ANTIPODAL SEISMIC EFFECTS OF LUNAR BASIN-FORMING IMPACTS: ENHANCED MAGNETIC AND GEOCHEMICAL ANOMALIES PERIPHERAL TO THE SOUTH POLE-AITKEN BASIN.

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Introduction: The largest concentrations of strong lunar crustal magnetization occur in regions antipodal to the youngest large basins including Imbrium, Orientale, Serenitatis, and Crisium (Figure 1) [1,2]. Recent numerical simulations support a model in which seismic waves converging in the antipodal region produced these magnetization concentrations through shock remanent magnetization (SRM) of pre-existing crustal materials in the presence of a magnetic field amplified by the converging impact vapor cloud [3,4]. The antipodes of the Imbrium and Serenitatis basins are located near the northern periphery of the South Pole-Aitken (SPA) basin where both magnetic and geochemical (e.g., Th) anomalies are found [5,6]. Recent improved mapping of low-altitude Lunar Prospector (LP) magnetometer (MAG) data shows that, in addition to being concentrated antipodal to these basins, magnetic anomalies tend to be distributed along the northern and western periphery of the SPA basin (Figure 2) [7]. Here, we discuss possible explanations for this result in the context of the seismic shock model and possible implications for the origins of the associated geochemical anomalies.

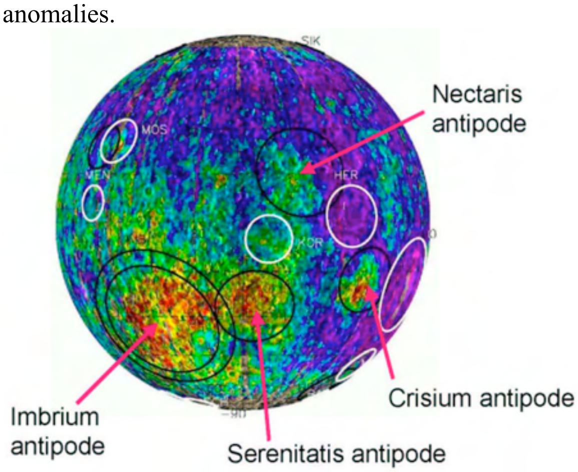

Figure 1

Crustal Field Mapping: Figure 1 is a map of the distribution of lunar crustal fields produced using the electron reflection method [8,9]. Dark circles are centered on the antipodes of the indicated basins. Figure 2 is a map of the magnetic field magnitude (C.I.: 2 nT) constructed from edited and detrended low-altitude LP MAG orbit segments obtained during the April 26-30, 1999 period. The effective altitude of the map varies from ~28 km at the southwest edge to ~32 km at the northern and eastern edges. Indicated on the map are the locations of the geometric antipodes of the Imbrium and Serenitatis basins. Also sketched on the map is the -2 km elevation contour estimated from Clementine topography, indicating the approximate periphery of the SPA basin. In both figures, a tendency for the magnetic anomalies to be distributed along the northern and western edges of SPA is evident (see also ref. 7 for more evidence for this tendency).

