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The Origin of Geomagnetic Fields and the Cause of Its Reversal

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Abstract: People's knowledge and utilization of geomagnetic field has been going on for thousands of years, and many hypotheses have been proposed about the origin of geomagnetic field, yet so far none of them is able to completely answer every question about the geomagnetic field, so Einstein once classified the origin of the geomagnetic field as one of the five difficult problems in physics. Recently, the author analyzed the formation and evolution of the Earth as well as its internal structure and external environment again, and has found the origin of the geomagnetic field: the polar vortexes at Earth's North and South Poles can produce spiral currents, then form a synthesized magnetic dipole at Earth's North and South Poles respectively, adding the local non-dipole magnetic fields produced by the atmospheric circuits around the clouds there, finally producing the present geomagnetic field. If the Earth enters a glacial period, there is little cloud vaporized from the non-polar regions and moved to the polar regions, so the polar vortexes are very weak, the resulting dipole magnetic fields are weaker than local non-dipole magnetic fields with different polarities, so the superposition of these two kinds of magnetic fields yields a new geomagnetic field with different polarity. This new theory can also reveal the origin of other stars' magnetic fields and the law of their reversal.

Keywords: Geomagnetic Field, Magnetic Dipole, Non-dipole Magnetic Field, Glacial Stage, Geomagnetic Reversal

1. Introduction

People found and utilized geomagnetic field as early as more than 2000 years ago, but they weren't able to reveal the electrical nature of magnetic phenomena in theory until Oster found "magnetic effect of electric current" in 1820 and Faraday discovered the phenomenon of "electromagnetic induction" in 1821, which were used to invent motors and generators respectively later. Only since then people have had a fundamental understanding of the electrical nature of magnetic phenomena [1]. Even so, people haven't got enough knowledge of the geomagnetic field around them, nor can they thoroughly understand the origin and variation law of the geomagnetic field. Although people have studied the origin of geomagnetic field for nearly 400 years and put forward a variety of hypotheses, none of them is able to completely answer every question about the geomagnetic field [2]. Hence, Einstein once classified the origin of the geomagnetic field as one of the five difficult problems in physics. Fortunately, the author recently analyzed the formation and evolution of the Earth as well as its internal structure and external environment again, and has found the origin of the geomagnetic field and the cause for its reversal. This new theory can also be used to reveal the origin of other stars' magnetic fields and the law of their reversal.

2. The Existing Hypothesis About the Origin of Geomagnetic Field

Due to the importance of the geomagnetic field, people have been exploring the cause of the formation of the geomagnetic field for a long time. After several hundred years of research, people have got a deeper understanding of the characteristics of geomagnetic field and put forward a variety of hypotheses.

Initially, people thought that the Earth's magnetic field is similar to that of a bar magnet tilted 11 degrees from the spin axis of the Earth, as is shown in Figure 1. The problem with that picture is that the Curie temperature of iron is about 770°C. The Earth's core is hotter than that and therefore no magnetic. So the Earth couldn't get its magnetic field from such a bar magnet.

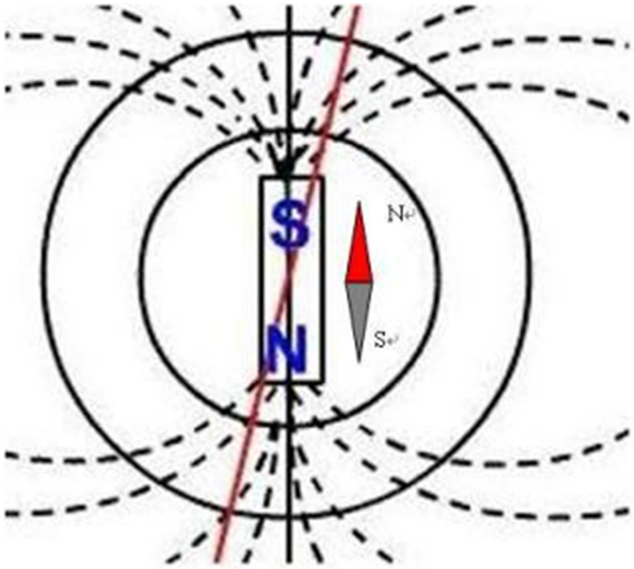

Figure 1. The early imagination of geomagnetic field.

