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Records of Lunar Magnetism and Implications for a Lunar Dynamo

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The strong surface magnetic fields (up to 100 μT) inferred from paleointensity measurements on Apollo samples have been used to propose the existence of a lunar dynamo from 3.9-3.6 Ga. Apollo-era surface magnetometry and sub-satellite magnetic measurements provided evidence for crustal magnetization, but the geographical restrictions of these data sets limited assessment of the proposed magnetic field era. New magnetic field models based on Lunar Prospector (LP) magnetometer (MAG) and Electron Reflectometer (ER) data now allow examination of magnetic anomalies globally. These models are consistent with magnetic fields of crustal origin, with small spatial scale variations across the lunar surface, and with the strongest anomalies occurring antipodal to the Orientale, Crisium, Serenitatis, and Imbrium basins. However, particularly puzzling for the dynamo hypothesis are the absence of a correlation between magnetic anomalies and the nearside mare basalts - most of which are thought to have formed during the 3.6-3.9 Ga interval - and the lack of magnetic anomalies within the Imbrian-aged Orientale basin. Instead, the anomalies mostly occur over (older) highlands terrain.

We have conducted a re-evaluation of published paleointensity data and new measurements of Apollo samples and conclude that the samples do not record a primary thermoremanent magnetization acquired by cooling in the presence of an ambient field. We present our results and show that they suggest a complex, multi-component magnetization history, possibly involving shock remanent magnetization. Specifically, these results no longer demand a 3.9-3.6 Ga dynamo field. From a thermal evolution

standpoint, a 3.9-3.6 Ga dynamo field is plausible, but difficult to achieve, because it places stringent constraints on core energetics that require either (a) sufficient heat flow through the core-mantle boundary and/or (b) solidification of an inner core (and associated concentration of light elements in the outer core) during this time period. An alternative hypothesis, not previously considered, but motivated by the high initial core heat flow common to many thermal evolution models, is that the Moon may have had a dynamo during its earliest cooling, resulting in magnetization of the primordial crust during solidification of the lunar magma ocean. In this scenario, the present crustal magnetic field would reflect (severe) subsequent modification primarily by impacts and mare volcanism. We examine the viability of this, and other magnetic field chronologies, including the possibility of no dynamo field, in light of the constraints from sample, surface and satellite measurements.