Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.34755

# Thermoelectric Generation of Large-scale Magnetic Fields in the Early Moon: Impacts of High-Conductivity Ilmenite Layers at the Core-Mantle Boundary

**TAKASHI YOSHINO**[1], YOSHIHISA MORI[2], KOYA TSUJIMOTO[2], YURI SHIMONE[2] AND HYU TAKAKI[3]

[1]Okayama University
[2]Okayama University of Science
[3]Institute for Planetary Materials

The origin of the lunar paleodynamo remains a significant enigma. While core-convection models struggle to explain the high surface field intensities (~10–100 μT) in Apollo samples, the hemispheric thermal asymmetry between the Procellarum KREEP Terrane (PKT) and the farside suggests a persistent internal temperature gradient [1]. We propose that this gradient, coupled with the Seebeck effect in ilmenite-rich cumulates at the core-mantle boundary (CMB), functioned as a planetary-scale thermoelectric generator.

We evaluated magnetic field intensity using updated experimental constraints. Laboratory measurements up to 1273 K reveal a critical p-to-n transition in the Seebeck coefficient (S) of ilmenite, reaching approximately -100 μV/K at high temperatures. This indicates that at lunar CMB temperatures (>1500 K), ilmenite acts as a stable n-type semiconductor. Assuming a hemispheric temperature difference (D*T*) of 200 K, a 150 km thick ilmenite layer, and a small metallic core (r = 330 km), we modeled the resulting global current loop.

Our model yields a total thermoelectric current of ~6.2 MA, producing a steady-state magnetic field of ~12 μT at the CMB. Notably, the n-type carrier reverses the expected current direction, leading to a field orientation that significantly deviates from a simple spin-axis-aligned dipole. This field is strong enough to serve as a seed for a Basal Magma Ocean (BMO) dynamo or to directly overprint crustal rocks with non-dipolar directions.

The high conductivity of ilmenite ensures the Seebeck effect is a primary driver of the lunar magnetic environment. This mechanism explains observed crustal asymmetries and magnetic longevity beyond core convection. The subsequent field decline is attributed to an "electrical cut-off" as cooling increased the geikielite ($MgTiO_3$) component.

[1] Weiss BP, Tikoo SM (2014) The lunar dynamo. Science 346, 1246753

[2] Park et al. (2025) Thermal asymmetry in the Moon's mantle inferred from monthly tidal response. Nature 641, 1188–1192