed from compaction of porous target material. The result was a deeper than normal simple crater without an identifiable increase in the volume of excavated material. While all of these craters formed in areas of high porosity, not all craters in high-porosity regions are unusually deep. It may be that some unusual impactor property is also required to produce an unusually deep crater, such as a high velocity impact, a near-vertical impact, or a dense impactor that yielded a large penetration depth.

Introduction

Figure 1. Simple craters with \( D = 15-20 \) km (purple circles) are confined to the highlands. The seven unusually deep craters are symbolized by purple circles outlined in black. Their locations coincide with 17-20% porosity on the lunar porosity map from Besserer et al. (2014).

Tests on Hypotheses

Table 1. List of frequencies of smaller well-preserved simple craters within radial distance of 100 km from each of the selected 15-20 km diameter simple craters. The proximity craters show a continuous decrease in percentage with reduction in porosity.

<table>
<thead>
<tr>
<th>Crater Type based on Depth</th>
<th>Porosity (%)</th>
<th>Sample Size</th>
<th>Average % of Surrounding Unusually Deep Simple Craters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unusually Deep</td>
<td>17-20</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>Normally Deep</td>
<td>17-20</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Normally Deep</td>
<td>10-17</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

Trends in Crater Morphometry vs Regional Porosity

Figure 3. In the legend, \( \Phi \) refers to porosity. a) The rim heights of all craters show significant overlap. b) Wall slope shows positive correlation with crater depth (correlation coefficient = 0.3). c) Floor diameter and crater depth display a weak inverse correlation (correlation coefficient = -0.3). d) Floor diameter appears to be independent of wall slope.

Figure 4. a) Percent distribution of \( \Phi \) of normally deep craters associated with various porosity ranges. Parentheses indicate respective sample sizes. Highest porosity regions are the most abundant in the deepest craters. b) Cavity profiles of two normally deep craters (purple) and two unusually deep craters (black).

Discussion and Conclusions

- Several lines of evidence favor the role of compaction of porous target in producing the unusually deep craters:
  - Highest abundance of the deepest craters around mare margins.
  - Similar volume of excavated material and a modification in the typical cratering process as reflected by similar rim heights and independence of wall slope from floor size.
  - The occurrence of only 7 unusually deep craters of the 61 craters in the high porosity regions could be a consequence of locally variable porosity and/or influence of an unusual impactor property.
  - Some results further weaken the importance of mafic intrusions in enhancing crater depth:
    - Presence of debris flows on all craters’ walls.
    - Visual evidence of mafic layering contributing to slumping.

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