SOURCES OF LUNAR MAGNETIC ANOMALIES AND THEIR BULK DIRECTIONS OF MAGNETIZATION, L.L. Hood, Lunar and Planetary Laboratory, The University of Arizona, Tucson, Az. 85721

Reported here are further studies of Apollo 15 and 16 subsatellite magnetometer data with relevance to the nature and origin of lunar crustal magnetization. Correlations of mapped anomalies (1) with surface geologic units continue to indicate that the most strongly magnetized materials may not be deep-seated in the crust as expected if their magnetization was acquired by slow cooling in the presence of a steady magnetic field. The least ambiguous correlations are found for relatively surficial units such as the Fra Mauro Formation and the Reiner Gamma swirls (2,3). A second example of a magnetic anomaly maximum detected with the subsatellite magnetometers over an area dominated by swirl markings is shown in Fig. 1. Although the radial field amplitude is less than 2 gammas (1 gamma = 10⁻⁵ G.) at 87 km above the surface, an approximate scaling for altitude differences indicates that the source dipole moment is comparable to or larger than that of other anomalies detected with both subsatellites including the Reiner Gamma anomaly and the Van de Graaff-Aitken anomalies. Fig. 2 is a sketch of the associated distribution of swirls (indicated in black) relative to nearby craters with longitude and latitude superposed as prepared from a Zond 8 photograph (supplied by Peter Schultz). This concentration of swirls is located within 5⁰ of the Crisium antipode raising to at least four the proposed number of young large impact basins that are nearly antipodal to concentrations of swirls and strong magnetic anomalies detected by both magnetometers and charged-particle instruments on board the Apollo subsatellites (4).

The Fra Mauro Formation is Imbrium basin ejecta. There is independent evidence that areas peripheral to other large impact basins are also magnetized (5). If the swirls are produced by either meteoroid or cometary impacts as has been suggested (6,7), then it remains possible that all observed anomalies are associated with impact-generated surface materials.

Fig. 1

Fig. 2
A quantitative method for distinguishing between local surface magnetizing fields such as may have been produced during impacts (8,9) and a large-scale or global magnetizing field is by estimating the bulk directions of magnetization of relatively strongly magnetized and isolated magnetic anomaly sources using the vector magnetometer data. In a previous study (10) that was limited primarily to the Van de Graaff-Aitken region on the south-central far side, it was found that (a) nearby sources are generally magnetized in very different directions; (b) the number of north-south oriented vectors is depleted relative to the number of east-west and radially oriented vectors; and (c) the inferred magnetization directions are otherwise nearly random. Assuming that these properties were repeated elsewhere on the moon, several interpretations were suggested. First, the negligible lunar magnetic dipole moment (11) was explained as due to the inferred lack of directional coherence for the magnetization rather than as a consequence of global crustal magnetization along dipolar field lines as earlier suggested (12). Second, the north-south depletion of the magnetization intensity was considered to represent an observational constraint that did not favor purely local surface origins of the magnetizing field. An exception was meteoritic or cometary impact processes that might tend to amplify the weak solar wind magnetic field which, on the average, is parallel to the lunar equatorial plane.

Since the time of that analysis, additional maps of the vector components of the crustal magnetic field have become available with low-altitude coverage exceeding that of older maps by a factor of about ten (1). Bulk directions of magnetization have been estimated for sources of the strongest and most isolated magnetic anomalies on these maps using the iterative forward modeling approach described earlier (3). Included are the Reiner Gamma anomaly, a number of anomalies apparently associated with exposed remnants of the Fra Mauro Formation, and the anomaly of Fig. 1. A total of twenty-five directions of magnetization excluding the Van de Graaff-Aitken region have thus far been estimated for sources that are widely distributed in longitude but that are confined latitudinally by the near-equatorial orbits of the Apollo subsatellites. The results again show that adjacent sources are, in general, magnetized in very different directions. This has already been documented for the important special case of the Fra Mauro anomalies (3). A further result is that the pole positions of a magnetizing dipole assumed to be centered in the moon which correspond to these twenty-five vectors are not clustered in any discernible manner. This finding contrasts with that of Runcorn (13) who found a significant clustering of pole positions corresponding to the bulk directions of magnetization inferred for the Van de Graaff-Aitken region.

In addition to the apparent absence of directional evidence for a global lunar magnetizing field, an additional constraint is imposed by the relatively small maximum size of the lunar metallic core radius as estimated from a variety of geophysical measurements. In particular, the most recent upper limit from magnetic sounding data is about 360 km (see accompanying abstract). To produce a magnetic field at the lunar surface with an amplitude of order 1 G as required by returned sample studies (14), the field at the surface of a 360 km core must exceed 100 G. For comparison, the corresponding field at the surface of the terrestrial core is about 5 G.
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Final evidence from orbital data for magnetic fields generated by impact processes would come in the form of a clear association of a mapped anomaly with a young (<< 3 b.y. old) surface geologic unit. Reiner Gamma is an obvious candidate but photogeologic considerations and the tendency for other swirls to be concentrated near the antipodes of large young impact basins require a cautious interpretation of these features (15).

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REFERENCES