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Long term evolution of Earth's magnetic field strength: Supercontinent cycles and nucleation of the inner core

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Earth's magnetic field is generated in the outer core, where an electrically conducting dynamic fluid mainly composed of iron and nickel acts as a geodynamo. Features like polarity reversals (∼10 kyr in duration), geomagnetic excursions (<10 kyr in duration), secular variation (∼0.2°/year), and geomagnetic jerks (several years in duration) are all evidence of short term variability of Earth's magnetic field. However, there are indications that the magnetic field also varies fundamentally on much longer time scales, particularly its strength. Significant changes in the long term strength of the magnetic field have previously been correlated to factors such as reversal frequency or the inner core nucleation. For example, a sudden Mesoproterozoic increase in field intensity has been interpreted as the nucleation of the inner core. However, such analyses have been criticized for insufficient statistical rigor.
Here we present an approach that does not attempt to detect mean values, but accepts an inherent variability in the intensity of Earth's magnetic field, especially on long time scales. Spectral analysis of all palaeointensity data and a quality-filtered dataset obtained from the palaeointensity database for all of Earth history yield a strong ∼600 Myr cycle, among other significant periodicities. Because large-scale changes in the heterogeneity of core-mantle boundary heat flux should have a direct effect on palaeointensity, we relate this cycle to the physical reorganization of superplume structures at the core mantle boundary, which in turn may be related to the supercontinent cycle. Furthermore, a common statistical test for detecting heteroscedastic behavior in datasets indicates the presence of a significant step change increase in palaeointensity ca. 1.3 Ga, coincident with the time that geologic and palaeogeographic evidence suggests the onset of quasiperiodic assembly and fragmentation of supercontinents. If the supercontinent cycle reflects a mantle flow regime that not just organized but increased core-mantle boundary heat flow, then there may be a causal link to inner core nucleation through increased core cooling. Our results thus have implications for both the age of the inner core and the long-term modulation of magnetic field strength through the influence of the supercontinent cycle on core-mantle boundary heat flow. If, in fact, inner core nucleation is related to formation of the first supercontinent, then there is an unexpected connection between these two major state changes in the history of our planet and a coupling between its innermost and outermost spheres.