Physical Mechanism for Reversals of the Earth's Magnetic Field During the Flood

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Abstract

Recent paleomagnetic data (Coe & Prevot, 1990, pp. 292–298; Humphreys, in press) strongly supports my hypothesis (Humphreys, 1986, pp. 113–126) that the earth's magnetic field reversed itself rapidly during the Genesis Flood. This paper shows specifically how convection upflows of the electrically conductive fluid in the Earth's core would produce such rapid reversals. The analysis shows that (a) the upflows had to have been faster than 3m/s and larger than 5km in diameter, and (b) each reversal would decrease the strength of the field slightly. All the evidence indicates that the Earth's magnetic field has continuously lost energy since its creation, implying that the field is less than 9,000 years old.

Keywords

Earth's Magnetic Field, Paleomagnetic Data, Earth's Core, Field Reversals, Heat, Fluid Convection, Magnetic Flux

Introduction

The earth's magnetic field has reversed its polarity many times in the past, according to a massive body of data (Humphreys, 1988, pp. 130–137). These reversals were not changes in the earth's rotation or gravity, but were simply 180° changes in the direction a compass needle would point. At lease 50 such polarity changes are recorded in geologic strata worldwide. Evolutionists (Dalrymple, 1983, pp. 124–132) and old-earth creationists ((Young, 1982, pp. 117–124) assume that millions of years elapsed between reversals, so they use the large number of reversals as evidence for a great age for the earth. However, the assumption of million-year reversal periods rests on the validity of radiometric dating methods, which young-earth creationists question (Gentry, 1988). In 1986, at the First International Conference on Creationism, I suggested that most of the reversals occurred during the Genesis Flood (Humphreys, 1986). Such a short timescale—approximately one year—implies that the average time between reversals was a few weeks, not millions of years. I showed how this hypothesis explains the paleomagnetic (magnetism of ancient rocks) data better than the evolutionary model does. In the conclusion, I suggested that a good test of my hypothesis would be to "look for strata which clearly formed within a few weeks and yet contain a full reversal." In particular, I proposed examining

> distinct lava flows thin enough that they would have to cool below the Curie temperature [at which cooling rock "freezes" magnetic information] within a few weeks.

A polarity transition recorded in such a thin layer would be strong evidence for rapid reversals.

Recently, to my great delight, two respected paleomagnetists, Robert Coe and Michel Prévot, have found such evidence and published it in *Earth and Planetary Science Letters* (Coe & Prévot, 1989). They found a Pliocene basalt flow, number B51, at Steens Mountain, Oregon which apparently recorded a polarity transition which took place in about a fortnight:

> … even this conservative figure of 15 days corresponds to an astonishingly rapid rate of variation of the geomagnetic field direction of 3° per day … The rapidity and large amplitude of geomagnetic variation that we infer from the remanence directions in flow B51, even when regarded as an impulse during a polarity transition, truly strains the imagination … We think that the most probable explanation of the anomalous remanence directions of flow B51 is the occurrence of a large and extremely rapid change in the geomagnetic field during cooling of the flow, and that this change likely originated in the [earth's] core.

A commentary in *Nature* (Fuller, 1989,

pp. 582–583) is cautiously favorable to this interpretation. Hitherto, most scientists have thought (a) that the earth's core requires more than a few thousand years to make such large magnetic field changes, and (b) that the earth's mantle was too conductive (at the time of the reversals) to allow a 15-day change to pass through to the earth's surface. Both assumptions appear to be wrong. This data implies that, somehow, the earth managed to reverse its magnetic field very rapidly in the past. But how did it do so?

Purpose and Outline of Paper

My 1986 ICC paper was not specific about the physical mechanism which caused the reversals, I merely showed that fast reversals were physically possible and suggested that strong convection (upflows and downflows) in the earth's fluid core might cause them. I suggested that a powerful event in the earth's core at the beginning of the Genesis Flood produced the convection. I do not know what that event was. It could have been, for example, heating of the core due to a sudden increase of radioactive decay (Humphreys, 1986, pp. 117, 125) or cooling of the mantle above the core (Baumgardner, 1986, pp. 17–30, see especially p. 29). It is not my purpose here to specify that event further. Instead, I want to develop a theory of how the resulting convection flows would produce magnetic reversals.