Magnetic fields surround electric currents, so one may surmise that circulating electric currents in the Earth's molten metallic core are the origin of the magnetic field. A current loop gives a field similar to that of the Earth. From these points of view, the German-born American physicist Walter M. Elsasser and the British geophysicist Edward Bullard during the mid-1900s proposed dynamo theory to explain the origin of the Earth's main magnetic field in terms of a self-exciting (or self-sustaining) dynamo. In this dynamo mechanism, fluid motion in the Earth's outer core moves conducting material (liquid iron) across an already existing, weak magnetic field and generates an electric current. (Heat from radioactive decay in the core is thought to induce the convective motion.) The electric current, in turn, produces a magnetic field that also interacts with the fluid motion to create a secondary magnetic field. Together, the two fields are stronger than the original and lie essentially along the axis of the Earth's rotation [3, 4].

Although various other mechanisms for generating the geomagnetic field have been proposed, only the dynamo concept is seriously considered today. But it still couldn't explain the in-homogeneity of the spatial distribution of geomagnetic field and the characteristic of constant change over time, including geomagnetic declination and geomagnetic reversal [5]. Hence, it isn't plausible to use this mechanism to explain the formation of the geomagnetic field.

3. The Real Origin of Geomagnetic Field

Through early paleomagnetic research and modern geomagnetic exploration, experts found that the geomagnetic field should be scientifically divided into two parts: the dipole magnetic field and the non-dipole magnetic field [6]. The dipole magnetic field occupies 90% of the total geomagnetic field, while the non-dipole magnetic field occupies only a small part of the total geomagnetic field. The superposition of the two parts produces the present geomagnetic field. The research also shows that it is a global mechanism that leads to the change of the dipole magnetic field, while it is a local mechanism that leads to the change of non-dipole magnetic field.

3.1. The Formation of Non-dipole Magnetic Field

It's already known that the age of the Earth is 4.54 ± 0.05 billion years. The evolution from the formation of the original earth to the formation of the earth's hierarchical structure needs only hundreds of millions of years. The most primitive crust appeared about 4 billion years ago, but the earliest geomagnetic records discovered so far were 3.5~4billion years ago. So the origin of the Earth's magnetic field is later than the formation of Earth's layered structure, but close to the formation of atmosphere in time. In addition, the temporal and spatial variability of Earth's magnetic field also shows that the formation of geomagnetic field is closely related to the formation and evolution of the atmosphere. So in the study of the origin of the geomagnetic field, we should start with the formation and evolution of the atmosphere [7].

The Earth's atmosphere is the product of the Earth's formation and evolution. The Earth's evolution has undergone three distinct stages: Earth's primordial atmosphere, Earth's second atmosphere and Earth's third atmosphere. With the increase of Earth's mass, the atmosphere is gradually thickened. The whole atmosphere shows different characteristics with different height, so it is generally divided into five layers:

1 *Troposphere*——It is the first layer above the surface and contains about 80% of the total mass of the atmosphere. Its average thickness is 12km. Clouds exist only in this layer.
2 *Stratosphere*——Above the tropopause is the stratosphere. This layer extends from an average altitude of 11 to 50 kilometers above the Earth's surface. This stratosphere contains about 19.9% of the total mass found in the atmosphere, but very little weather occurs in the stratosphere.
3 *Mesosphere* ——It stretches from 50 km to 85 km.
4 *Thermosphere* ——It extends from about 85 km to more than 690 km. Under the action of solar ultraviolet rays and cosmic rays, the air of this layer is ionized, leaving the ions and free electrons floating, and a plasma region is formed at the bottom of the layer, which is called ionosphere. In addition, some of these positive and negative ions will diffuse down into the troposphere, gathered respectively at the top or bottom of clouds.
5 *Exosphere*——Exosphere is the upper limit of the atmosphere. It ranges from about 690 km up to 1,000 km. This layer is where atoms and molecules escape into space. The atmosphere becomes very thin in this layer. Gas particles in the exosphere either come down into the lower atmosphere due to Earth's gravitational pull or escape into

outer space.

