Magnetic signature of the lunar South Pole-Aitken basin: Character, origin, and age

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[1] A new magnetic map of the Moon, based on Lunar Prospector magnetometer observations, sheds light on the origin of the South Pole-Aitken basin (SPA), the largest and oldest of the recognized lunar basins. A set of WNW-trending linear to arcuate magnetic features, evident in both the radial and scalar observations, covers much of a 1000 km wide region centered on the NW portion of SPA. The source bodies are not at the surface because the magnetic features show no first-order correspondence to any surface topographic or structural feature. Patchy mare basalts of possible late Imbrian-age are emplaced within SPA and are inferred to have been emplaced through dikes, directly from mantle sources. We infer that the magnetic features represent dike swarms that served as feeders for these mare basalts, as evident from the location of the Thomson/Mare Ingenii, Van de Graaff, and Leeuwenhoek mare basalts on the two largest magnetic features in the region. Modeling suggests that the dike zone is between 25 and 50 km wide at the surface, and dike magnetization contrasts are in the range of 0.2 A/m. We theorize that the basaltic dikes were emplaced in the lunar crust when a long-lived dynamo was active. Based on pressure, temperature, and stress conditions prevalent in the lunar crust, dikes are expected to be a dominantly subsurface phenomenon, consistent with the observations reported here.

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1. Introduction

[2] The mapping of magnetic fields has proven to be a useful tool for providing a third dimension to surface observations of the Earth's composition and geologic structure. A suite of mathematical techniques has been developed [*Blakely*, 1995] to facilitate the interpretation of these fields. Application of these techniques to the Moon may permit new insights into the geologic processes acting there.

[3] The magnetic anomalies of the South Pole-Aitken (SPA) basin region have previously been interpreted to be related to impact shock effects in a transient magnetic field by virtue of their locations approximately antipodal to the Imbrium, Serenitatis, and Crisium basins [*Hood et al.*, 2001; *Hood and Artemieva*, 2008].

[4] Magnetic anomalies on the Earth are often the consequence of igneous activity, with the magnetic signal locked in as the magnetic minerals cool below their Curie temperature. An abundance of dikes should exist in the crust of the Moon [*Head and Wilson*, 1992], just as on the Earth [*Wilson and Head*, 1981], although we expect that most of these dikes were probably emplaced early in the history of the Moon before compressive stress reached present levels, and most of them reside in the lower crust. On the Moon, eruptive volcanic phases probably originate from dikes directly from mantle sources, without shallow crustal magma reservoirs. Theoretical analyses of the ascent and eruption of magma, combined with observations of shallow dike intrusions and related deformation on the Moon [*Wilson and Head*, 1981; *Head and Wilson*, 1992] suggest that mare basalts were emplaced in blade-like dikes with dimensions of several tens to many hundreds of kilometers length and tens to 250 m width. Dikes tend to approach the surface from depth with a broad convex-upward shape, and magma eruption usually takes place at the point where the convex portion of the dike first intersects the surface. Radiating, arcuate, and linear mafic dike swarms are common in the Earth [*Ernst et al.*, 1996] and these dikes often have recognizable magnetic signatures [*Reeves*, 2000]. One example of a lunar dike (Rima Sirsalis) with a purported magnetic signature has been identified [*Srnka et al.*, 1979; *Head and Wilson*, 1993; *Hood et al.*, 2001]. The recognition of magnetized dikes would imply the existence of a magnetic epoch in the Moon's history, possibly associated with a lunar dynamo. The paucity of examples identified to date may

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