# MAGNETIC FIELD REVERSALS ON EARTH: POSSIBLE IMPLICATIONS FOR THE BIOSPHERE

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## ABSTRACT

The generation and behaviour of geomagnetic field reversals are closely tied to other planetary environmental processes, for example enhanced surface particle exposure, enhanced solar wind interaction with the atmosphere, and climate change scenarios. Consequently, a discussion of fundamental aspects of the Earth's paleomagnetic research is related to effects of the biosphere and life. We discuss the behaviour of the Earth's dipole field and its reversals, give possible explanations of reversals, and show the classes of magnetospheres caused by different field orientations of the Earth's internal field. We study further the solar wind interaction with the Earth atmosphere during the time when the protecting magnetic field is weak. Further we compare and discuss magnetic reversal time scales with biodiversity.

## 1. THE EARTH MAGNETIC FIELD AND ITS REVERSALS

In 1835 Gauß [1] did the first reliable calculations concerning the amount of the Earth magnetic field. Since that time the amount is decreasing and will disappear in about 2000 years. Paleomagnetic records, spanning a period of 172 million years, show that this behaviour is quite usual but highly irregular, suggesting that there is a random element in the way reversals are generated.

In **classical dynamo models**, a steady dipole field is maintained by a two-stage process. Nonuniform rotation of the liquid core first draws the poloidal field into a toroidal magnetic field. The toroidal field is then twisted into meridional loops of poloidal field by cyclonic convection. If a meridional loop has the same sense as the large-scaled dipole then the dipole field is regenerated. If a loop has the opposite sense, the dipole field is degraded. This model is especially attractive from the viewpoint of paleomagnetism because it offers a possible explanation not only for the occurrence of individual reversals but also for the long-term changes in the average frequency of reversals. The latter might be produced by changes in the core-mantle boundary conditions in either of two ways. The first is the development of new hot spots at the core-mantle interface along the equatorial zone of reversed toroidal flux. The increase in turbulence would decrease the stability of the dynamo and result in a higher frequency of reversals. The second is by a general increase in the roughness of the interface at all latitudes, which would increase the general level of turbulence in the core. This would increase the complexity of the pattern of alternating zones of normal and reversed toroidal flux and provide more opportunities for random turbulent fluid motions to trigger a reversal. In principle there are two possibilities how a reversal process take place.

**CASE 1:** The first one is that the magnetic field decreases until there is no dipole field left and only a quadrupole field is remaining. Then the dipole field increases again with opposite direction.

**CASE 2:** The other possibility is that the dipole field remains constant in amount and is moving from one pole to the other so that we get also a reversed field orientation.

## 2. THE MAGNETOSPHERE DURING A REVERSAL

The basic principles of **magnetohydrodynamics** (MHD) postulate that a highly conductive plasma cannot penetrate a magnetic field and vice versa. The plasma is separated from the magnetic field through a thin boundary. Such a process occurs when the solar wind is interacting with the Earth magnetic field, where a magnetic field dominated cavity, the magnetosphere, is generated, separated from the solar wind by the magnetopause.

Our **magnetic field model** assumes a complex plane which represents the noon-midnight magnetopause and the magnetic field is derived from a complex potential.

The magntopause can be mapped systematically by means of several conformal mappings.
The present Earth has a dipole moment parallel to the rotation vector and perpendicular to the solar wind bulk velocity. During field reversals the dipole moment may be within the ecliptic plane, and so the dipole moment is perpendicular to the rotation vector and the solar wind bulk velocity too. This magnetospheric configuration corresponds to CASE 2. Twice a rotational period a so-called pole-on magnetosphere is established, where the dipole moment and the solar wind bulk velocity have a parallel orientation. If we consider a non-dipolar magnetic moment we get a further type of a magnetosphere corresponding to CASE 1.