I will assume that the reader is familiar with basic electricity and magnetism, for which Barnes' textbook (Barnes, 1965, 1977) is an excellent introduction. In the following section I will explain some very important background concepts from some more specialized areas of study. After that I will introduce the main idea of this paper, reversed flux generation, listing some characteristics of the new flux and the type of convection flows needed to generate it. Then I will show the history of a magnetic flux line step by step, estimate the period of the reversals, and comment briefly on my theory. Finally, I will discuss the earth's magnetic field today and how this theory implies that the field is young. In all of this I will not try to be mathematically rigorous, but instead emphasize basic concepts. From time to time, I will refer to the sun, which like the earth's core is a sphere of hot, electrically conducting fluid. Astronomers have observed the sun reversing its general magnetic field every 11 years (Montie, 1982, p. 196; Newkirk & Frazier, 1982, pp. 25–34; Sheeley, 1981, pp. 1040–1048).

Background Concepts

To understand my theory, the reader needs to understand some important results from geophysics and *magnetohydrodynamics* (MHD), the study of magnetic fields in electrically conducting fluids. These results are well-understood by specialists, and well-verified experimentally. Shercliffe's textbook (1965) is a concise introduction to MHD. Moffatt's (1978) and Parker's (1979) books are more advanced, but quite helpful.

Earth's Interior Structure

The earth's core is a sphere of hot, dense material 3,500 km in radius at the center of the earth (Figure 1). Some of it (the very center) is solid, but most of the core is an electrically conductive fluid, an abyss more than 2,000 km deep. Above this great deep is the earth's mantle, 3,000 km of dense rock foundation supporting the granite crust beneath our feet. The mantle is much less electrically conductive than the core.

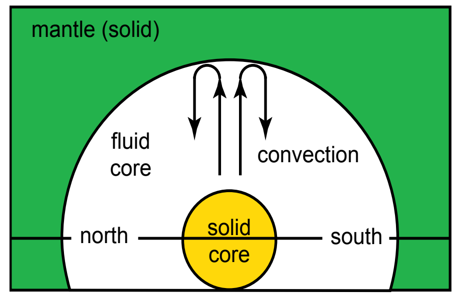

Figure 1. Convection flow in the earth's core.

Heat and Convection

When the lower parts of a body of fluid are sufficiently hotter than the upper parts, the fluid begins to circulate in the following way: Imagine a small parcel of fluid deep in the earth's core which becomes hotter than the fluid around it. The parcel expands and becomes less dense. Buoyancy then pushes the parcel upward, as if it were a bubble. As the parcel moves up, the pressure on it from the surrounding fluid decreases because the amount of material above it has decreased. Because the pressure decreases, the parcel expands further. The expansion decreases the temperature in the parcel slightly. But the parcel has moved to a higher altitude, where the surrounding fluid is cooler. If the fluid within the parcel always remains hotter than the surrounding fluid, the parcel will continue to rise all the way to the surface of the core. The extra heat in the parcel will be transferred by conduction to the cooler mantle, and the fluid in the parcel will move to one side away from still-rising hotter fluid and begin to sink. This circulation of hot fluid rising from the interior and cool fluid sinking down, shown in Figure 1, is what we mean by convection. Evidence of small- and large-scale convection has been seen on the Sun, causing the patterns called "granulation" and "supergranulation" (Noyes, 1982, pp. 22–25, 136–140). More familiar examples are the rise of bubbles in a boiling pot of oatmeal, or the turbulent upwelling of a thunderhead as it rises into the stratosphere.

Frozen Flux

Now let us consider what our rising parcel of hot fluid does to a magnetic field. One of the most fundamental results of MHD is *Alfven's theorem*: conductive fluids moving perpendicularly to magnetic lines of force tend to carry the lines along with them, as if the magnetic field were "frozen" into the fluid (Moffatt, 1978, p. 43). This means that if the parcel of fluid contains some horizontal magnetic lines of force before it begins to rise, it will carry those lines upwards as it rises. The portions of the same lines of force in non-rising fluid will stay below, and the lines of force at the boundary will be stretched out like rubber bands between non-moving and rising portions of the fluid as Figure 2 shows. This transporting and stretching of magnetic flux has been observed in the laboratory (Kolm & Mawardi, 1961, pp. 1296–1304) and on the Sun (Wang, Nash, & Sheeley, 1989, pp. 712–718). Thus convection flows carry magnetic flux upward from the interior to the surface.

