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What the age of the lunar rayed craters tells us about the cratering rate over the last 500 My?

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Abstract

Despite the crater chronology efforts, the impact rate in the solar system over the last 3 Gy is still not understood neither well constrained. The LROC images at 50 cm per pixel offer a unique opportunity to assess the relative age of the youngest impact craters on the Moon by quantifying the small size crater density that occur after their formation. We evaluate the crater size distribution inside 92 lunar rayed craters. They have a large range of age from 4.2 Gy to 0.5 My. From the analysis of the number of craters by age bin and size bin, we suggest that the lunar rayed craters are the complete record of the impact rate over the last 500 My. They have recorded the recent impact rate. Their age distribution presents a clear apparent increase of the impact rate with time that raises discussions about the impact rate over the last 500 My.

1. Introduction

From the link of lunar crater density analysis and the radiometric ages of the Apollo samples [1, 2, 3, 4, 5], the impact rate in the inner solar system has been estimated about constant over the last 3 Gy [1, 5]. However, this statement is not well constrained. We still do not know if the impact rate has been decreasing over the last 3 Gy as suggested by [6] or by [7] and/or if the impact rate has experimented spikes as suggested by the impact spherules in Apollo samples [7, 8] or by the collisional evolution models of the asteroids belt [9].

The rayed impact crater population on the Moon has been interpreted as the youngest impact craters on the surface of the Moon to have conserved their bright rays pattern. The Lunar Reconnaissance Orbiter Camera (LROC) onboard Lunar Reconnaissance Orbiter (LRO) provides high resolution images down to 50 cm per pixel. These images give us the remarkable opportunity to assess the small size crater density that superimposed the rayed craters since their formation. We systematically analyse the crater density postdating 92 rayed craters. It allows us for the first time to assess the relative age of the lunar rayed craters and suggests their absolute ages. These results raise discussion about the used method, the conservation of the rays and the impact rate over the last 500 My.

2. Method

We construct a Geographic Information System (GIS) to combine lunar data set at a wide range of spatial resolution. Our GIS includes: global data set released to public by the United States Geological Survey (USGS), as well as geo-processed LROC images: the wide angle LROC images (LROC WA) at around 60 m per pixel and the LROC narrow angle images (LROC NA) at 50 cm per pixels.

LROC NA data allow us to document the crater size frequency distribution (SFD) down to 4 m of diameter. We mapped all the craters down to 4 m present on the rayed impact crater floors. We exclude crater count on crater ejecta to avoid self secondaries impacts contamination and we restrict our crater counts on the floor of the impacts. However, we have to keep in mind that resurfacing processes may have occurred inside impact craters but we hypothesise that they occur only right after the impact formation. As we adopt the same method for all rayed craters, we are confident at least in relative age obtained. We plot our results in incremental representation of crater size vs crater density from [9] (Figure 1).

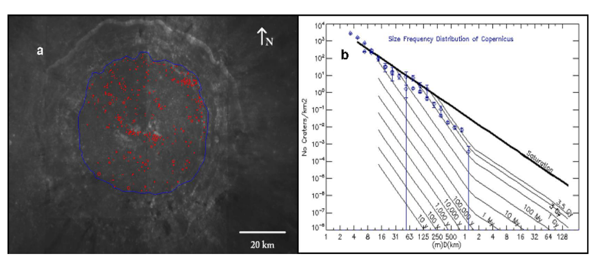

Figure 1: (a) Map of craters on the Copernicus inner floor; (b) SFD on the Copernicus melt pond.

The incremental diagram being more sensitive to slope variations of the distribution than cumulative plots [10].

3. Results

We analyse the crater size distributions over 92 lunar rayed craters that are a merge of rayed crater databases from [11] and [12]. The figure 2 presents the global map of the rayed craters studied here. The diameters of the studied rayed craters range from 15 to 127 km. The number and size of rayed craters related to the surface of the Moon reveal a crater size distribution with a lower slope than the theoretical isochrones. The densities of rayed craters larger than 88 km in diameter implies an age of 3 Gy while the rayed craters smaller than 22 km seem to have been conserved only since 800 My. These results are consistent with previous estimation of ray conservation that suggests all rayed craters on the Moon are preserved for the last 1 Gy [12].

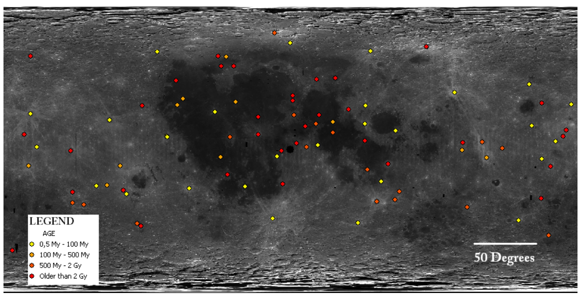

Figure 2: Map of the lunar rayed crater and their ages.

The deduced ages from small size crater density analysis range from 4.2 Gy to 0.5 My according to the Hartmann age model [9]. We analyse the results crater size bin by crater size bin. For instance, for the crater size bin between 16 and 22 km, we studied 30 rayed impact craters with ages ranging from 0.5 My and 3.2 Gy. The comparison of the cumulative distribution of these ages and the theoretical distribution of these crater sizes suggest that beyond 500 My, the rayed craters at this size have not been conserved. From larger sizes, we also confirm this statement and conclude that the rayed craters on the Moon are the complete record of the last 500 My impact rate.

We restrict our analysis to the rayed craters younger than 500 My. We analyse the cumulative number of rayed craters younger than 500 My. It reveals a clear increase of the number of rayed craters with recent time. It resembles to the apparent increase with time obtained on Martian landslides or on Martian cratering processes that where interpreted by [6] as an issue with the impact rate model used in the age model. [6] suggested that this apparent increases with time may be explained by the cratering rate decreasing by a factor of 3 over the last 3 Gy instead of being constant as it is hypothesised in the age model. We suggest here also that the apparent regular increase of the formation of rayed craters of the Moon may just be explained by an overall decrease of the cratering rate over the last 500 My.

4. Summary and Conclusions

We determine the ages of the lunar rayed craters. We confirm that the rayed craters are a complete record of the impact rate over the last 500 My. We also reveal an apparent increase of the impact rate using the age model assuming a constant crater rate over this period. This may suggest an overall decrease of the impact rate over the last 500 My.

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