Determining a Correlation Between Ejecta Radius and Crater Diameter for Differing Lunar Materials

Chenango Forks Team 1

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Abstract

There are three major materials on the moon: highland, mare, and ejecta (subdivided into mare ejecta on highland and highland ejecta on mare). Because these materials differ in composition and, therefore, in hardness, it was decided that there may be a correlation between ejecta radius and crater diameter depending on the impact site material. Data was collected from the different materials and was compared. It was determined that mare produces the least amount of ejecta, highland produces the most, and combination materials fall somewhere between (leaning slightly closer to highland’s radii than mare).
Materials

Mare
- Basaltic lava flows
- Low albedo
- Basalt is composed mostly of plagioclase feldspar and pyroxene. Plagioclase has a hardness of about 6 on the Mohs scale. The hardness of pyroxene is between 5 and 6.

Highland
- Lighter in color
- Anorthositic composition
  - Labradorite (hardness of 6.5)
- More heavily cratered
- Older than the mare

Highland on Mare
- The first impactor hit highland that bordered mare. The ejecta that shot out after the impact was, therefore, of highland composition. The second impactor landed on that ejecta.

Mare on Highland
- The first impactor hit mare that bordered highland. The ejecta that shot out after the impact was of mare composition. The second impactor landed on that ejecta.

Note: The hardness of mare and highland will vary from the hardness of their components because all materials must be taken into account.
Ejecta

What is thrown up from the surface after an impactor hits. There are two types: continuous and discontinuous. For our analyses, only continuous ejecta was measured. Note in the picture below the two craters. Both display easily visible ejecta. The left-hand crater has its continuous ejecta marked in blue while the right-hand crater has a portion of its discontinuous ejecta marked in green.
Objective

To determine the correlation, if any, between impact site material and ejecta radius. To do so, the relationship between crater diameter to ejecta radius based on the site material was analyzed.
Hypothesis

The softest material, producing the largest ejecta radius will be highland. The hardest material, producing the smallest ejecta radius will be mare. Combination material impact sites will produce ejecta radii that fall somewhere between the aforementioned. Combination materials include highland ejecta on mare and mare ejecta on highland.
Process

A data table was created containing the following information:

- Crater diameter
- Crater radius
- Ejecta radius
- Impact site material
- Coordinates of Crater center
- Simple or Complex
Sample Section of Data Table

<table>
<thead>
<tr>
<th>Crater Number</th>
<th>Crater Diameter (km)</th>
<th>Crater Radius (km)</th>
<th>Ejecta Radius (km)</th>
<th>Material of Crater Location</th>
<th>Simple or Complex</th>
<th>Coordinates of Center</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>32.25</td>
<td>16.125</td>
<td>24.875</td>
<td>Highland</td>
<td>Complex</td>
<td>(-25.96612, 35.20256)</td>
</tr>
<tr>
<td>2</td>
<td>10.08</td>
<td>5.04</td>
<td>6.94</td>
<td>Highland</td>
<td>Simple</td>
<td>(-26.02298, 36.53902)</td>
</tr>
<tr>
<td>3</td>
<td>9.75</td>
<td>4.875</td>
<td>7</td>
<td>Highland</td>
<td>Simple</td>
<td>(-25.38815, 37.56958)</td>
</tr>
<tr>
<td>4</td>
<td>19.38</td>
<td>9.69</td>
<td>14.625</td>
<td>Highland</td>
<td>Simple</td>
<td>(-24.44537, 35.93597)</td>
</tr>
<tr>
<td>5</td>
<td>28.5</td>
<td>14.25</td>
<td>21.5</td>
<td>Highland</td>
<td>Complex</td>
<td>(-22.62389, 37.22864)</td>
</tr>
<tr>
<td>6</td>
<td>18.43</td>
<td>9.215</td>
<td>12</td>
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<td>Simple</td>
<td>(-22.31060, 39.46289)</td>
</tr>
<tr>
<td>7</td>
<td>11.46</td>
<td>5.73</td>
<td>8.94</td>
<td>Highland</td>
<td>Simple</td>
<td>(-23.27426, 38.96805)</td>
</tr>
<tr>
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<td>5.125</td>
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<td>Simple</td>
<td>(-23.53808, 39.08759)</td>
</tr>
<tr>
<td>9</td>
<td>9.08</td>
<td>4.54</td>
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<td>Simple</td>
<td>(-24.02781, 38.83518)</td>
</tr>
<tr>
<td>10</td>
<td>5.95</td>
<td>2.975</td>
<td>6.69</td>
<td>Highland</td>
<td>Simple</td>
<td>(-24.15233, 39.64776)</td>
</tr>
</tbody>
</table>
Method of Measuring