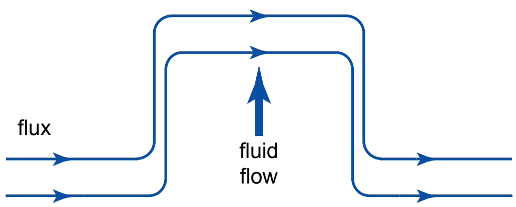

Figure 2. Transport of magnetic flux.

Reconnection

When an upward convection flow reaches the surface of the core, it spreads out to the side and then sinks down again. This pattern of flow distorts a flux line into the shape shown in Figure 3(a). Notice the regions where several parts of the line of force are next to one another, but in opposite directions. If such line segments are close enough together, another MHD phenomenon will occur, the rapid reconnection of adjacent but opposite flux lines (Parker, 1979, pp. 392–439), resulting in the more simplified structure of Figure 3(b).

Magnetic Buoyancy

Lines of force in the same direction in turbulent fluid tend to cluster, forming tubes of flux in which the magnetic field is stronger than in the surrounding fluid. The stronger field expels some of the fluid in the tubes, making the tubes less dense than the surrounding material, and thus buoyant (Parker, 1979, pp. 205–272, 314–358). The buoyancy of the flux tubes makes them resist being carried downward with the sinking cooler fluid. It is easier for the fluid to carry magnetic flux upward than downward. Thus convection flows carry more flux up than down, and flux accumulates at the surface.

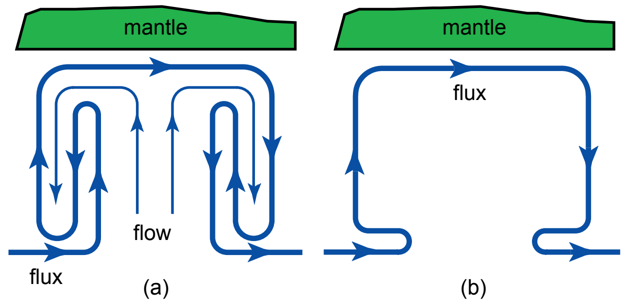

Figure 3. Effects on a magnetic line of force. (a) After convection. (b) After reconnection.

Diffusion and Flux Transport

Magnetic diffusion causes concentrations of flux to spread out into areas having less flux, whether fluid or solid (Shercliff, 1965, pp. 32–34). Diffusion is a slow process, very much like heat conduction. The higher the electrical conductivity of the medium, the slower the diffusion. This means that flux diffuses slowly through the core but rapidly through the mantle. For example, the effect of a sudden change in magnetic field deep in the interior of the core would take thousands of years to diffuse up through the highly conductive core fluid to the core surface. Convective fluid flow, on the other hand can carry flux upward much faster. Flux accumulated within the topmost few kilometres of the core will diffuse up into the mantle within a few weeks. Thus the combined effect of convection, magnetic buoyance, and diffusion is to carry magnetic flux up from the deep interior, as shown in Figure 3(b), and push it outward into the mantle. Related concepts in MHD literature are "flux exclusion" and "topological pumping" (Moffatt, 1978, pp. 59, 70; Parker, 1979, pp. 314–358, 440–463), both of which also move flux out of the interior. Once flux is out of the core, it can diffuse rapidly up through the much less conductive mantle, reaching the earth's surface within days.

Reversed Flux Generation

This section describes an effect which is crucial to the theory I am developing: Magnetic flux being moved rapidly generates new magnetic flux of the opposite polarity. I have not been able to find this effect described anywhere in the literature, but it follows straightforwardly from basic electromagnetic phenomena and the reasoning described below.

