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Statistical analysis of the magnetization signatures of lunar impact basins

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Abstract

Studying the magnetic signatures of lunar impact basins allows us to reconstitute the global magnetic field at the time of their formation and further constrain the period of activity of the core dynamo, which is currently believed to have been active before 3 Ga [1]. While there have been qualitative studies of the distribution of these magnetic signatures as a function of the basin age [2, 3], they do not incorporate new data from the SELENE and GRAIL missions, nor do they perform a rigorous statistical analysis. Here, we quantify the magnetic signatures of the largest lunar impact basins using this new data as well as robust statistical bounds.

1. Data

This study uses digital elevation maps created with data from LOLA to identify the basins as well as lunar magnetic field strength maps produced by [4], at a resolution of 2 pixels per degree. From these, we produce equal-area grids with constant latitude and variable longitude spacing to allow for accurate statistical analysis. We study all the lunar impact basins with a radius greater than 200 km (74 in total).

2. Method

As magnetic anomalies associated with basins tend to have radial symmetry, we produce radial profiles for each basin by binning the data according to distance from the basin center. Data within 1.5 basin radii is used to produce the profiles. We define the following areas within each profile, normalized over the basin radius R: within the peak ring ($0 - 0.5R$), within the main ring ($0 - 1R$) and outside the main ring ($1 - 1.5R$).

Using the mean magnetic field strength $< |B| >$ of these areas we define a statistic M representing the strength of the basin's magnetic anomaly, defined in one of two ways (the distinction being made visually):

1. If the magnetic anomaly appears to be confined to the peak ring, then:

$$M = \frac{< |B| >_{0-0.5R}}{< |B| >_{1-1.5R}} \tag{1}$$

2. If the anomaly extends over the entire basin, then:

$$M = \frac{< |B| >_{0-1R}}{< |B| >_{1-1.5R}} \tag{2}$$

We calculate the value of M for all basins, and classify the results according to the sign and/or presence of a magnetic signature. The statistical bounds are established via Monte Carlo modeling as described below.

2.1. Synthetic maps

To establish a base distribution with which the observed results are to be compared, we generate a set of synthetic maps. To do this, we work with the spherical harmonic expansion of the magnetic field strength map: assuming a Gaussian distribution, we calculate the power spectrum of the original map, which we use to generate a map with the same statistical properties as the observed data. This process is repeated 10000 times, and M is calculated for each basin's location in the synthetic maps, which gives us a base statistical dispersion and thus the cutoff threshold for defining a statistical anomaly. We calculate the probability of obtaining the observed M value for each basin using the cumulative distribution function for the synthetic M values. For basins where $p < 0.05$ we have a magnetic anomaly: the basin is magnetized if $M > 1$, demagnetized otherwise.

3. Results and discussion

Figure 1 shows the M and p values for all the basins with a known stratigraphic age group (36 of the total 74) as defined by [5]: from 1 (youngest) to 15 (oldest). Figure 2 shows the distribution of basin magnetic signatures in the three major lunar geological periods (known for 38 basins): Imbrian (corresponding to age groups 1-3), Nectarian (4-6) and pre-Nectarian (7-15). We can see that the magnetic signature of a basin strongly depends on its age: early pre-Nectarian basins are chiefly neutral (with some positive and negative signatures), while nearly 40% of Nectarian basins are strongly magnetized and all Imbrian basins are demagnetized. This is partially coherent with earlier publications [1, 2]: the early Nectarian magnetization peak is consistent with the theorized early activity of the core dynamo. The strong demagnetization of Imbrian basins, however, is at odds with the Apollo sample paleo-intensity measurements. Our results are susceptible to bias from the following sources:

- The signatures of larger and older basins have significant overlap with those of smaller craters;
- As only large basins were studied, the sample size is quite small especially where Imbrian basins are concerned.

We expect to continue this study by extending the dataset to smaller impact craters to correct some of the above biases and produce a more precise analysis. We will also attempt to correlate the basin statistics with the corresponding magnetization causes.

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References

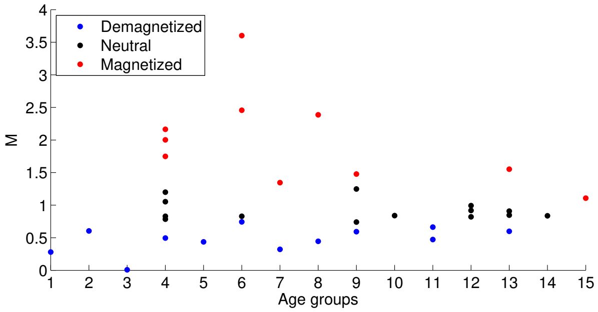
[1] Weiss, B. P., Tikoo, S. M.: The lunar dynamo. Science 346 (6214), 1246753, 2014.

[2] Halekas, J. S., Lin, R. P., Mitchell, D. L.: Magnetic fields of lunar multi-ring impact basins. Meteoritics & Planetary Science 38 (4), 565–578, 2003.

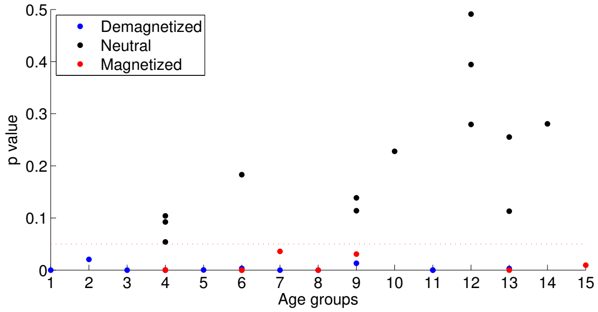
[3] Halekas, J. S., Mitchell, D. L., Lin, R. P., Hood, L. L., Acuña, M. H., Binder, A. B.: Demagnetization signatures of lunar impact craters. Geophysical Research Letters 29 (13), 2002.

[4] Tsunakawa, H., Takahashi, F., Shimizu, H., Shibuya, H., Matsushima, M.: Surface vector mapping of magnetic anomalies over the Moon using Kaguya and Lunar Prospector observations. Journal of Geophysical Research: Planets 120 (6), 1160–1185, 2015.

[5] Wilhelms, D. E., John, F., Trask, N. J.: The geologic history of the Moon. Technical report, 1987.



(a) M value as a function of age group.



(b) p value as a function of age group.

Figure 1: Basin statistics as a function of age group, with magnetization thresholds calculated from synthetic data.

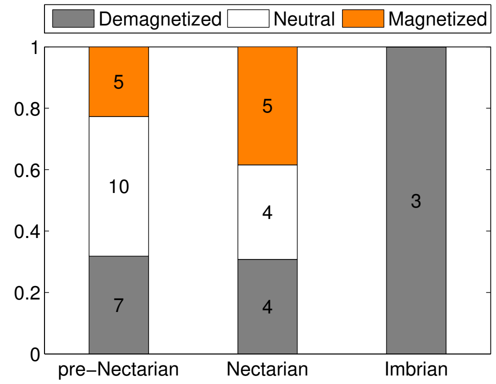


Figure 2: Distribution of magnetic field signatures in the major lunar geological periods. The number in each box denotes the total number of basins of that type and age.