THE FATE OF THE SOUTH POLE-AITKEN IMPACTOR AND THE ORIGIN OF LUNAR MAGNETIC ANOMALIES. M. A. Wieczorek[1], B. P. Weiss[2], and S. T. Stewart[3]; [1]Institut de Physique du Globe de Paris, France, [2]Massachusetts Institute of Technology, Cambridge, USA, [3]Harvard University, Cambridge, USA (wieczor@ipgp.fr).

Introduction. Mapping of the Moon's magnetic field from orbit during the Apollo and Lunar Prospector missions has shown that portions of the lunar crust are strongly magnetized. The origin of these anomalies is poorly known for several reasons. First and foremost, there is no clear correlation between lunar magnetism and geology. Second, most pristine crustal materials are not magnetic enough to account for the observed magnetic intensities. Third, the origin of the magnetizing field is unknown [1].

Paleomagnetic analyses have shown that the dominant ferromagnetic mineral in lunar materials is metallic iron. The most magnetic samples are the mafic impact melt breccias, which are believed to be derived from the largest impact basins that formed about 4 billion years ago. These impact melts contain up to 2 wt.% metallic iron, and the composition of this iron is consistent with having an asteroidal origin [2].

In order to create a magnetic anomaly, both metallic iron and a magnetizing field are required. Here we address the origin of the metallic iron and how it is distributed across the lunar surface. We find that the lunar magnetic anomalies are largely consistent with being derived from metal-rich ejecta derived from the projectile that formed the largest recognizable impact basin in the Solar System: the South Pole-Aitken basin.

The distribution of lunar magnetic anomalies. One possible correlation between lunar geology and magnetic anomalies is that some of the largest anomalies are located approximately antipodal to four of the youngest large impact basins. A possible mechanism for the formation of these anomalies involves the amplification of ambient magnetic fields by an impact-generated plasma cloud, the deposition of iron-rich ejecta antipodal to the basin, and shock remanent magnetization resulting from either ejecta deposition or the antipodal focusing of seismic waves [3]. Many details with this scenario remain to be worked out, including the strength and duration of the amplified fields, and the quantity of magnetic carriers that are deposited at the basin antipode.

As an alternative correlation, we note that the largest concentrations of magnetic anomalies on the Moon are located in the northern portion of the South Pole-Aitken basin (Figure 1). Geophysical and geochemical data indicate that the South Pole-Aitken basin is decidedly non-circular, with an elongation axis in roughly the north-south direction [4], and this structure has been interpreted as the result of an oblique impact, with an impact direction from the south to north. The most prominent lunar magnetic anomalies are located entirely in the northern half of this elliptical structure, and the strongest of these are located close to the basin rim. This observation is suggestive of the deposition of iron-rich projectile materials in the down-range direction of an oblique South Pole-Aitken basin impact.

The distribution of SPA projectile materials. The amount of metallic iron in the projectile that formed the South Pole-Aitken basin is potentially enormous. If this projectile were 200 km in diameter and had a composition similar to that of the bulk Earth or enstatite chondrites (~30 wt.% metallic iron), the thickness of an equivalent global layer of pure iron would be about 14 meters.

To test if the amount of projectile materials that remain on the Moon from such an impact is sufficient to account for observed distribution and intensity of lunar magnetic anomalies, we are performing a series of numerical oblique impact simulations using the code

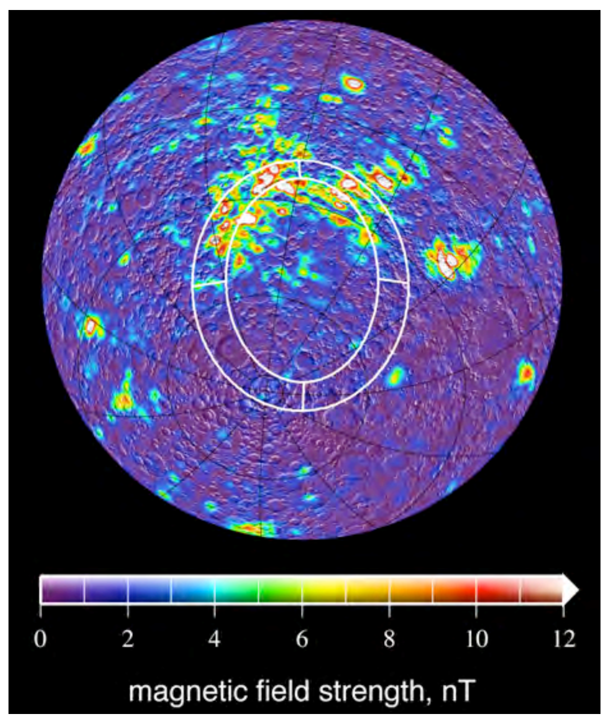

Figure 1. Magnetic field intensity of the Moon at 30 km altitude, centered over the South Pole-Aitken impact basin and displayed in a Lambert azimuthal equal-area projection. Magnetic field data are from the Lunar Prospector based sequential estimation model of [5]. Inner and outer ellipses (with major axes of 1940 and 2400 km, respectively) denote the floor and structural rim of the South Pole-Aitken basin [4]. The largest concentrations of magnetic anomalies are located on the northern rim of this basin.