For the following discussion, it is very important to clearly visualize the various directions (see Figure 4). Imagine yourself standing within the Earth's core near its Equator. "Down" is toward the center of the earth, beneath your feet, and "up" is toward the core-mantle interface, above your head. Define "up" to be the x-direction. Now face toward sunrise (if you could see through the mantle), just as if you were on the earth's surface. That direction is "east," which we

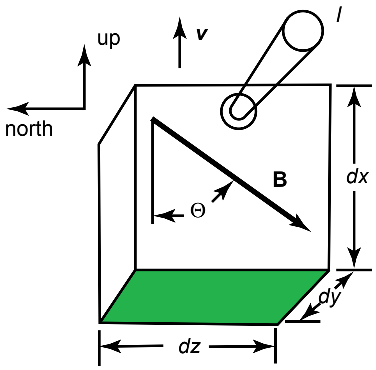

Figure 4. Fluid parcel moving up. Current I is eastward, into paper.

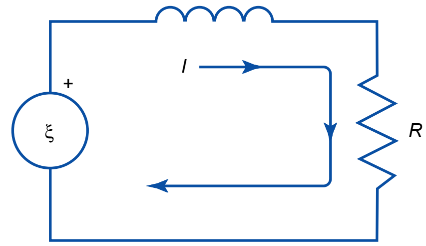

Figure 5. Equivalent electric circuit for current induced by v× B force.

define as the *y*-direction. Keep on facing east for the next two sections of this paper. To your left is "north," which we define as the *z*-direction. Your frame of reference is at rest with respect to the center of the earth; it does not move during our discussion.

Imagine a rectangular parcel of fluid in front of you. It has dimensions *dx*, *dy*, and *dz*. Suddenly, at time t=0, the parcel begins moving upward in the *x*-direction at velocity **v** (bold type denotes vectors) with respect to your frame of reference. The parcel contains a southward (toward your right) magnetic field **B** making an angle θ with the (vertical) *x*-axis. As mentioned in the previous section, this magnetic field is "frozen" into the parcel and moves upward with it. The Lorentz force, **F**, on an ion of charge *q* moving with the parcel is:

$$\mathbf{F} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B}) \tag{1}$$

where **E** is the electric field in the parcel, initially zero. According to the familiar right-hand rule for vector products, the **v**×**B** force pushes positive ions eastward (the direction you are facing) in the *y*-direction, producing an eastward electric current *I* through the parcel. Imagine, for now, an instant when the parcel has not moved up very far compared to its dimension *dx*. Since current is conserved in an electrical conductor, this current must leave the east side (away from you) of the parcel, circle back around you, and return from the west (behind you). Most of the current will be in your vicinity. The resulting loops of current constitute an electric circuit whose self-inductance is *L* and resistance is *R* (Figure 5). Since the rest of the fluid in your vicinity is not moving, this circuit is motionless in your frame of reference. The voltage source in this circuit is the electromotive force (e.m.f.) ξ produced by the **v**×**B** force over the length *dy* of the moving parcel:

$$\xi = |\mathbf{v} \times \mathbf{B}|\, dy = v \sin \theta\, B\, dy \tag{2}$$

where $v = |\mathbf{v}|$ and $B = |\mathbf{B}|$. Some readers may think the parcel will produce no e.m.f. because the source of the field is moving along with the conductor, but it turns out that this is not so (Panofsky & Phillips, 1955, p. 150). The induced e.m.f. of the inductance *L* and the voltage drop across the resistance *R* produce an electric field **E** in the parcel which exactly balances the **V**×**B** force. That is, the current I and its rate of change *dI*/*dt* will be such that:

$$\xi = L\frac{dI}{dt} + IR \tag{3}$$

Since the parcel began moving at time zero and maintains a constant velocity thereafter, the electromotive force of Equations (2) and (3) will be a step function of time. Then the solution of Equation (3) is:

$$I(t) = I_{\max}(1 - e^{-t/\tau}) \tag{4}$$

where I_m=(ξ/*R*) is the maximum current, and τ=(*L*/*R*) is the time constant of the circuit. If the velocity v greatly exceeds a critical velocity v_{crit} such that:

$$v >> v_{crit} = \frac{dx}{\tau} \tag{5}$$

then the parcel will move a distance equal to its own *x*-dimension *dx* in a time *dt* which is much less than the time constant τ. During that time, the second term of equation (3) is much smaller than the first term, and we have:

$$\xi = L\frac{dI}{dt} \tag{6}$$

The current *I* moving through inductance *L* produces magnetic flux, Φ_{new}, which did not exist previously. The next section discusses the location and orientation of this new flux (Figure 7). Since by the definition of inductance, $\Phi_{new}=LI$, the rate of increase of the new flux is:

$$\frac{d\Phi_{new}}{dt} = L\frac{dI}{dt} \tag{7}$$

Using Equations (2) and (7) in Equation (6) gives:

$$\frac{d\Phi_{new}}{dt} = v \sin \theta\, B\, dy \tag{8}$$

The magnetic field intensity B in the moving parcel is simply the old flux, $d\,\Phi_{old}$, in the parcel divided by the area normal to the field lines:

$$B = \frac{d\Phi_{old}}{\sin\theta\, dx\, dy} \qquad (9)$$

Using this equation and the fact that $v=(dx/dt)$ in Equation (8) gives us:

$$\frac{d\Phi_{new}}{dt} \approx \frac{dx}{dt} \sin\theta \frac{d\Phi_{old}}{\sin\theta\, dx\, dy} dy = \frac{d\Phi_{old}}{dt} \qquad (10)$$

Integrating equation (10) shows that the amount of new flux generated in the circuit is approximately equal to the amount of old flux moving through it:

$$\boxed{\Phi_{new} = \Phi_{old}} \qquad (11)$$

After the old flux in the rising parcel moves out of your vicinity, the electromotive force in the circuit of Figure 5 will drop to zero, but the magnetic energy stored in the inductance L will keep the current I circulating around the circuit (Nayfeh & Brussel, 1985, pp. 395–396). This means that the new flux will continue to exist in your vicinity, even though the old flux which produced it has moved away from you. The current and the new flux will then decay with time constant τ as power is dissipated in the circuit resistance R.

Characteristics of the New Flux

Figure 6(a) shows a new loop of flux generated by a brief upward motion of a line of old flux. The crossed-circle symbol (arrow going into the paper) shows the newly-generated electric current going eastward (away from you). As I mentioned above, this current circles back around all sides of the new flux loop and re-enters the parcel from its west side. Most of this current will be within a radius several times the dimensions of the parcel. The upper side of the new flux loop is next to the old flux, and it points in the same direction, south (to your right). The lower side of the new flux remains right in front of you at the location where the old flux started its journey upward, and it points in the opposite direction, north (to your left). Figure 6(b) shows a second loop of new flux created by a second brief motion of the old flux. Notice that in the region where the two new loops are next to one another, the two flux lines are in opposite directions, and reconnection can occur. The two loops cancel where they oppose one another and combine to form the larger loop shown in Figure 6(c). If the motion had been continuous, the flux loop of Figure 6(c) would have been produced immediately.

In Figure 6(c) there is twice as much current as there was in Figure 6(a). But the flux lines circle a perimeter which is twice as long, so by Ampere's law the field B along the perimeter remains the same.

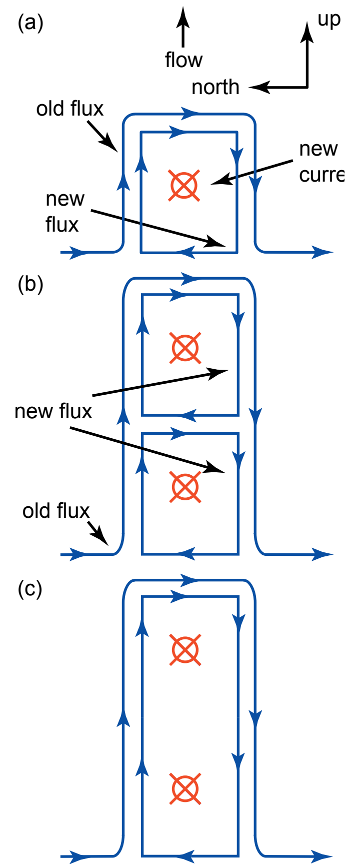

Figure 6. (a) New flux generated by brief upward motion of the fluid. (b) Additional new flux made by a second upward motion. (c) After new flux reconnects. Currents eastward, into paper.