Thus we see that common clouds can only be formed in the troposphere, because only in a place where air's vertical motion is strong, can water vapor rise to meet cold air to form clouds, but above the troposphere this condition is not satisfied. In fact, there are various clouds with different altitudes, which can be divided into high, middle and low clouds. The altitude of high clouds is between 8 km and 13 km, looks like thin veils or feathers; the altitude of middle clouds is between 2 km and 8 km, usually covering all the sky, sometimes also producing continuous precipitation; the altitude of low clouds is below 2 km, looks like cotton candies or expanding foams, sometimes also producing thunder showers. Hence, the study of cloud charging mechanism should mainly consider the middle and low clouds.

Due to the collision and friction of clouds as well as the action of solar ultraviolet rays and cosmic rays, Earth's atmosphere can produce a large amount of positive and negative ions. The charge distribution is uneven on cloud droplets: The molecules of the outermost layer is negatively charged while the molecules of the intra-layer positively charged, the potential difference between the inner layer and the outer layer is 0.25 Volts. In order to balance this potential difference, water droplets in the cloud must first absorb negative ions in the atmosphere, causing the droplets to be negatively charged. When the convective activity begins, the lighter positive ions are gradually brought up by the updraft to the upper portion of the cloud, while the larger cloud droplet is either suspended in the middle of the cloud or falls toward the lower portion of the cloud, causing the lower portion to be negatively charged and the upper portion to be positively charged. When the air humidity is very large and there is a voltage difference between two clouds, the moist air will become a conductor letting electrical current pass through the space between the two clouds. Therefore, there are electric fields and currents everywhere in the atmosphere [8], as is shown in Figure 2. Especially, due to the frequent frictions and collisions between clouds, frequent discharges or thunderstorms are caused inside clouds or between clouds. According to the recent studies in atmospheric physics, we know that at any given moment, there are about 2000 thunderstorms in action on the earth. Each discharge or thunderstorm acts as an electrostatic motor, which can sends currents to the upper layer of the cloud, the lower layer of clouds or the ground, forming a series of complete atmospheric circuits, as is shown in Figure 2. The loop electric current in each atmospheric circuit can produce a weak local magnetic field, the superposition of these local magnetic fields with different polarity forms a local non-dipole magnetic field. As the earth rotates from west to East, under the action of universal gravitation, the clouds also revolve with Earth's self-rotation, so the mainstream of clouds is from west to East, and the loop currents perpendicular to the earth's rotating axis are much stronger than other loop currents in different circulation planes, therefore these loop currents play a dominant role in the formation of local non-dipole magnetic fields, making the local non-dipole magnetic field produced by superposition be such a magnetic field with its magnetic north pole pointing towards geographic north pole and its magnetic south pole pointing towards its geographic south pole.

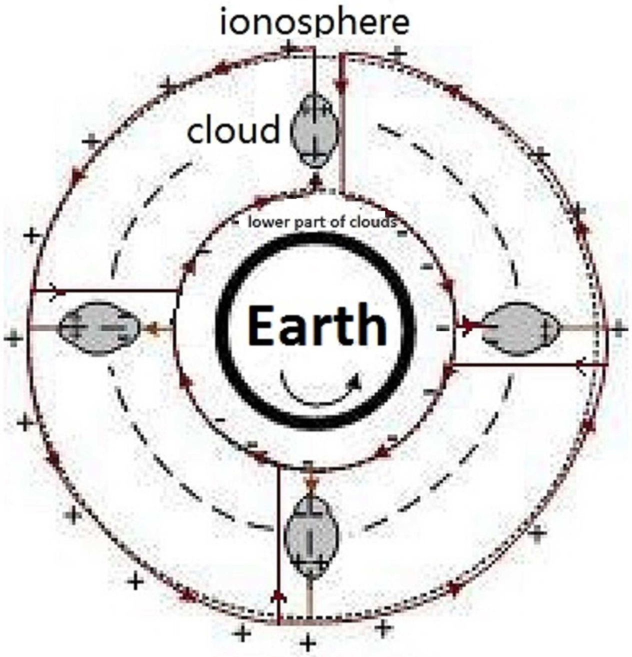

Figure 2. *Atmospheric currents produce local non-dipole magnetic field.*

3.2. The Formation of Dipole Magnetic Field

Since in the past, people regarded the earth as a simple magnetic dipole, when looking for the cause of the earth's magnetic field, they only concentrate on the internal structure, and often ignore the external environment of the Earth. In fact, the electromagnetic field of a star is mainly produced by the movement of charged ions in its outer atmosphere. Hence, when we study a star's magnetic field, we shouldn't consider only the inner structure of the star, instead, we should pay more attention to its outer environment.

