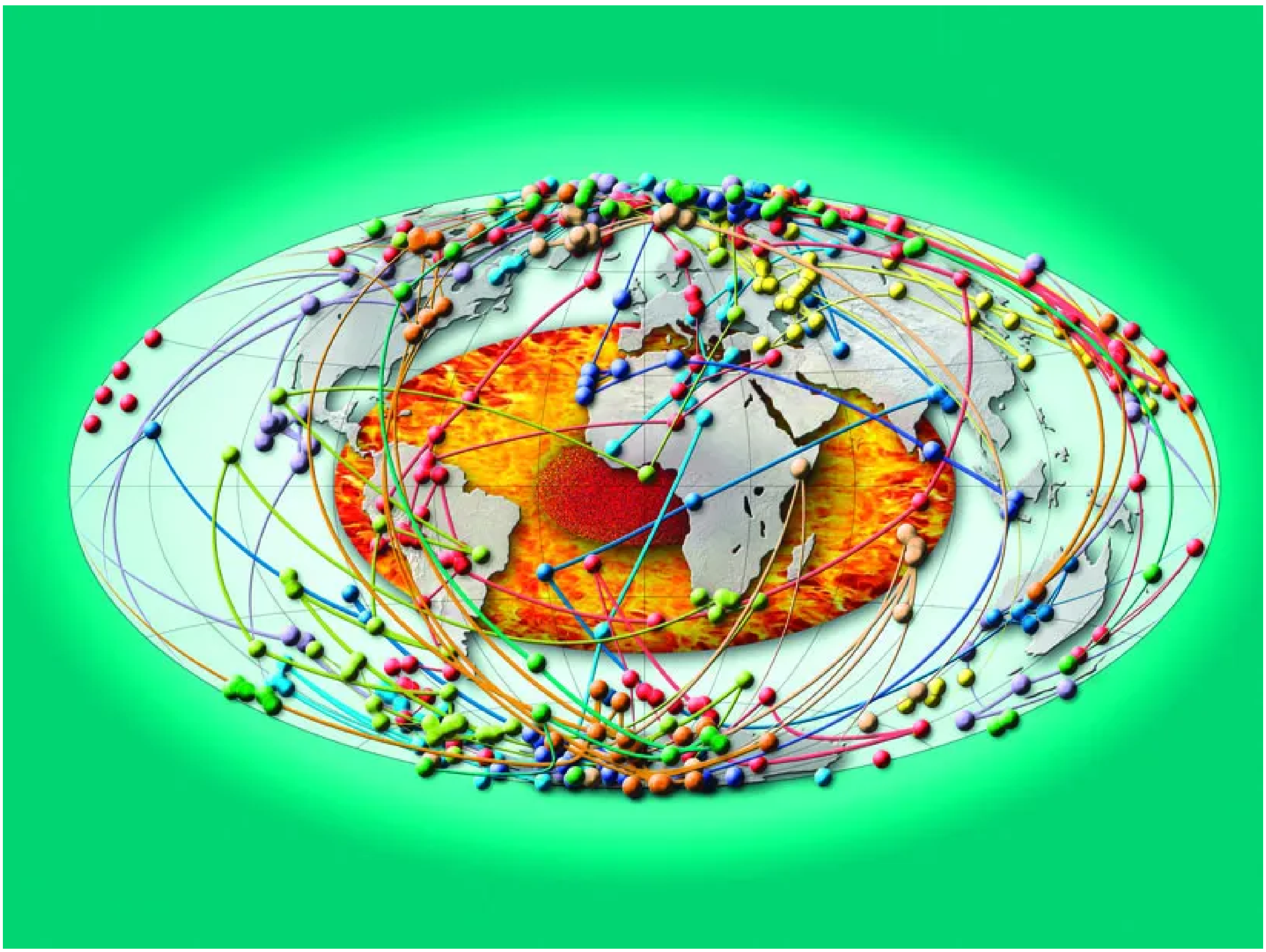
Eos

Polarity Reversals in the Earth’s Magnetic Field

Studies of geomagnetic polarity reversals have generated some of the biggest and most interesting debates in the paleomagnetic and wider solid Earth geophysics communities over the last 25 years.

By **F. Florindo**
29 April 2016



Apparent motions of the north geomagnetic pole recorded in sequences of lava flows during several reversals. Each colour corresponds to a distinct reversal record. Also shown in the center of the planet is the solid inner core (red) surrounded by the conducting liquid outer core (orange). Credit: Valet and Fournier, 2016, doi:10.1002/2015RG000506

Earth's natural magnetic field is generated by complex motions of molten iron alloys in the outer core of the planet, at depths in excess of 2,900 km, and varies on time scales ranging from milliseconds to millions of years. At irregular intervals, lasting several hundred thousand years on average, one of the Earth's most remarkable phenomena takes place: the Earth's magnetic field reverses, and the North and South Magnetic Poles switch places relatively quickly. During the short time period between the two polarities the geomagnetic field changes can be magnetically recorded by sediments and by sequences of lava flows. These magnetic data are of value to paleomagnetists in reconstructing past geomagnetic fields and, more specifically, in constraining the structure and geometry of the transitional field more accurately.