Thus the total number of flux lines in the loop remains the same from 6(a) to 6(c). The flux lines now occupy a great volume, which means that the energy stored in the new flux has increased. In other words, it requires energy to increase the area of a flux loop. This energy comes from the rising parcel, and ultimately from the heat which creates the buoyancy of the parcel. The buoyant force works against a retarding force produced by the action of the old flux on the new current. You can feel the same retarding force in a hand-cranked electrical generator whose output has been shorted with a loop of wire. In a similar way, the buoyant parcel performs work to produce the new currents and flux. Some of this energy is dissipated immediately in ohmic heating, but much of it is stored in the new magnetic flux. Regardless of the energy losses, the amount of new flux will be nearly the same as the amount of old flux, if the fluid is moving fast enough to generate the new flux in a time which is short compared to the decay time τ of the loop. However, because the fluid cannot move infinitely fast, the amount of new flux will always been less than the amount of old flux:

$$\boxed{\Phi_{new} < \Phi_{old}} \qquad (12)$$

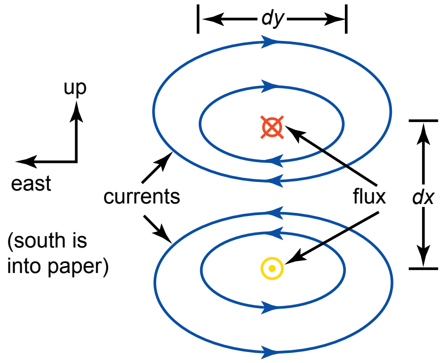

Figure 7. Electric currents around new flux.

Critical Size and Velocity of Flows

Figure 7 shows the electrical currents around the new flux in the case that $dx \approx dz$. By approximating the current configuration as a section of coaxial cable, one can show that the time constant τ of the circuit is of the order of

$$\tau \approx \mu_o \sigma (dx)^2 \tag{13}$$

where μ_o is the magnetic permeability of free space and σ is the electrical conductivity of the fluid. Solving this for the critical linear dimension dx_{crit} necessary to get a certain value of τ gives:

$$dx_{crit} \approx \sqrt{\frac{\tau}{\mu_o \sigma}} \tag{14}$$

The conductivity of the earth's core as estimated from the observed decay rate is about 40,000 mho/m (Barnes, 1973, pp. 222–230; 1983, pp. 81–99), which agrees with Stacey's rough estimate based on material properties (Stacey, 1967, pp. 204–206). To get a decay time greater than two weeks, Equation (14) requires that the rising parcel of fluid must have linear dimensions greater than about 5 km. Convection of parcels much smaller than this will not have any effect on reversals having a period of several weeks. Equation (14) also shows that the flux generation process which I describe could not be used to support the idea of very slow reversals, because periods greater than 20,000 years would require convection flows whose scale is larger than the earth's core.

Now we can determine the critical fluid velocity v_{crit} referred to in the previous section, the velocity which the fluid must exceed to generate a significant amount of new flux. Using Equation (14) in equation (5) gives:

$$v_{crit} \approx \frac{1}{\sqrt{\mu_o \sigma \tau}} \tag{15}$$

For the conductivity of the earth's core fluid given above and a time constant of two weeks, $v_{crit} = 0.4$ cm/s. Even at the critical velocity, the amount of new flux generated would be less than half the old flux. For efficient new flux generation, the fluid velocity would have to be more than an order of magnitude greater than the critical velocity, say roughly 10 cm/s. Below we shall see that another condition raises the required velocity to several meters per second.

History of a Magnetic Flux Line

Figure 8 shows, in a simplified way, how the above process eventually results in reversed flux outside the core. In Figure 8(a) we see an original, first-generation line of force which points southward in the core and northward outside it. By Ampere's law, the electric current which maintains this line must be within it. Since the core is a much better conductor than the mantle, most of the maintaining current will be in the core. This current circulates westward around the whole core, as shown by the circle-and-dot symbols (arrows coming out of the paper).

Figure 8(b) shows what happens as a parcel of heated fluid carries a segment of the flux line to the surface of the core. A second-generation loop of flux has been created. The electric current maintaining the new flux moves eastward through it and circles back westward around it on all sides. Part of the first-generation line has popped out into the mantle, along with some of the westward current maintaining it.

In Figure 8(c) we see the result of many parcels having risen to the surface. Now the first-generation line has been pushed almost completely out of the core, and its maintaining current is circulating westward through the mantle around the core. There are many loops of second-generation flux left behind in the core, each with their own maintaining currents.