It is well known that Earth has a dense atmosphere. Due to the effect of centrifugal force, the rotation of earth around its axis has caused it to bulge around the Equator, making the earth become an oblate spheroid with the radius of the two poles of the earth is less than the radius of the equator and other places, while the gravitational force is inversely proportional to the square of the distance. When the earth rotates quickly, the rotation will produce strong centrifugal force, making the clouds over the equator and low latitudes tend to move away from their orbits to the South pole or the North Pole. Because the gravitational attraction of the polar position is greater than that of other locations, when clouds move above the polar regions, they are easily attracted by the gravitational pull of the polar regions, after inhaling cold air, they condense into thick clouds and sink gradually. Many polar-plunging clouds form a strong circulation around the pole as the Earth rotates, that is polar vortex, as is shown in Figure 3. The earth has two vortexes, located at the South pole and the North pole respectively, which can span troposphere and stratosphere. This kind of vortex structures exist throughout the four seasons, reaching maximum strength in winter. When the Arctic is in summer and its vortex structure become weaker than in winter, the Antarctic is in winter and its vortex become stronger than in summer, and vice versa. So these two vortex structures have complementary advantages.

Figure 3. *Earth's polar vortex.*

Figure 4. *Earth's polar spiral currents.*

Since the clouds involved in polar vortex are numerous and revolve downward rapidly in a spiral manner，a series of parallel thick spiral cloud path can be formed, which facilitate not only the downward flow of heavier negatively charged water droplets but also the transfer of charge, as is shown in Figure 3 and Figure 4. Hence, this kind of cloud path is a good circuit with excellent electrical conductivity. Since the clouds involved in polar vortex are numerous and revolve rapidly, it is easy to have violent frictions and collisions among clouds, making the vortexes filled with positive ions and negative ions. Water droplets in the cloud must first absorb negative ions in the atmosphere, causing the droplets to be negatively charged，and the larger cloud droplet falls toward the lower part of the cloud or even the lower portion of the vortex along a spiral cloud path, while the lighter positive ions are gradually brought up by the updraft to the upper part of the cloud or even the upper portion of the vortex along the spiral cloud path, forming a current from the lower portion of the vortex to the upper portion of the vortex along the spiral cloud path, as is shown in Figure 4. In addition, since the clouds along the spiral cloud path are numerous and revolve rapidly, it is easy to have violent frictions and collisions among clouds, producing frequent electrical discharge or thunderstorms. Each electrical discharge or thunderstorm acts as an electrostatic motor, which can send currents to the upper portion of the vortex and the lower portion of the vortex, forming an intense current following the cloud path from the bottom of the vortex to the top of the vortex. Since there is a continuous flow of currents along the spiral cloud path from the bottom of the vortex to the top of the vortex, therefore forming a powerful dipole magnetic field with its magnetic north pole pointing towards geographic south pole and its magnetic south pole pointing towards its geographic north pole, as is shown by Figure 5. Since the Earth has two vortex structures located at the south pole and the north pole, consisting of two groups of parallel spiral cloud paths, therefore producing two groups of corresponding dipole magnetic fields located at the south pole and the north pole, equivalently forming two synthesized magnetic dipoles at Earth's North and South Poles. It is the superposition of the two synthesized magnetic dipoles of the same polarity and the local non-dipole magnetic fields that forms the present geomagnetic field.

