APPLICATION OF A NEW METHOD FOR EXPLORING THE COPERNICAN CRATERING RECORD.
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\textbf{Introduction:} Here we investigate the Copernican-era lunar impact flux using a new method for determining crater ages.

Customarily, geological maps and crater counting methods have been used to determine the ages of lunar terrains and individual features. Those methods, however, are (i) extremely time consuming, (ii) are limited by image quality, image availability, and the need to identify small craters over datable regions, and (iii) are subject to systematic errors derived from uncertainty in the crater production function and small number statistics. For these reasons, it would be useful to have another way to explore this challenging problem.

It has recently been shown that the rockiness of large craters’ ejecta, derived from the Lunar Reconnaissance Orbiter’s Diviner thermal radiometer data [2], provides an alternative method for estimating the ages of Copernican craters (younger than roughly one billion years old) [1]. Young surfaces have fresh, sharp rocks, while older terrains have lower rock abundances, with both impacts and thermal cracking producing rock demolition over time [3]. The rate that rocks are eliminated can then be quantified using the rock abundances found on or near lunar craters with known absolute ages. This method is not subject to the constraints of traditional crater counting methods using visible images. The results of [1] show that in essence, only craters younger than \~1 Ga have ejecta blankets with rock abundance values that are higher than the background regolith. This broadly corresponds to the Copernican era [4].

In this work, we counted all craters with visible rocky ejecta, recorded their sizes, and calculated the rock abundance of their ejecta. We first compared the size-frequency distribution of our rocky craters to those craters previously defined as Copernican on the basis of geologic mapping and crater rays [4, 5]. Next, we calculated ages for each of our craters using the regression in [1] in order to determine whether or not the impact rate on the Moon has remained constant over the past billion years. The number and sizes of craters on the lunar surface reflect the number and sizes of impactors that created those craters (i.e., the Earth-crossing object population), which in turn tell us how the main asteroid belt population, particularly the inner main belt population, has changed with time. Therefore, it is possible that Copernican-era impacts can possibly tell us about asteroid disruption events and fragment evolution in the asteroid belt.

\textbf{Methodology:} We investigate the size-frequency distributions and ejecta rock abundances of rocky craters five kilometers and larger, and compare the results to canonical relationships for Copernican craters. The Diviner Rock Abundance (RA) dataset expresses the rock abundance as the areal fraction of a given field of view occupied by rocks large enough to remain warm through the lunar night [2]. Such craters are very distinct in the RA dataset, as shown in Figure 1.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{rock_abundance_map_jackson_crater}
\caption{Rock Abundance Map of Jackson Crater (22.4° N, 163.1° W, \~17.4km diameter)}
\end{figure}

In contrast, older craters have ejecta blankets with RA values similar to the background regolith, as shown in Figure 2.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{rock_abundance_map_alphonsus_crater}
\caption{Rock Abundance Map of Alphonsus Crater (13.4° S, 2.8° W, \~120km diameter)}
\end{figure}
We identify about 620 craters larger than 5 km between 80° N and 80° S with rocky ejecta. Using the regression from [1], shown below, we calculate the crater ages by first finding the 95th percentile RA values.

\[ \text{RA}_{95:5} = 0.27 \times \text{(age[m.y.]})^{0.46} \]

**Analysis and Results:** The preliminary size-frequency distribution of our craters, together with those of Copernican craters identified by [4] and [5], is shown in Figure 3.

![Figure 3: Size-frequency distribution comparison: Copernican Craters shown in red[5], versus identified craters with distinct rock abundance in their ejecta, shown in blue, and the Neukum 2001 Production Function [6].](image)

It is evident from Figure 3 that our Copernican craters are broadly similar in population statistics to those identified by [4] and [5]. We are currently analyzing these size-frequency distributions in order to interpret discrepancies between the two. Furthermore, we are investigating the statistics of sub-populations of this dataset in a range of age bins as calculated using the regression of [1].

**Individual craters.** When comparing our results with those previously defined as Copernican [4, 5], some are in strong agreement. Giordano Bruno Crater is an example of such craters (Figure 4).

On the contrary, some specific craters do not show high rock abundance in their ejecta, and we therefore exclude them from our dataset. An example is the Coriolis Y Crater; note the low rock abundance in the ejecta blanket (Figure 5).

![Figure 4: Giordano Bruno Crater (35.9° N, 102.8° E, ~22 km diameter) shown in the Rock Abundance dataset (left), and LROC WAC Equatorial Mosaic (right)](image)

**Current Work:** As outlined above, we are currently analyzing sub-populations of Copernican craters with ages calculated using the regression of [1]. We will thereby identify any deviations from the Neukum production function [6], and eventually, relate these to events in the asteroid belt.