THE LUNAR MAGNETIC FIELD ENVIRONMENT: INTERPRETATION OF NEW MAPS OF THE INTERNAL AND EXTERNAL FIELDS.

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Summary: Long, arcuate magnetic field features whose origin may lie deep within the moon's crust have been isolated from Lunar Prospector magnetic field observations from the South Polar-Aitkien (SPA) basin region. These features, possibly reflecting compositional variations or tectonic responses to the SPA impact, may have been magnetized in a primordial lunar field. The isolation of these features has been made possible by a new parameterization of the magnetic field, which allows solution for both external and internal magnetic fields in the near-lunar magnetic field environment.

Introduction: The mapping of magnetic fields has been a primary tool used for identifying resources, mapping geology and structure, and characterizing the local environment. Magnetometers accompanied man to the moon, on the lunar rovers, and measured fields of 6 to 300 nT [1], values not unlike, but generally smaller, than those on Earth produced by magnetic materials in the crust. Mapping the lunar magnetic field from orbit [2] has proven difficult for two reasons. First, magnetometers in lunar space are between 17 and a few hundred km above the source of the crustal field, and the decay of the field with distance means that the measured fields are typically less than 1 nT, and always less than 30 nT. Hence signal/noise ratios are typically about 1, and always less than 50. Second, the magnetometers are immersed in a space plasma that is either part of the Earth's magnetic tail, or more commonly, part of the solar wind. Spacecraft charging effects, and its passage through the lunar wake, induce further complications. This has meant that historically, the lunar magnetic field has been better resolved using an electron reflection approach [3], rather than with a direct measurement of the magnetic field.

As a first step towards developing a Comprehensive Model (CM) [4] of the lunar magnetic field environment, we report here a simple parameterization of the low-altitude observations, applied in a two-step, sequential process. We estimate first the external field, then the internal field parameters; a true CM would co-estimate all parameters. Results from this simple parameterization agree with independently derived external field predictions, and shed new light on the magnetic anomalies of the South Polar-Aitken basin region, previously interpreted to be of impact origin by virtue of their locations approximately antipodal to the Imbrium, Serenitatis, and Crisium basins [2].

Two-step parameterization and validation within the Earth's magnetotail: The external field was parameterized as a uniform field over each Lunar Prospector (1998-1999) satellite half-orbit. This external field was determined in a least-squares sense from the vector data. The external field directions and intensities were compared with the T96 [5] predictions in a situation where Lunar Prospector was in the Earth's magnetotail.

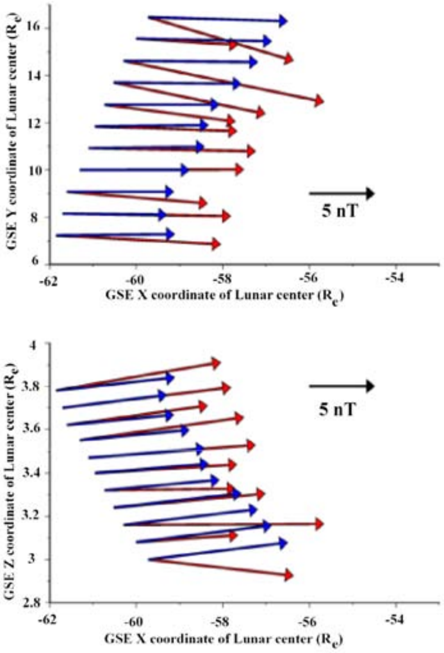

Figure 1. T96 predictions (blue) and Lunar Prospector estimates (red) in Earth's magnetotail on 30-31 March 1999. Cartesian selenographic coordinates.

Shown in Figure 1 are the magnetic field vectors predicted from Lunar Prospector data in red and the geodipole plus T96 model in blue for the period March 30-31, 1999, when the Moon and spacecraft were in the northern magnetotail lobe. The T96 model vectors in Figure 1 were calculated using concurrent observations of the interplanetary medium by the ACE solar wind monitor at the L1 point (220 R_e upstream from Earth), taking into account the time lag of about 1 hour, for the propagation time of the solar wind from ACE to

Earth. Generally, the Lunar Prospector magnitudes are larger than those of T96, but the directional agreement is very good, except for a few vectors at the end of the interval. At that time, the Moon and Lunar Prospector approached the boundary of the tail plasma sheet, where more variability can be expected.