Figure 8(d) shows what happens after the second-generation loops of flux reconnect, forming a single large loop within the core. Similarly, the maintaining currents link up with currents from other second-generation lines to the east and west, becoming larger in diameter until the currents go all the way around the core eastward. In the meantime, the first-generation flux is dying away, because its westward maintaining currents have been dissipating themselves in the higher-resistance material of the mantle.

Figure 8(e) shows the second-generation flux after it has partly diffused out of the core surface. Once free of the core, it moves rapidly up to its full extent, as shown in Figure 8(f). It is very similar to the first-generation flux, except that its direction is reversed. In the meantime, convection flows continue, beginning to produce third-generation flux. This cycle of reversals will continue as long as convection flows greater than the critical size and velocity persist. When the upflows become smaller or slower, the reversals cease.

Period of the Reversals

In actuality, convection flows are much more

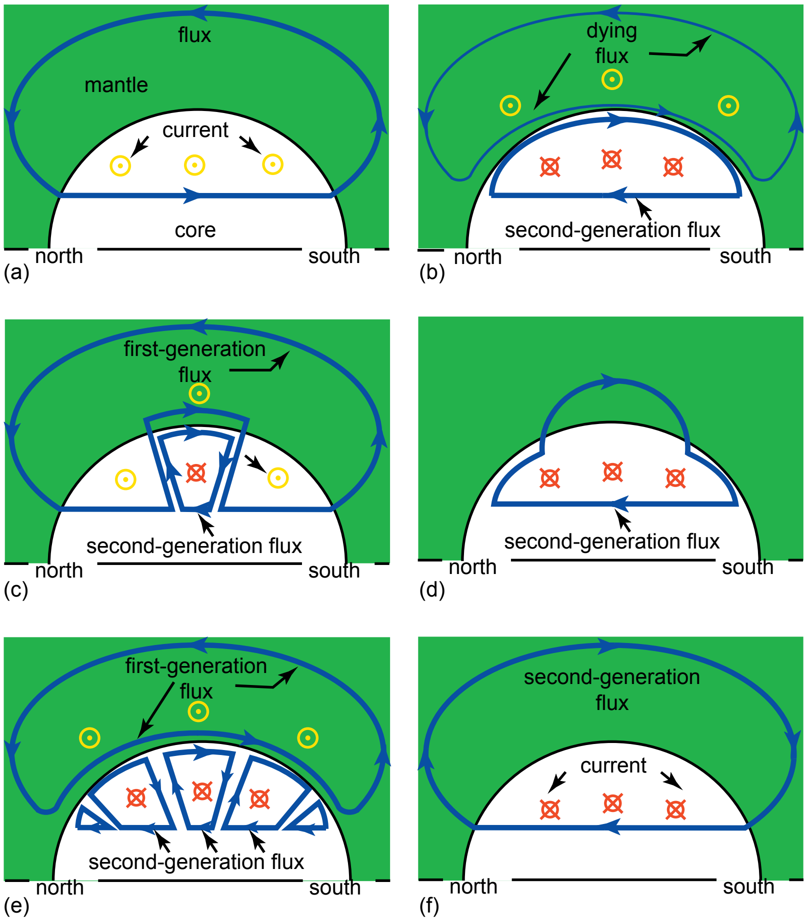

Figure 8. (a) First-generation flux and current.
(b) New flux is generated.
(c) First-generation flux out of core.
(d) Second-generation flux reconnects.
(e) Flux begins emerging from core.
(f) Reversed flux and current.

turbulent than Figure 8 would suggest, and Figure 8(c) should probably look more like Figure 9, a large number of small second-generation flux loops. These loops will not reconnect until the core becomes crowded enough with them to bring them close enough together to cause reconnections. During this complex stage, no net third-generation flux is created, because the effect of fluid parcels containing northward flux is cancelled by an equal number of parcels containing southward flux. Eventually, however, the interior becomes crowded with second-generation loops, and reconnections begin. When the reconnected second-generation loops become comparable in size to the core, as in Figure 8(d), then creation of third-generation flux begins.

