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Geodynamically consistent inferences on the uniform sampling of Earth's paleomagnetic inclinations

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Abstract

Paleomagnetism is a key method to reconstruct the Earth's paleogeography and thus essential for understanding tectonic evolution, but it assumes that the Earth's magnetic field structure has always averaged to a geocentric axial dipole (GAD). The GAD hypothesis may be tested using the observed inclination frequency distribution, but only if continents have sampled all of Earth's latitude uniformly, which is not known. Here, we provide new insight into the uniform sampling problem by employing a suite of 3D spherical mantle convection models that feature the self-consistent evolution of mantle convection, plate tectonics and continental drift over timescales of 2 Gyr or more. Our results suggest that continents unlikely sampled latitudes uniformly during the Phanerozoic, consistent with previous suggestions. This finding is robust for a variety of geodynamic evolutions with different mantle and lithosphere structures, at least in the absence of true polar wander. For longer sampling durations, uniform sampling typically becomes more feasible, but may only be achieved with confidence after time scales of minimum 1.3 Gyr. This time scale depends on the structure of the mantle and lithosphere and may be shortest when upper mantle viscosity is small due to reduced resistive drag at the cratonic base that allows for faster continental drift. Weak plates (low plastic yield strength) promote more dispersed configurations and also facilitate uniform sampling. If these conditions are not met, the sampling time scale can easily exceed several billion years. Even the minimum estimate of 1.3 Gyr challenges the validity of using the Phanerozoic inclination frequency distribution to infer the past average magnetic field structure; the approach could, however, still be applicable to the Precambrian inclination record.

Keywords: Geodynamic modelling, Mantle convection, Continental Drift, Plate Tectonics, Paleomagnetism

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