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Central Magnetic Anomalies of Nectarian-Aged Lunar Basins: Probable Evidence for an Early Core Dynamo

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Detailed studies of orbital magnetometer (MAG) data to evaluate the existence and history of a former core dynamo have only recently become possible. A major complication has been that, at the Moon, impact processes have played an important role both in producing crustal magnetic sources and in generating transient magnetic fields. In particular, the largest concentrations of strong crustal fields occur antipodal (diametrically opposite) to the four youngest large basins [1,2]. Current model simulations suggest that these antipodal magnetization enhancements can be explained with or without a pre-existing core dynamo field, i.e., by impact shock effects (SRM) in the presence of transient fields generated during the impact [3]. The strongest lunar anomalies have therefore demonstrated an important role for impact shock in producing lunar crustal magnetization [4] but have not clearly constrained the existence of a dynamo.

In this paper, we report more detailed mapping of weaker magnetic anomalies within a series of Nectarian-aged lunar basins using Lunar Prospector (LP) vector magnetometer (MAG) data. In addition, iterative forward modeling of relatively strong anomalies within the Crisium basin is carried out to constrain the orientation and scale size of the magnetizing field. A previous study using LP electron reflectometer (ER) data found evidence for anomalies within basins of this age that could have sources in the form of impact melt. Such sources may have had a thermoremanent (TRM) origin, consistent with a steady magnetizing field [5]. Similar anomalies are found within many terrestrial impact craters [6]. However, the ER study could not confirm a TRM origin and it was not possible to evaluate the directional properties of the magnetization.

1. Data Selection and Mapping

All available LP MAG data were re-examined within the low-altitude phase of the LP mission (Jan. - July, 1999) with coverage over the following basins: Moscoviense, Mendel-Rydberg, Humboldtianum, Crisium, and Bailly. The mapping procedure follows that described in [2] and consists of a combination of (a) careful orbit selection and editing of individual orbits to minimize short-wavelength external fields; and (b) quadratic detrending to minimize longer-wavelength external fields within the edited orbit segments. Regional maps are constructed on the slowly varying surface defined by successive orbit passes during a given lunation. Repetition of anomaly structures on adjacent orbits allows a direct empirical test of whether a given apparent anomaly is of crustal or external origin.

2. Results

The existence of central anomalies is confirmed within the Crisium, Moscoviense, Mendel-Rydberg, and Humboldtianum basins. No detectable central anomaly is present within Bailly at an altitude of ∼35 km.

The Moscoviense, Mendel-Rydberg, and Humtoldtianum anomalies consist of single maxima in the field magnitude with scale sizes of ∼5° (150 km) and with peak intensities located within a few degrees of the basin centers. The Moscoviense anomaly has a peak amplitude of ∼2.8 nanoTeslas (nT) at an altitude of ∼29 km; the Humboldtianum anomaly has a peak amplitude of ∼2.3 nT at an altitude of ∼31 km; the Mendel-Rydberg anomaly has an amplitude of ∼4.0 nT at an altitude of ∼34 km. Since these anomalies maximize near the basin centers, their sources could be either SRM at a large depth or TRM of impact melt at a shallow depth. No firm constraint on the nature of the magnetizing field is implied.

However, as shown in Figure 1, the Crisium anomalies are not located at the basin center but consist of two elongated maxima that are distributed in a semicircular arc about the basin center. It is unlikely that the sources consist of ejecta from a later basin-forming impact that happened to be covered by mare fill because (a) both maxima occur within the inner topographic rim of the basin; and (b) there are no anomalies of comparable magnitude within 15° of the basin. Moreover, the semi-circular pattern of the anomalies suggests a genetic relationship to the basin. A possible interpretation is that the sources consist of impact melt concentrated in a trough around the central uplift.

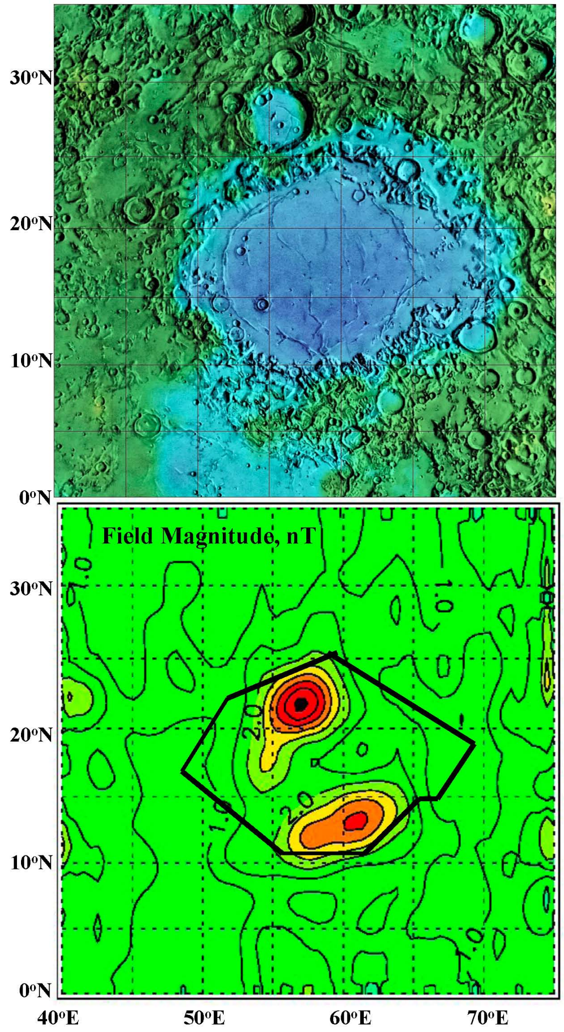

Figure 1: Top: Clementine LIDAR shaded relief map of Crisium region. Bottom: Field magnitude in nT (C.I. = 0.5 nT) at altitudes ranging from ∼35 km near 0^oN. The dark lines outline several outer topographic ring structures.

The northernmost Crisium anomaly is relatively strong (4.7 nT at 37 km altitude), dominantly dipolar, and isolated from adjacent anomalies. It therefore has a high signal-to-noise ratio and is well suited for iterative forward modeling. Assuming a variety of source models (point dipole, vertical cylinder, etc.), a consistent direction of magnetization is obtained that is radially inward and tilted toward the north. A least squares fit to the available data yields a paleomagnetic pole position at 81° ± 19°N, 143° ± 31°E, i.e., not far from the present rotational pole. Assuming no significant true polar wander since the Crisium impact, this position is very consistent with that expected for a core dynamo magnetizing field.

Further iterative forward modeling demonstrates that the remaining Crisium anomalies can be approximately simulated assuming a multiple source model with a single magnetization direction equal to that inferred for the northernmost anomaly. This result is most consistent with a steady, large-scale magnetizing field. The inferred mean magnetization intensity within the strongest Crisium source is ∼1 A/m assuming a 1 km thickness for the source layer. Future low-altitude orbital and surface magnetometer measurements will more strongly constrain the depth and/or thicknesses of the sources.

References

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