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<u>The Magnetic Field of the Earth</u>

The Earth is about 4.6 billion years old and its magnetic field has existed three quarters of its life time (Jeanloz 40). This field has a very important role. It acts as a shield against the solar wind, which consists of ions and harmful radiation emitted by the Sun (Jeanloz 40). The purpose of this report is to explain why the Earth has a magnetic field. The answer lies below the surface of the planet.

The Earth is composed of several layers. The thin, outer-most region is called the crust (Broad). The next region is the mantle and it is composed of hot plastic rock (Broad). The outer core is the following region, which is composed mainly of hot liquid iron (Broad). Finally, the inner core is the last region. It consists mainly of hot, solid iron (Broad). The inner core and outer core are responsible for the Earth's magnetic field.

Magnetic field measurements are made using the surface of the Earth as the frame of reference. These fields can be described by placing an imaginary bar magnet through the center of the planet (Jeanloz 40). The north pole of the magnet would be located at the Antarctic, and the south pole of the magnet would be located at the Arctic. The field lines exit the Antarctic, enter the Arctic, and pass through the core (see Figure 1). In this dipolar configuration, magnetic field lines follow simple, closed circular paths (Jeanloz 40). However, upon closer study, scientists believe that the paths become temporarily distorted while travelling through the core (Jeanloz 40). It should be noted that scientists do not know why closed paths are formed by magnetic fields. This description accounts for 90% of the field lines. The remaining 10% are more complicated and can only be described using multiple poles (Jeanloz 40). Although the magnetic field can easily be determined by scientists, they do not fully understand, "how it is generated, when and how it started, and how it has evolved," (Jeanloz 40).

Scientists believe that the movement and properties of the inner core and outer core produce the Earth's magnetic field. The role of the inner core is to intensify, strengthen, and stabilize the magnetic fields that pass through it (Broad). The inner iron core is able to perform these functions because it maintains its magnetic properties despite temperatures of around 5500°C (Jeanloz 40). Under normal atmospheric conditions iron can not be magnetized at temperatures over 750°C. While in the core, iron maintains its magnetic properties because of enormous pressures ranging from 1.3 million to 3.5 million atmospheres (Jeanloz 40).

The inner core rotates slightly faster than the rest of the planet (Broad). This rotation is responsible for the slightly twisted shape of the field lines near the poles (Jeanloz 40). This theory was developed using seismic data collected from earthquakes (Broad). Seismometers, which are instruments used to detect ground vibrations, were used to collect this data (Broad). In this process computer simulations and the orientation of the seismic data led scientists to conclude that the inner core was rotating faster than the rest of the planet (Broad).

The liquid outer core rotates at the same speed as the surface of the planet (Broad). It may also have localized screw-like rotations caused by the rotating inner core (Jeanloz 40). The exact fluid motions of the outer core have not been determined (Jeanloz 40).

A recent discovery within the outer region is the presence of two ring-shaped liquid currents, called jets, above and below the inner core (see Figure 2) (Broad). Scientists believe the current in the rings produce Earth's magnetic field (Broad). Rotational and thermal forces cause the liquid iron to flow towards two spots located along the rotation axis (Broad). The inward motion together with the rotation of the planet causes the ring paths to form (Broad).

Liquid in these rings rotate faster than the surface of the planet (Broad). The rapid rotation of the rings allow them to conduct thermal energy as well as electricity (Jeanloz 47). The situation is analogous to creating an electromagnet. The two rings form part of a coil that conducts electricity. The inner core forms the iron solenoid that is placed inside the coil to strengthen the electromagnet.

Figure 1 - Earth's Magnetic Field Lines (Jeanloz 42)

Figure 2 - Creating the Magnetic Field (Broad)

There are two possible driving forces that circulate the liquid iron in the outer core. Thermal convection is one possibility (Jeanloz 46). This type of motion can be seen in a pot of boiling water (Jeanloz 46). Cooler molecules sink to the bottom while hotter molecules rise to the surface (Jeanloz 46). Compositional convection is another possibility (Jeanloz 46). Convection occurs because denser materials sink while less dense ones rise (Jeanloz 46). Both of these possibilities could provide the continuous, cyclical motion that is needed.

Regardless of the forces driving the motion, a source of energy is needed to maintain it (Jeanloz 46). The magnetic field is maintained when the circulation of liquid in the outer core is maintained (Jeanloz 46). Without this movement, the magnetic field would only exist 10 000 years (Jeanloz 40). There are three possible sources of energy. Radioactive decay of uranium and potassium could provide the energy (Jeanloz 46). Another source of energy is from "primordial heat" (Jeanloz 46). This is the heat released during the formation of the Earth (Jeanloz 46). One final possibility is from the latent heat of crystallization, which is the energy released when a liquid turns into a solid (Jeanloz 46). This could occur when liquid iron from the outer core enters the inner core. The liquid turns into a solid and releases energy (Jeanloz 46).

The study of the liquid motion in the outer core is very complicated because the magnetic fields and the liquid motion affect one another (Jeanloz 40). Perhaps this is the reason why scientists can not explain what causes the Earth's magnetic field to reverse every 200 000 years (Broad). This reversal has been discovered from measuring the magnetism in past lava flows (Jeanloz 44).

The Earth has a magnetic field because of interactions between the inner and outer core. This magnetic field is created in the same way an electromagnet is created. Although the finer details of the process are unknown, the general principles are accepted among the scientific community. Research that is currently conducted by geophysicists will lead to a better understanding in the near future (Broad).

REFERENCES

William J. Broad, "Spin Doctors; Deep in the heart of Earth", Globe and Mail, Saturday Dec. 28, 1996.

Raymond Jeanloz, "The Earth's Core", Scientific American, Vol. 249, No.3 September 1984, pp. 40-49.