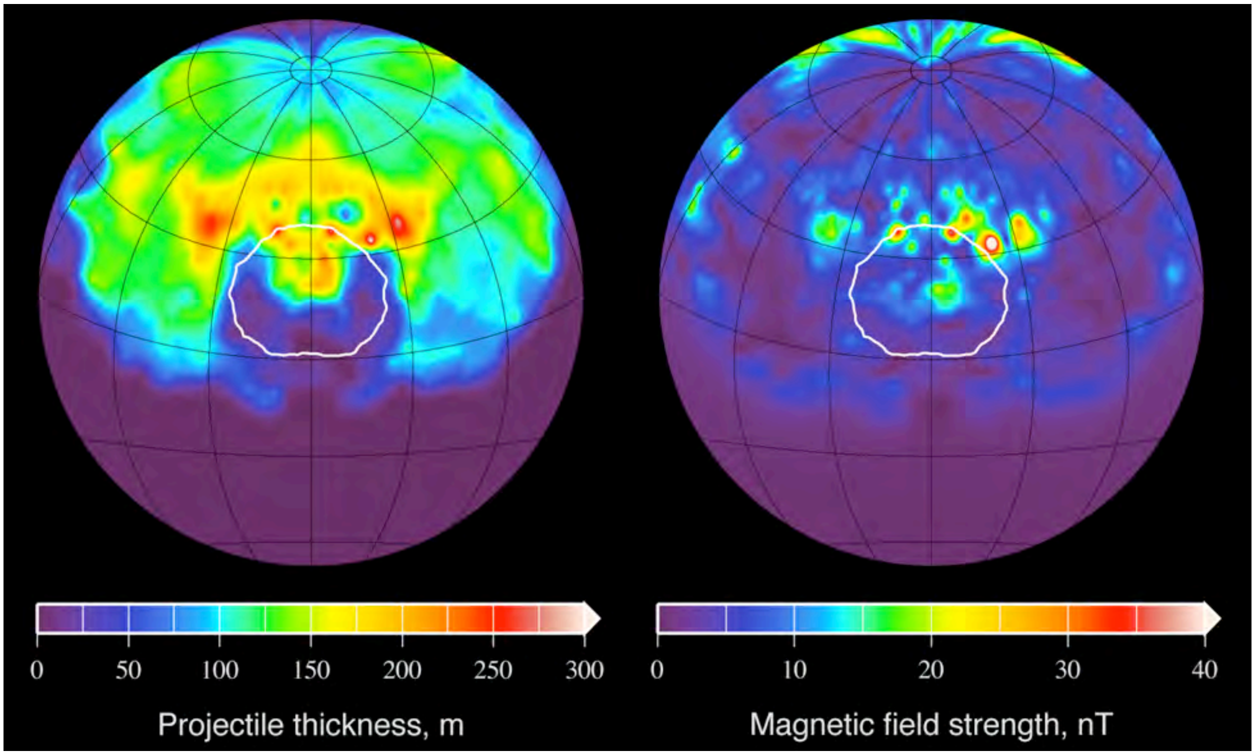

Figure 2. (left) Integrated thickness of projectile materials following a South Pole-Aitken basin forming oblique impact event. For this simulation, the projectile direction was from south to north, the impact angle was 45°, the projectile diameter was 125 km, and the impact velocity was 15 km s^{-1}. (right) Predicted magnetic field strength at 30 km altitude assuming that the projectile materials were magnetized by a dipolar magnetic field generated by a core dynamo. For this simulation, the projectile materials were assumed to have the magnetic properties of enstatite chondrites, and the dipolar magnetic field strength at the Apollo landing sites was assumed to be 100 μT. The white ellipse outlines that region where most of the crust is excavated, which is analogous to the inner ellipse in Figure 1.

CTH. These simulations track the locations of projectile materials during the impact event, and for our initial simulations, we assume that the projectile is undifferentiated.

Figure 2 shows the results of one oblique impact simulation, where the projectile direction is from the south to north and the impact angle is 45°. The left panel shows that the projectile materials are concentrated in the downrange direction and that the greatest quantity of these materials is located just exterior to the region of thinned crust (denoted by the white line). For this simulation, the integrated projectile thicknesses reach up to 300 meters on the basin rim.

If the Moon possessed a dipolar magnetic field at the time the South Pole-Aitken basin formed, the projectile materials would have obtained a thermoremanent magnetization as they cooled through the Curie temperature of metallic iron. Using the magnetic properties of enstatite chondrites, and a dipole magnetic field strength of 100 μT at the Apollo landing sites, the right panel of Figure 2 shows the predicted magnetic field strength at 30 km altitude. Comparison with Figure 1 shows that not only is the distribution of magnetic anomalies from this simulation similar to the observations, but that the magnetic intensities are also comparable. Our simulation predicts the presence of magnetic anomalies far from the impact basin, and we suspect that these isolated enrichments of metallic iron could account for many of the nearside magnetic anomalies, such as Reiner-γ and Descartes.

Conclusions. The most prominent concentrations of lunar magnetic anomalies are located on the northern rim of the South Pole-Aitken impact basin. The distribution and intensity of these anomalies are consistent with magnetized iron-rich ejecta from an oblique South Pole-Aitken forming impact even, where the metallic iron is derived from the projectile. Additional impact simulations are being undertaken to determine how the amount of retained projectile materials depends upon factors such as impact angle and impact velocity, and whether the projectile was homogeneous in composition or differentiated.

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