Evidence for a Long-lived Lunar Dynamo Questioned: Robust Definition of the Magnetic History of the Moon

John A. Tarduno[1,2] and Rory D. Cottrell[1]

[1]Department of Earth & Environmental Sciences, University of Rochester, Rochester, NY 14627 (john.tarduno@rochester.edu)
[2]Department of Physics and Astronomy, University of Rochester, Rochester, NY 14627

The timing and strength of lunar magnetic fields [1-2] present extreme challenges to dynamo models, and consequently imply profound constraints on the rotational history and thermal evolution of the Moon. These issues have been heightened by the interpretation of magnetization (~5 microTesla) from a regolith breccia for a late lunar dynamo until at least 2.5 Ga and possible as young as ~1 Ga [3]. But both the satellite and sample records are highly complex; multiple processes can result in the acquisition and later modification of magnetization. Establishing whether these complexities reflect variations in field strength (and even existence) in time, or simply difficulties inherent in studying the magnetic field is critical to understanding lunar evolution. We have recently sought to place bounds on the lunar magnetizations through the study of a young Apollo lunar sample 64455 [4-6]. This basaltic impact melt is thought to have maintained its orientation over the last ~2 million years since it landed on the lunar surface. The sample is covered by a thick black glass, and has been linked to the South Ray crater. We find that the 64455 glass contained spherical polycrystalline Fe-Ni-S inclusions ranging in size from ~5 to <1 microns in diameter. The small subdivisions of some inclusions should be stable magnetic recorders [7], whereas larger divisions are expected to have low stability typical of most lunar samples. Magnetic hysteresis profiles of unheated samples are "wasp-waisted", indicating a mixture of ultra-fine particles and larger particles, consistent with our scanning electron microscope observations. Total-TRM (thermal remanent magnetization) experiments, Thellier-Coe double heating, and REM' paleointensity experiments yield paleointensities ranging from 10 to almost 40 microTeslas [8-9]. Given the young age of 64455, it is unlikely that the magnetizations record a lunar dynamo; instead these appear to be the first clear record of impact plasma related fields from lunar samples. Moreover, because the field intensities are similar to those reported from older samples, these new data raise the question about the reality of a past long-lived lunar dynamo.

Paleointensity values are very difficult on lunar samples, whereas directional analyses should be more straightforward. ***Therefore, we propose that emphasis should be placed on the recovery of oriented basalt samples of varying age from new lunar explorations. These data could provide direct and robust tests of the current contrasting interpretations of Apollo era data (impact vs. dynamo magnetizations), with profound implications for the evolution of the Moon's interior and surface.***

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