Internal field validation: After removing the model of the external field from these field profiles, the residual vector field data from this region, the Descartes region [6], has been used in a least-squares sense to characterize the internal, crustal field via a grid of dipoles located at the surface of the moon. Other profiles covering this same region, collected when the moon was in a steady solar wind, are also utilized for this same purpose. The internal field solution is used to calculate the radial field at an altitude of 37 km for the three days used in the model, and for a combined solution (Figure 2). The subset solutions agree well with each other, and are centered on the Descartes anomaly [5], one of the largest lunar magnetic anomalies.

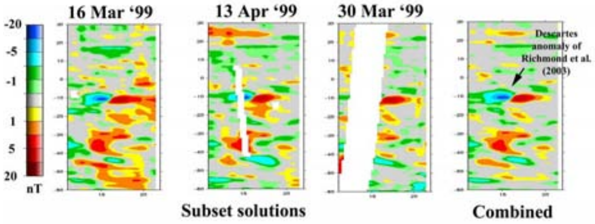

Figure 2. Magnetic models of the Descartes region of the Moon developed from quiet-time Lunar Prospector observations collected from steady solar wind (March 16, 1999 and April 13, 1999) and tail (March 30-31, 1999) conditions.

Internal fields of the South Polar-Aitken Basin: This same two-step approach was used with the low-altitude observations in the South Polar-Aitken (SPA) basin region. Initial data selection was done on a day-by-day basis, retaining only those days in which stacked profile plots of the internal field estimate showed significant pass-to-pass coherence. These were then separated into ascending (Figure 3) and descending (not shown, but similar and sparser) passes as stacked profile plots. Although these profiles are not altitude-normalized, arcuate (in map view) features of internal origin can clearly be seen extending for distances in excess of 1000 km near the northern boundary of the SPA. These features show no obvious correspondence to topography; and their great length suggests that they originate deep within the crust of the moon, and have acquired their remanence in a primordial lunar field. Their proximity to the SPA feature, especially its northern and western boundaries, suggests that they may be tectonic in origin, or represent compositional segregations in a cooling magma. Arcuate features can also be clearly seen running E-W through the center of SPA, between 45 and 60 degrees South latitude. These arcuate features are absent from the eastern and southern boundaries of SPA.

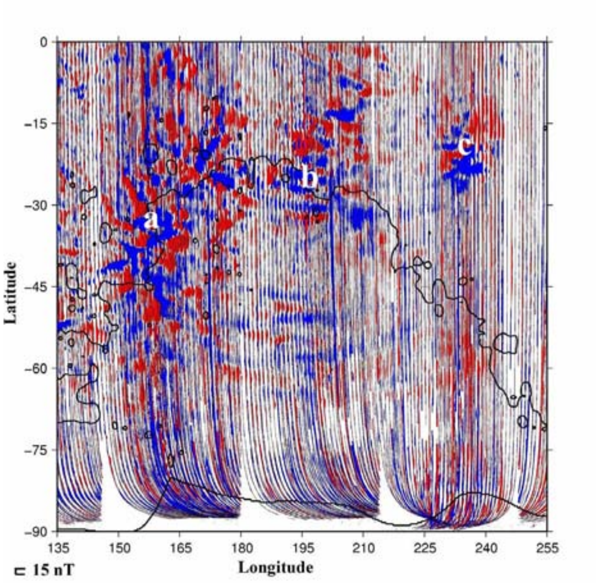

Figure 3. Stacked profile plot from ascending passes of the radial field over the South Polar-Aitken (SPA) basin region after removal of a model of the external field. Median altitude = 31 km. Red is positive radial field, blue is negative. 15 nT scale bar shown in lower left hand corner. The –2 km elevation contour is shown as the solid black line, outlining the SPA basin. Also shown are the approximate antipodes of Imbrium (a), Serenitatis (b), and Crisium (c).

References:

[1] Fuller M. and Cisowski S. M. (1987) *Geomagnetism, v.2,* 307–524. [2] Hood L. L. et al. (2001) *JGR., 106,* 27825-27839. [3] Halekas J.S. et al. (2001) *JGR,* 27841-27852. [4] Sabaka T. J., Olsen N. and Purucker M. (2004) *GJI*, 159 521-547[5] Tsyganenko N.A. (1996) *ESA SP-389,* 181-185. [6] Richmond N. C. et al. (2003), *GRL*, 30, 1395-1397.