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Detection of relative plate motions and a reversing core dynamo on Earth by 3.5 Ga

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Clear records of measurable differential plate motions extend only to 2.7-2.5 Ga, and the sparse and often-ambiguous early geologic record has led to proposals of exotic Archean geodynamics that do not invoke a horizontally mobile lithosphere. Paleomagnetic data are the only direct constraints on lithospheric motions and their driving forces in deep time, and also directly probe Earth's magnetic field and the processes deep in the interior that generate it.

We document a sequence of 3.48-3.45 Ga paleomagnetic poles from North Pole Dome (East Pilbara Craton, Western Australia; Fig. 1A), supported by a uniquely robust set of age constraints (passing baked contact, fold, and reversal tests). These results are contemporaneous with existing poles from the Barberton Greenstone Belt (Kaapvaal Craton, South Africa; Fig. 1B). Comparing the two reveals that the East Pilbara moved rapidly around 3.48 Ga while the Barberton was stationary (Fig. 1C). This is the oldest unambiguous confirmation of internal mobility of the lithosphere, advancing the record of measured plate motions one billion years further into deep time. However, these plate motions changed velocities rapidly and likely had non-uniformitarian driving forces, suggesting either an episodically-mobile lithosphere or unstable subduction (i.e., not necessarily plate tectonics *sensu stricto*).

Additionally, we document a geomagnetic reversal at 3.46 Ga, over 200 million years older than the next oldest example. The geometry and directional stability of this reversal demonstrate that like today, the 3.5 Ga geodynamo was strongly dipolar and axially-aligned, but unlike today, the reversal rate was far lower than in recent geologic time, suggesting different driving mechanisms powered this dynamo.

This work therefore showcases that the 3.5 Ga Earth hosted modern geophysical processes like differential plate motions and an axial dipolar core dynamo. Yet these were accompanied by unfamiliar features like rapid velocity changes and very low reversal rates, evidence of non-uniformitarian driving forces which motivate further study. These findings are also particularly important to understanding Earth's earliest life, providing unprecedented geodynamic context for the earliest preserved habitats, which also occur in the 3.5 Ga rocks of North Pole Dome.