Studies of geomagnetic polarity reversals have generated huge debates in the paleomagnetic and wider solid Earth geophysics communities over the last 25 years. Some of these debates were among the most interesting ones in Earth Science over this period. Nevertheless, the topic has received less attention in recent years because of widespread difficulties and controversies concerning data reliability.

A recent **article** published in *Reviews of Geophysics* by Jean-Pierre Valet and Alexandre Fournier of Institut de Physique du Globe de Paris provides a mature reflection on the challenges faced in such research, with a critical review of the main reversal features derived from paleomagnetic records and analyses of some of these features in light of numerical simulations. As well as providing a critical review of past work, this contribution is sure to provide valuable direction for future research on the subject. AGU asked the authors of the article to highlight the important results that have emerged from their research and some of the important questions that remain.

Why is this topic timely and important? What recent advances in particular are leading to a new understanding or synthesis?

Reversals are one of the most enigmatic characteristic of the earth's magnetic field and as so they generate many questions. How often do reversals occur and how long do they last? What is the field morphology when it reverses? Does the field weaken or collapse and then recovers with the opposite polarity? What are possible consequences of reversals for the biosphere? When should the next reversal happen? Reversals are relatively rare events if we compare their duration with the length of the polarity intervals. The unique observational evidence for the behavior of the field during a polarity reversal comes from records of the paleomagnetic field. For almost fifty years paleomagnetists attempted to gather information by studying sequences of lava flows and sediments which acquired their magnetization during their formation, and stored this signal over geological times. However reversals occur over a few thousand years at most and it is a real challenge to acquire detailed information over this short transitional period between the two polarities. In fact, there is no perfect magnetic recorder, most sediments are characterized by low temporal resolution and volcanism is sporadic in nature with lava flows irregularly distributed in time. Therefore, the results can be biased by artifacts that are not always fully understood so that many observations remain controversial. It was thus necessary to decipher the paleomagnetic records that have been gathered around the world by reviewing critically the dominant geomagnetic features. Recent progress in studies of geomagnetic reversals is also due to numerical simulations that have provided new insights into the mechanism of the geodynamo and its reversals. Despite being still far from the earth dynamo, hundreds of polarity reversals have been documented by numerical models. In many cases the numerical features are similar to the paleomagnetic observations, giving us the opportunity to compare and analyze data and simulations together.

What are the implications for a broader understanding of Earth's processes?

The structure of geomagnetic polarity reversal remains largely unsolved. The geomagnetic field is maintained by rapid motions of the conductive iron-rich fluid in the outer core of the Earth. This liquid moves in complex ways as a result of convection within the core. There is now overall agreement that reversals occur without external forcing and therefore can be seen as an intrinsic property of the Earth's dynamo. Therefore, determining the structure and processes associated with geomagnetic reversals is essential for a full understanding of the geodynamo processes. Typical timescales that characterize polarity reversals constrain the fluid dynamical timescales and hence our knowledge of the earth's core. Reversals tell us also how the earth system responds to extreme global changes of the earth's magnetic field.

What are the major unsolved or unresolved questions and where are additional data or modeling efforts needed?

The analysis of the database shows that the overall strength of the field, anywhere on the Earth, may be no more than a tenth of its strength now. Reversals seem to occur in several phases with a precursor and a rebound. We learned also that field geometry during the transition is much more complex with several poles wandering at the surface of the earth and can thus be described as a multipolar field. However it is very difficult to obtain a good description of the field geometry (quadrupolar, octopolar etc…) and to describe its time-evolution. This requires to obtain many detailed records of the same reversal (the last one being the best candidate) with good geographical coverage including in the southern hemisphere and the polar regions. Sedimentary records are only appropriate to reach this goal but most records collected from deep-sea sediments do not provide adequate resolution to unravel the field morphology constrained by the very rapidly changing nature of the non-dipole field that govern during the transition between the two polarities. Future studies will have to rely on very tiny specimens that require new technologies and on sequences of lava flows that are rare and discontinuous. Another objective is to constrain further the periods preceding and following the polarity reversals in order to better understand the processes leading to their occurrence. Of particular interest is the evolution of field intensity and specifically the decreasing and recovery phases prior and after each reversal. Detailed datasets would document how we switch from a stable dipolar dynamo to a reversing regime. Apart from promising developments generated by high resolution records of relative paleointensity in sediments, changes in cosmogenic isotope production such as beryllium 10 with its long half-life of 1.4 Ma, provide in principle another indirect estimate of geomagnetic intensity changes with time. ^{10}Be production rate is constrained by penetration of cosmic particles inside the magnetosphere and, therefore, depends on the strength of magnetic field. Large ^{10}Be production rate peaks are expected during periods of weak geomagnetic field intensities and, therefore, a significant ^{10}Be production increase is observed during geomagnetic reversals.

The past ten years have seen constructive interactions between the observational and modeling communities. Reversals produced by numerical dynamos that simulate more Earth's like conditions will continue as computational power increases. There is no doubt that the convergence of both approaches will substantially improve our understanding of the nature of the geomagnetic reversals.

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Citation:

Florindo, F. (2016), Polarity reversals in the Earth's magnetic Field, *Eos, 97*, https://doi.org/10.1029/2018EO051383. Published on 29 April 2016.

justinburch505
8 years ago

But I saw an Associated Press article all about how all of this is due to anthropogenic climate disruption and if we pay our carbon taxes this will all go away.