NEW MAPPING AND MODELING OF MAGNETIC ANOMALIES IN LUNAR IMPACT BASINS: FIRST MAPPING RESULTS, L. L. Hood\textsuperscript{1} and J. S. Oliveira\textsuperscript{2,3}, \textsuperscript{1}Lunar and Planetary Laboratory, University of Arizona, 1629 E. University Blvd., Tucson, AZ 85721; lon@lpl.arizona.edu, \textsuperscript{2}ESA/ESTEC, SCI-S, Noordwijk, Netherlands, \textsuperscript{3}CITEUC, Geophysical & Astronomical Observatory, University of Coimbra, Coimbra, Portugal.

Introduction: Modeling of lunar magnetic anomalies to infer paleomagnetic pole positions and evaluate evidence for true polar wander has so far led to inconclusive results with proposed clustering of poles in at least three different locations \textsuperscript{[1,2,3,4]}. In principle, this could reflect either (a) deficiencies in the mapping/modeling or (b) a real diversity of magnetization directions. Deficiencies in the mapping may be caused by global modeling efforts (e.g., spherical harmonic approaches) that can effectively filter out some weak anomalies. For example, a distinct magnetic anomaly within the Imbrium basin has recently been mapped using a regional technique that is not present on global maps \textsuperscript{[5]} (see Figure 1 below). Here, we report initial efforts toward new regional mapping of other lunar basins that should provide an improved basis for either paleomagnetic pole determination or identification of a different magnetic dynamo morphology than expected from the centered dipole hypothesis.

Magnetic anomalies within impact basins are important because the sources of these anomalies were probably thermoremanently magnetized, requiring slow cooling in a steady, long-lived magnetizing field. This inference follows from numerical impact simulations, which show that the interiors and subsurfaces of large craters were heated to high temperatures and required long periods (~ $10^5$ years) to cool below the temperature at which magnetization can be retained. Likely source materials include impact melt containing metallic iron deposited by the impactor \textsuperscript{(6,7,8)}. In contrast, at least some magnetic anomaly sources in the lunar highlands could have acquired their magnetizations much more rapidly (e.g., via shock), and could therefore have been magnetized in short-lived magnetic fields of external origin, yielding erroneous pole positions.

Here, we describe initial efforts to apply the new regional mapping approach to 13 selected lunar basins.

Mapping Approach: Table 1 lists the selected lunar basins. The mapping method uses an equivalent source dipole technique and is a refined version of that used to produce the first detailed vector field maps of the interiors of the Imbrium and Schrödinger basins \textsuperscript{[5]}. A key difference of this mapping method as compared to alternate (e.g., spherical harmonic) approaches is data selection: Only the best measurements over a particular region (i.e., those obtained at the lowest altitudes with minimal external field contamination) are considered.

This requires a careful re-examination of all low-altitude (< 40 km) measurements from both the Lunar Prospector and Kaguya (KG) missions with coverage over the region in question. Editing to eliminate segments when external field variability was relatively large is done objectively by differencing adjacent orbit segments to minimize the crustal field contribution and discarding segments whose residuals have rms deviations greater than a chosen threshold (e.g., twice the rms deviation for all orbits over the region). This approach is valid only for adjacent segments separated by a distance comparable to or larger than the spacecraft altitude so that any real crustal fields will be approximately repeated on those segments. The orbit track separation for a low-altitude, lunar polar orbiting spacecraft is about 1 degree of longitude, which ranges from about 30 km at the equator to nearly zero near the poles.

For orbit segments when the spacecraft altitude is substantially less than the track separation (e.g., 15 km altitude at the equator), some of the differenced data can be due to real crustal fields. This could result in overestimation of the rms due to external field components, potentially leading to data being unnecessarily discarded. Therefore, for those segments (a small fraction of the total), only segments containing visually obvious external field spikes and high-frequency noise are eliminated.

In order to produce maps of the vector field components at a constant altitude from the measured radial field component along the selected passes of either LP or KG magnetometer data, a "classical" ESD technique (e.g., \textsuperscript{[9,10,11]}) is applied in which the sources are assumed to consist of an array of vertically oriented magnetic dipoles at some depth beneath the planetary surface. The amplitudes and orientations (vertically...
inward or outward) of the individual dipole moments are determined via a least squares fit of the model field to the spacecraft magnetometer measurements along the orbit tracks. Once a final set of dipole moments is determined, these can be used to estimate the three field components and field magnitude on a constant-altitude surface. The optimal depth of the array for a given spacing of the dipoles is determined by repeating the inversion procedure for a series of depths until a minimum rms deviation of the model radial field values from the observed radial field values is obtained.

![Figure 1](image_url)  

**Targeted Basins:** The selected basins are listed in Table 1 in approximate relative age order. After removing basins that could be overlain by magnetized ejecta from later basin-forming impacts, two Pre-Nectarian basins remain that contain likely central anomalies [12]: Birkhoff (59°N, 213°E; 330 km in diameter; LP data coverage) and Coulomb-Sarton (52°N, 237°E; 360 km; LP coverage). Relative ages are from Wilhelms [13] but more recent age evaluations (e.g., [14,15]) are also considered. Eight nominally Nectarian-aged basins have been identified as containing probable intrinsic anomalies [12,16]: Bailly (67°S, 292°E; 300 km in diameter; KG coverage); Hertzprung (2°N, 231°E; 570 km; KG data); Serenitatis (27°N, 19°E; 740 km; may be pre-Nectarian; LP data); Crisium (18°N, 59°E, 635 km, LP data); Humboldtia-num (24°S, 320°E; 440 km; KG data); Mendel-Ryberg (50°S, 266°E; 630 km; KG data). In addition, at least one probably Nectarian-aged large crater, Leibnitz (38°S, 179°E; 245 km in diameter; KG data coverage) is known to contain an apparent central anomaly [3,17]. Finally, at least two lower Imbrian-aged basins contain internal anomalies [5]: Imbrium (35°N, 343°E; 1160 km in diameter; LP data) and Schrödinger (75°S, 133°E; 316 km; KG data).

**Results:** Currently, the two Imbrian-aged basins (Imbrium and Schrödinger) are mapped. Mapping of several other basins (e.g., Leibnitz) is in progress and results will be presented at the meeting. As an example, Figure 1 shows a map of the field magnitude in nT over the Imbrium basin at an altitude of 15 km estimated by the equivalent source dipole technique [5]. The map is superposed on a color-coded map of Clementine topography (Mercator projection). The lowest elevations are about 2 km below the mean lunar radius and the highest elevations are about 1 km above it. The anomaly in the south-central part of the basin is verified to be real by repetitions on adjacent orbit tracks. It is not shown on published global maps (e.g., [3,18]). Similar anomalies in other basins such as Leibnitz are found that are not shown on global maps. While relatively weak, these anomalies are important for accurate modeling to estimate directions of magnetization and paleomagnetic pole positions.

**Acknowledgment:** Supported under grant 80NSSC18K1602 from the NASA Lunar Data Analysis Program.

**References:**