SAMPLE

Earth's Dynamic Systems: Geomagnetic Reversal

When North Becomes South

Aira Astralis

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Conclusion

This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

A geomagnetic reversal is a change in the Earth's dipole magnetic field such that the positions of magnetic north and magnetic south are interchanged (not to be confused with geographic north and geographic south). The Earth's magnetic field has alternated between periods of normal polarity, in which the predominant direction of the field was the same as the present direction, and reverse polarity, in which it was the opposite. These periods are called chrons. Reversal occurrences appear to be statistically random.

There have been at least 183 reversals over the last 83 million years (thus on average once every ~450,000 years). The latest, the Brunhes-Matuyama reversal, occurred 780,000 years ago with widely varying estimates of how quickly it happened. Some sources estimate that the four most recent reversals took on average 7,000 years to occur. Clement (2004) suggests that this duration is dependent on latitude, with shorter durations at low latitudes and longer durations at mid and high latitudes.

The geomagnetic poles are antipodal points where the axis of a best-fitting dipole intersects the surface of Earth. This theoretical dipole is equivalent to a powerful bar magnet inside the Earth. When the best-fitting magnet is allowed to sit slightly off the planet's center, the description improves; that refinement is the eccentric dipole model.

For modern-day Earth (unlike most planets in our Solar System) a simpler centered dipole model is a close enough approximation to be used for some purposes. There are historical periods when the Earth's field did not resemble a dipole at all. In contrast to the geomagnetic poles, the observed magnetic poles or dip poles of the Earth are places where the actual magnetic field intersects the surface.

The magnetic poles are not antipodal: asymmetries in the earth and variations in its magnetic field mean that the line on which they lie does not pass through Earth's center. Owing to the motion of fluid in the Earth's outer core, the magnetic field is constantly moving, in what is called geomagnetic secular variation. This leads to short-term changes in the magnetic and geomagnetic poles.

Although the geomagnetic poles average out local variations in the magnetic field, they are useful in geophysics as an efficient and more slowly-changing approximation than the magnetic poles. For example, since it is the entire field that determines the positions of auroras, the geomagnetic poles are an effective model for predicting their behavior.

Chapter 1: The Discovery of Geomagnetic Reversal

Most paleomagnetic research in the late 1950s included an examination of the wandering of the poles and continental drift.

Although it was discovered that some rocks would reverse their magnetic field while cooling, it became apparent that most magnetized volcanic rocks preserved traces of the Earth's magnetic field at the time the rocks had cooled through the Curie temperature. In the absence of reliable methods for obtaining absolute ages for rocks, it was thought that reversals occurred approximately every million years.

A group led by Neil Opdyke at the Lamont-Doherty Earth Observatory showed that the same pattern of reversals was recorded in sediments from deep-sea cores. During the 1950s and 1960s information about variations in the Earth's magnetic field was gathered largely by means of research vessels, but the complex routes of ocean cruises rendered the association of navigational data with magnetometer readings difficult.

As a first-order approximation, the Earth's magnetic field can be modeled as a simple dipole (like a bar magnet), tilted about 9.6° with respect to the Earth's rotation axis (which defines the Geographic North and Geographic South Poles) and centered at the Earth's center. This is known as the centered dipole model of the field. The North and South Geomagnetic Poles are the antipodal points where the axis of this theoretical dipole intersects the Earth's surface.

Thus, unlike the actual magnetic poles, the geomagnetic poles always have an equal degree of latitude and supplementary degrees of longitude respectively (2017: Lat. 80.5°N, 80.5°S; Long. 72.8°W, 107.2°E). If the Earth's magnetic field were a perfect dipole, the field lines would be vertical to the surface at the Geomagnetic Poles, and they would align with the North and South magnetic poles, with the North Magnetic Pole at the south end of dipole.

As a better second-order approximation, the field can be modeled as a dipole somewhere other than the center of the Earth. This is known as the eccentric dipole model. Even this approximation is imperfect; the magnetic poles migrate a greater distance each year than the geomagnetic poles, and usually lie hundreds of kilometers apart. Like the North Magnetic Pole, the North Geomagnetic Pole attracts the north pole of a bar magnet and so is in a physical sense actually a magnetic south pole.

It is the center of the 'open' magnetic field lines which connect to the interplanetary magnetic field and provide a direct route for the solar wind to

reach the ionosphere. As of 2020, it was located at 80.65°N 72.68°W / 80.65; -72.68 (Geomagnetic North Pole 2020 est), on Ellesmere Island, Nunavut, Canada, compared to 2015, when the same pole sat near 80.37°N 72.62°W / 80.37; -72.62 (Geomagnetic North Pole 2015 est), also on Ellesmere Island.

Why should a general reader care which end of the planet points north? Because the answer turns out to encode some of the Earth's deepest behavior. The field comes from a churning sea of liquid metal thousands of kilometers below the surface; its wanderings and occasional collapses record the physics of the planet's heart; and its record in ordinary rocks — lava, ash, river mud, even baked oven floors — can be read by anyone with a magnetometer and patience. A subject that began with a physicist wondering why French lava flows pointed the wrong way now dates the human occupation of caves, steers satellites, and sets the terms of one of the most persistent questions in the life sciences: what happens to a biosphere when its magnetic shield falters?

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ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.