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Absence of a long-lived lunar paleomagnetosphere and opportunities for future exploration

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Understanding whether the Moon had a long-lived magnetic field is crucial for determining how the lunar interior and surface evolved, and in particular for assessing whether a paleomagnetosphere shielded the regolith. Magnetizations from some Apollo samples have been interpreted as records of a global lunar magnetic field between approximately 4.2 and 1.5 Ga that would have created shielding, but the inferred paleofields are too strong and continuous to be generated by the small lunar core. Moreover, vast areas of the lunar crust lack magnetic anomalies that should mark the past presence of a dynamo. New paleointensity data from an Apollo impact glass associated with a young 2 million-year-old crater records a strong Earth-like magnetization, providing evidence that impacts can impart intense signals to samples recovered from the Moon, and other planetary bodies (Tarduno, Cottrell, Lawrence et al., *Science Advances*, 2021). This observation provides motivation for future lunar collections to constrain impact size - magnetization scaling relationships. Moreover, new data from silicate crystals bearing magnetic inclusions from Apollo samples formed at 3.9, 3.6, 3.3, and 3.2, Ga are capable of recording strong core dynamo-like fields but do not, indicating the lack of a global magnetic field (Tarduno, Cottrell, Lawrence et al., *Science Advances*, 2021). Together, these new data indicate that the Moon did not have a long-lived core dynamo. As a result, the Moon was not sheltered by a sustained paleomagnetosphere, and the lunar regolith should hold buried 3He, water, and other volatiles resources acquired from solar winds and Earth's magnetosphere over some 4 billion years. These findings highlight the opportunity to learn about the evolution of the solar wind and Earth's earliest atmosphere during future lunar exploration. This could in turn provide key data to better understand how Earth evolved as a habitable planet despite the expected extreme solar forcing during its first billion years (Tarduno, Blackman, Mamajek, *Phys. Planet Inter.*, 2014).