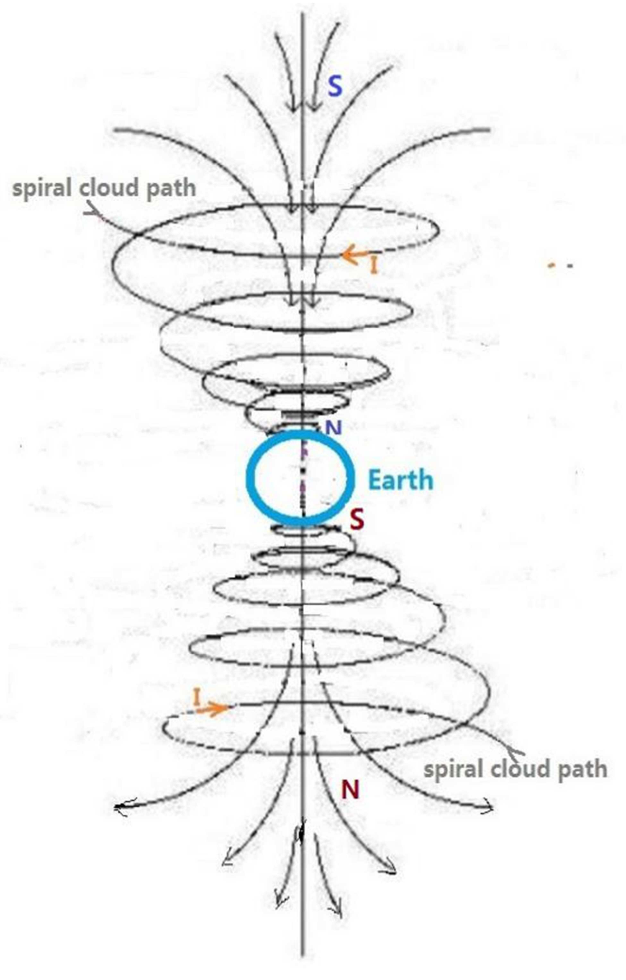

Figure 5. *Dipole magnetic fields located at the north and south geographic poles.*

4. The Cause of Geomagnetic Reversal

Because the Earth is in the interglacial age, the Earth's surface temperature is high enough to evaporate a lot of water vapor, which rises to meet cold air to form clouds. When the Earth rotates quickly，the rotation will produce strong centrifugal force, making the clouds over the equator and low latitudes tend to move away from their orbits to the South pole or the North Pole. Because the gravitational attraction of the polar position is greater than that of other locations, when clouds move above the polar regions, they are easily attracted by the gravitational pull of the polar regions, after inhaling cold air, they condense into thick clouds and sink gradually. Many polar-plunging clouds form a strong circulation around the pole as the Earth rotates, that is polar vortex, as is shown by Figure 2. The Earth has two vortexes, located at the South pole and the North pole respectively. It is these two vortexes that produce two groups of corresponding dipole magnetic fields, dominating the current geomagnetic field whose magnetic north pole pointing towards geographic south pole and magnetic south pole pointing towards geographic north pole.

When the earth enters an great ice age, most of the land and sea are covered by ice, it is difficult to evaporate large amounts of water vapor to form clouds, and clouds are also hard to move to the poles to form vortex, so the polar vortexes are weak, the dipole magnetic fields produced by the polar vortexes are weaker than local non-dipole magnetic fields, geomagnetic polarity reverses [9, 10, 11, 12].

Since Jupiter’s surface temperature is-168°C, it’s very cold there, Jupiter's thick clouds condense on the surface of Jupiter, difficult to move to the polar region of Jupiter. Hence, the dipole magnetic fields produced by the polar vortexes are weaker than local non-dipole magnetic fields produced by thick clouds, so Jupiter’s magnetic field and the current geomagnetic field have opposite polarity [13, 14, 15].

5. Conclusions

Since some people have wrongly attributed the cause of geomagnetic field to the result of the movement of the Earth's interior material, ignoring the movement of atmosphere and the change of winds and clouds, therefore the existing hypotheses about the origin of geomagnetic field are contradictory and unbelievable, unable to explain the in-homogeneity of the spatial distribution of geomagnetic field and the characteristic of constant change over time. Thus the author, starting from the formation and evolution of the Earth, has analyzed the formation and evolution of atmosphere, and found the origin of geomagnetic field. This new theory can answer every question about the geomagnetic field, so it is a scientific theory.

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