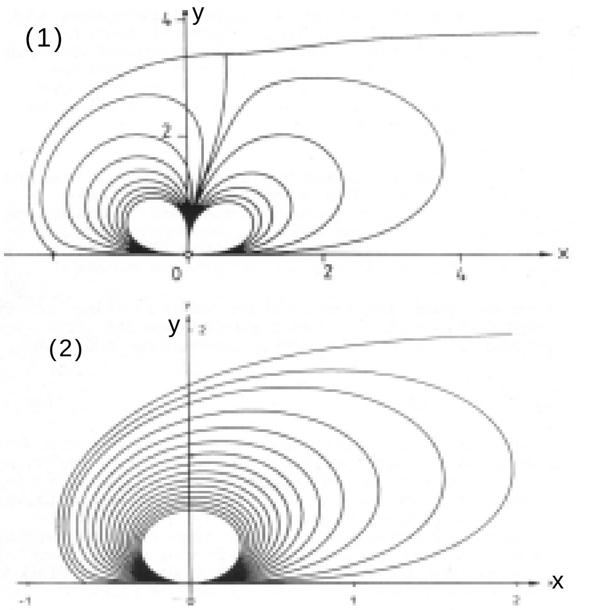


Fig. 1. Magnetic field structure of the magnetospheric noon-midnight meridian plane for different cases: (1) axial quadrupole perpendicular to the solar wind flow (CASE 1), (2) dipole parallel to the solar wind flow (CASE 2).

## 3. SOLAR WIND INTERACTION DURING REVERSALS

For the present Earth the stand-off distance of the magnetopause is approximately 10 Earth radii, but if only a quadrupolar moment is left the amount of the magnetic field is much less. If we use common values for the solar wind density and the solar wind velocity we get an equilibrium magnetic field of 115 nT. The quadrupol field strength at the Earth surface is about 10% of the total magnetic field. Using these assumptions we estimate a stand-off distance to be about 2 Earth radii.
If the magnetic field is weaker a **Venus-like solar wind interaction** could occur [2]. The solar wind is in contact with the Earth's ionosphere and thus the plasma can penetrate into the ionosphere leading to additional ionization and charge exchange processes between solar wind protons and oxygen ions. An other effect is additional heating of the ionosphere by hot solar wind plasma.
During reversals **cosmic ray particles** can boost cloud growth by knocking electrons off atoms, forming charged ions that can trigger $H_2O$ droplets to condense, much easier than during a protected atmosphere. At high altitudes cosmic ray produced ions bump into one another and recombine into neutral particles. While at lower altitudes the ions last long enough to trigger new clouds. These additional formed clouds are responsible for the absorption of solar radiation and **climate changes.**

## 4. BIOLOGICAL IMPLICATIONS

Species are grouped into genera, genera into families, and so on until the highest taxonomical level. It is enough to find one species of one genera of a given family for this family to be recorded at present, while total disappearance involves the extinction of all the species of a family. It is interesting that we could not find a strong correspondence between periods with increased magnetic activity and stages with higher/lower family extinctions or organizations. Our result might reinforce the hypothesis that it is the **internal organization** of the global biota which mainly leads to macro-evolutionary dynamics. External perturbations are probably responsible as a triggering mechanism of extinctions, but it is the internal organization of the system at that point in time that determines the intensity of the highly non-linear response.

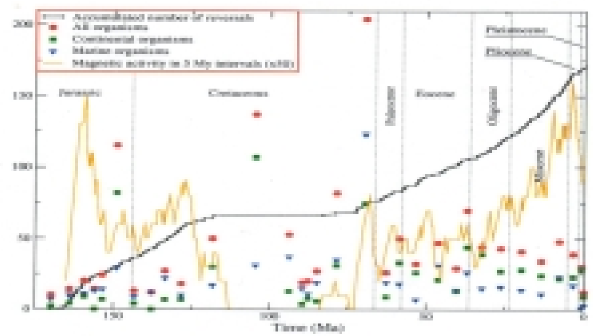

Fig. 2: Magnetic field reversals and extinctions in the last 172 Myr.

## 5. REFERENCES

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