MODELLING THE PALEO-EVOLUTION OF THE GEODYNAMO

JULIEN AUBERT

Dynamique des Fluides Géologiques, Institut de Physique du Globe de Paris, France.
Email : aubert@ipgp.jussieu.fr

Although it is known that the geodynamo has been operating for at least 3.2 Ga, it remains difficult to infer the intensity, dipolarity and stability (occurrence of reversals) of the Precambrian magnetic field of the Earth. In order to assist the interpretation of paleomagnetic data, we produce models for the long-term evolution of the geodynamo by combining core thermodynamics with a systematic scaling analysis of numerical dynamo simulations. We update earlier dynamo scaling results by exploring a parameter space which has been extended in order to account for core aspect ratios and buoyancy source distributions relevant to Earth in the Precambrian. Our analysis highlights the central role of the convective power, which is an output of core thermodynamics and the main input of our updated scalings. As the thermal evolution of the Earth's core is not well known, two end-member models of heat flow evolution at the core-mantle boundary are used, respectively terminating at present heat flows of 11 TW (high-power scenario) and 3 TW (low power scenario). The resulting models predict that the geodynamo has been active for ages younger than 3.8 Ga. From that time to the appearance of the inner core, a thermal dynamo driven only by secular cooling can produce a dipole moment of strength comparable to that of the present field, thus precluding an interpretation of the oldest paleomagnetic records as evidence of the inner core presence. The observed lack of strong long-term trends in paleointensity data throughout the Earth's history can be rationalized by the weakness of paleointensity variations predicted by our models relatively to the data scatter. Specifically, the most significant internal magnetic field increase which we predict is associated to the sudden power increase resulting from inner core nucleation, but the dynamo becomes deeper-seated at the same time, thus largely cancelling the increase at the core and Earth surface, and diminishing the prospect of observing this event in paleointensity data. Our models additionally suggest that the geodynamo has lied close to the transition to polarity reversals throughout its history. In the Precambrian, we predict a dynamo with similar dipolarity and less frequent reversals than at present times, due to conditions of generally lower convective forcing. Quantifying the typical core-mantle boundary heat flow fluctuations required to switch the geodynamo from a reversing to a non-reversing state, we find that it is unlikely that these may have caused superchrons in the last 0.5 Ga without shutting down dynamo action altogether

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Julien Aubert, Dynamique des Fluides Géologiques, Institut de Physique du Globe de Paris, 4 place Jussieu, case 89, 75252 Paris cedex 5. aubert@ipgp.jussieu.fr