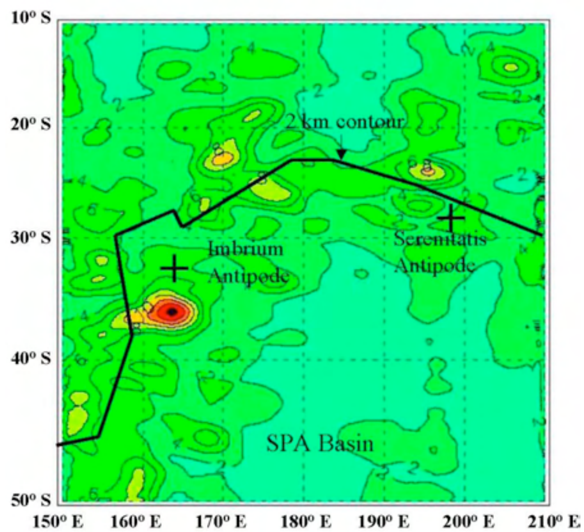

Figure 2

Relation of Magnetic Anomalies to SPA: Any interpretation of the observed anomalies should be consistent with constraints imposed by returned sample data and by surface and orbital data elsewhere on the Moon. Both sample analyses and surface magnetometer measurements point to impact-produced materials (breccias, ejecta) as being the most strongly magnetized materials on the Moon [10,11]. Several quantitative analyses of orbital data on the geologically less complex near side have demonstrated correlations of orbital anomalies with surface exposures of basin ejecta materials including the Cayley and Descartes Formations [12,13].

Any interpretation should also be consistent with the observed concentrations of anomalies in young basin antipode zones. Recent model simulations have indicated that converging seismic waves are the most probable cause of both the antipodal magnetization concentrations and unusual terrain visible near the Imbrium and Orientale antipodes [3]. The seismic waves produce antipodal shock stresses that have been calculated to be near the range of 5-20 GPa where stable SRM of shocked lunar soils has been found experimentally to occur [14]. The simulations further indicate that antipodal basin ejecta deposits are too thin (< 30 m) to be the sources of the observed magnetic anomalies. Pre-existing ejecta, re-shocked by converging seismic waves, are the most probable sources. These waves also produce vertical displacements sufficient to explain the observed unusual terrain, as originally proposed by Schultz and Gault [15] (see also ref. 16).

Seismic stresses generated by basin-scale impacts were not limited to basin antipode zones. Larger stresses and surface displacements occurred where seismic waves encountered relatively unconsolidated crustal material. This factor may explain why similar unusual terrain and magnetic anomalies are found in other areas such as near Rima Sirsalis and the Apollo 16 landing site [15,4]. As first pointed out in ref. 15, regions adjacent to old impact basins are characterized by unusually thick ejecta deposits, which are especially susceptible to seismic amplifications. Although SPA is a very degraded basin, identifiable mainly by its large topographic signature, the region peripheral to this basin should still have relatively thick ejecta deposits, perhaps extending several km in depth. In addition to being susceptible to seismic shock, this ejecta would carry more Fe remanence carriers as needed to produce strong magnetization. It is therefore suggested that the tendency for magnetic anomalies to occur peripheral to SPA as well as antipodal to Imbrium and Serenitatis is because of increased efficiency of seismic shock and SRM in the SPA ejecta mantle.

Relation to Geochemical Anomalies: As discussed, for example, in ref. 5, the SPA basin contains higher-than-average Th abundances, which consist of two main components. The first low-abundance, diffuse component correlates negatively with elevation and is interpreted as consistent with a higher abundance of Th with increasing depth in the crust. The second, higher-abundance Th component is concentrated near the northwest boundary of the basin with two maxima centered near 28S, 174E and 40S, 164E. This component does not correlate with topography and its origin is unresolved. The two maxima may be caused, in part, by excavation of near-surface KREEP-rich material by nearby Eratosthenian-aged craters [17]. An additional constraint on the origin of this Th component is that it correlates somewhat with the distribution of unusual grooved and mounded terrain [17, 18]. It had earlier been suggested that antipodal deposition of Imbrium basin ejecta could explain both this terrain and the Th anomalies [18 and refs therein]. However, recent numerical simulations indicate that the terrain was seismically produced [3]. The same seismic waves may have produced deep-seated fractures, enhancing the impacted zone beneath SPA and providing conduits for magma ascent in the crust [15]. This may have effectively increased the concentration of KREEP in the upper crust in the northwest part of SPA nearest to the Imbrium antipode. It has been suggested that the anomalous Th could be associated with hidden mare (cryptomare) deposits in the region [19]. If so, then we suggest that these deposits must be Th-enriched relative to other mare deposits in and near SPA, possibly because of their origination at greater depths in the Imbrium antipode zone.

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