Using the LROC ACT-REACT Map at http://target.lroc.asu.edu/da/qmap.html, we used the “Search” tool to draw thin rectangles along the desired section of the crater (diameter or ejecta). An information box then popped up and provided information such as the width, height, and area of the box just drawn.
Crater Diameter

Using the aforementioned measuring method, a rectangle was drawn across the width of the crater. The width of the box was then roughly estimated to be equal in value to the crater diameter. All measures were taken in kilometers (km).
Crater Radius

As simply as it sounds, the crater radius was determined by dividing the crater diameter by two. This data value was only included in the case that it was needed to determine correlations. Generally the correlations and ratios were determined using crater diameter and ejecta radius. As before, these measures were also recorded in kilometers (km).
Ejecta Radius

Ejecta radius was determined using the same measuring method as described earlier. A rectangle/box was drawn from the one edge of the ejecta to the other edge of the ejecta, measuring the area around the crater that demonstrated the largest radii. The crater diameter was then subtracted and the subsequent value was divided by two. This method was used instead of drawing a rectangle from the ejecta edge to the crater rim simply to account for any uneven ejecta distribution.
Impact Site Material

As formerly mentioned, there were 4 impact site materials observed: mare, highland, mare ejecta on highland, and highland ejecta on mare. Mare material appears darker and has a lower albedo than highland, which appears much lighter. Mare is also smoother in appearance.
Simple or Complex

Complex craters are those that display a mound of material, or crown, in the center of the crater. Some even have multiple crowns. Simple craters lack a crown and are generally smooth on the interior. Crowns are the result of uplifting after impact.
Coordinates of Center

Coordinates of the center were determined only for the means of re-analyzing craters and to keep track of the data.
Graphs

The following graphs were made to determine any correlations, if any, between ejecta radius and crater diameter depending on impact site material. They are logarithmic in nature, as is usually so when discussing craters.
Ejecta Radius vs. Crater Diameter for Mare Craters

\[ y = 20.63 \ln(x) + 19.42 \]

\[ R^2 = 0.606 \]
Ejecta Radius vs. Crater Diameter for Combination Craters

\[ y = 13.88\ln(x) + 12.26 \]

\[ R^2 = 0.574 \]
About the Graphs

For the graphs just viewed, crater diameter was on the y-axis and ejecta radius on the x-axis. While determining possible correlations, different graphing methods were used. First the trendline was linear, but this was found to be exceedingly inaccurate, so the graphs were done logarithmically. Also, graphs were made with crater diameter on the x-axis and ejecta radius on the y-axis (the opposite of those described before). These correlations were found to be less significant than when the axes were switched.
Conclusion

When the data points were separated by material and graphed, logarithmically, the coefficients were compared. They were as follows:

\[ y = 10.80 \ln(x) + 9.765 \text{ (Highland)} \]
\[ y = 20.63 \ln(x) + 19.42 \text{ (Mare)} \]
\[ y = 13.88 \ln(x) + 12.26 \text{ (Combination)} \]

A larger coefficient means that the ejecta radius was not as great (*), therefore, one could say that mare has the smallest amount of ejecta, highland has the largest amount, and combination materials resulting from previous ejecta blankets fall somewhere in between.

Thus, the aforementioned hypothesis has been confirmed. Highland creates the most ejecta, mare the least, and combination in between.

*This is because a larger number divided by a small number (a large crater diameter divided by a small ejecta radius) is larger than a number divided by another number closer in value to the first. A larger value will result from shorter ejecta radius, and thus, the aforementioned conclusions can be made.

For ease of explanation, say that the crater diameter is 20 km and the ejecta radius is 10 km. This will produce a coefficient of 2. (This represents a crater on highland). Say that another crater, also 20 km, has an ejecta radius of 5 km. The coefficient will then be 4. (This represents mare). Note how a larger coefficient results from a shorter ejecta radius.
Sources of Error

Small sample size (172 craters)

LROC ACT REACT measuring technique

Ignored discontinuous ejecta

Varying viewpoints during data collection
Advice for Further Research

Calculate crater depth and determine possible correlations between depth, crater diameter, and ejecta radius

Expand sample size significantly

Include both continuous and discontinuous ejecta

Use more high-definition imaging with more specific measurements
A. Nahm, personal communication.


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