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Exploring the role of a basal magma ocean in generating Earth's ancient magnetic field

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Observations of Earth's magnetic field extending back to 3.45 billion years ago indicate that generation by a core dynamo must be sustained over most of Earth's history. However, recent estimates of thermal and electrical conductivity of liquid iron at core conditions from mineral physics experiments indicate that adiabatic heat flux is approximately 15 TW, nearly 3 times larger than previously thought, exacerbating difficulties for driving a core dynamo by convective core cooling alone throughout Earth history. A long-lived basal magma ocean in the lowermost mantle has been proposed to exist in the early Earth, surviving perhaps into the Archean. While the modern, solid lower mantle is an electromagnetic insulator, electrical conductivities of silicate melts are known to be higher, though as yet they are unconstrained for lowermost mantle conditions. Here we explore the geomagnetic consequences of a basal magma ocean layer for a range of possible electrical conductivities. For the highest electrical conductivities considered, we find a basal magma ocean could be a primary dynamo source region. This would suggest the proposed three magnetic eras observed in paleomagnetic data originate from distinct sources for dynamo generation: from 4.5-2.45 Ga within a basal magma ocean, from 2.25-0.4 Ga within a superadiabatically cooled liquid core, and from 0.4-present within a quasi-adiabatic core that includes a solidifying inner core.