Simulations shed light on Earth's history of magnetic field reversals

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A new analysis of computer simulations of Earth's magnetic field suggests that its behavior was different early in Earth's history, resulting in greater stability and fewer reversals of the magnetic field. The findings by researchers at the University of California, Santa Cruz, are helping to reconcile the geologic record of magnetic field reversals with the current understanding of how the Earth's core generates the planet's magnetic field.

Robert Coe and Gary Glatzmaier, both professors of Earth sciences at UCSC, combine studies of the paleomagnetic records preserved in rocks with complex computer models of the "geodynamo" that generates the magnetic field. Working together, they are gaining new insights into the effects on the magnetic field of processes occurring deep within the Earth.

Coe will present their findings this week at the Fall Meeting of the American Geophysical Union in San Francisco.

The magnetic field arises as a result of interactions in the Earth's iron-rich core, which consists of a solid inner core and a fluid outer core. The flow of heat from the core drives fluid motions in the outer core that produce an electric current and generate the magnetic field.

On human timescales, the magnetic field reliably aligns compass needles, helps animals navigate, and deflects some of the Sun's radiation. But on geologic timescales, it is far from stable--weakening, strengthening, and sometimes even reversing itself. A reversal of the magnetic field would cause the needles on compasses to point south instead of north.

In the last 15 million years (a relatively brief interval in Earth's history), the magnetic field has reversed roughly four to five times every million years. But records from the ocean floor indicate that reversal rates have been much lower at various times in the past. In fact, during a period that began 120 million years ago, there are no records of any magnetic reversals for nearly 35 million years, Coe said.

The geodynamo simulations show that the shape of the magnetic field may be an important factor controlling reversal rates. The symmetry and stability of the simulated field varies depending on the pattern of heat flow imposed at the core-mantle boundary. When the field is symmetrical in Northern and Southern Hemispheres, the simulations show frequent reversals. Conversely, when the field is strongly antisymmetric, with the Northern and Southern Hemispheres displaying opposite features, it reverses infrequently or not at all.

This finding is consistent with studies by other researchers of the paleomagnetic record of Earth's magnetic field during the 35 million years with no reversals, indicating that it was much more antisymmetric then than it is today.

The simulation that produced the most antisymmetric and most stable field is one with an inner core only one-quarter of its current size. Scientists believe that as the core cools, iron crystallizes out of the fluid outer core onto the solid inner core, causing the inner core to grow slowly over time. Thus, this simulation mimics conditions deep in Earth's past and predicts that reversals would have occurred much less frequently then than now. A survey of the sparse literature on the magnetic field 2 billion and more years ago suggests that this may well have been the case, Coe said.

"The data are consistent with simulations showing that field symmetry influences reversal rate," he said.

The Earth's magnetic field has been weakening for 2,000 years, and that trend continues today, leading some to worry that it may be heading for a reversal. Although the idea of an impending magnetic field reversal has captured the imaginations of writers and television producers, Coe said he thinks that a reversal would be unlikely to produce a catastrophic effect. Furthermore, reversals take thousands of years, and the field has decreased many times in the past and not reversed, he said.

Source: UC Santa Cruz

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