The time required to go from Figure 8(a) to Figure 8(f), that is, the half-period of a reversal cycle, is partly, and perhaps mainly, determined by the time it takes the convection flows to push most of the first-generation flux up to the surface out of the core. Thus the reversal period is roughly related to the effective velocity of flux transport, v_{eff}:

$$\tau \approx \frac{R}{v_{eff}} \tag{16}$$

where R is the radius of the core. This effective velocity depends on what fraction k of core fluid is moving at any given time, the average velocity v_{ave} of the flows, and the efficiency ε with which the flows manage to deposit flux at the surface without taking it back down again:

$$v_{eff} = \varepsilon k v_{ave} \tag{17}$$

From Equation (16) we find that to get flux from near the center out to the 3,500 km radius of the core in two weeks would require an effective velocity of 3 m/s.

Comments

This theory hinges on the validity of the mechanism for generating reversed flux outlined in equations (1) through (11). This mechanism is a new effect, not discussed in any of the MHD literature as far as I know. Thus I invite careful scrutiny of that section. If it is a valid effect, then we must ask ourselves why it has not been noticed before. Two of the reasons could be that: (a) Most MHD discussions of similar situations center on steady-state effects instead of time-dependent, transient effects, and (b) the external circuit is rarely considered. For example, textbooks often discuss Hartmann flows (Shercliff, 1965, pp. 143–149), which have the same orientation of magnetic field, fluid velocity, and induced current as in Figure 4. However, the textbooks only consider the steady-state solution and do not say where the current goes, thus neglecting transient effects and inductance in the external circuit.

The process I have outlined above is simple compared to the evolutionary "dynamo" theories. It differs fundamentally from the dynamo theories

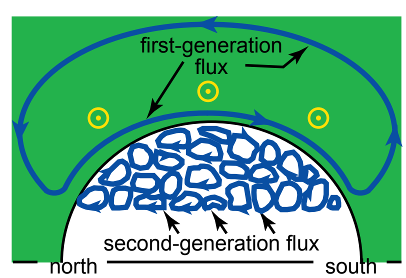

Figure 9. New flux before reconnection.

in that it is not intended to maintain the Earth's magnetic field for billions of years. Rather, it inverts a previously-existing field over and over again. Far from maintaining a field indefinitely, this process accelerates the decay of a planetary field. The field strength at the peak of each cycle is less than the peak of the previous cycle, because the inverting process does not completely reproduce the flux, according to Equation (12). New flux rises, phoenix-like, from the ashes of the old flux, but the new is always less than the old. This means that the energy contained in the post-Flood magnetic field would be considerably less than that of the pre-Flood field.

Paleomagnetic (during-Flood) data could support this view, but analysis is complicated because the attenuation of the earth's mantle (Humphreys, 1986, pp. 114–115) would decrease as convection velocities and reversal periods slowed down during the Flood. Archeomagnetic (post-Flood) data show a much lower field energy than the estimated pre-Flood level (Footnote 1), just as we would expect. The core disturbances during the Flood would excite non-dipole (four or more poles) components of the field. After the Flood such components would die away, causing the field at any given point of the earth's surface to fluctuate up and down for several thousand years (Humphreys, 1986, pp. 119–120). During that time the total energy in the field would continue to decrease (Footnote 2). Slowing convection flows persisting after the Flood probably also contributed to these fluctuations. According to archeomagnetic data, magnetic fluctuations stopped about 1,500 years ago and the field began decaying steadily.

The Earth's Magnetic Field Today

There is evidence that slow convection flows are occurring in the earth's core at present. Contour charts of the field's strength and direction show a pattern of "hills" and "valleys" which change shape over decades, like isobars on a weather chart. The whole pattern drifts westward at about 0.18° per year (Bloxham & Gubbins, 1985, pp. 777–781; Vorhees, 1976, pp. 12444–12466). The simplest explanation for this behavior would be the existence of convection flows. If there are convection flows at present, then there is a chance that the reversal process could still be going on today. Let us consider this possibility.

According to the magnetic contour data, the average upflow velocity is $v_{ave}=0.04\,\text{cm/s}$ (Bloxham & Gubbins, p. 781; Moffatt, 1978, p. 89), and the fraction of core affected appears from the charts to be roughly $k\approx0.1$. If the upflows were 100% efficient in carrying flux to the surface, we would have $\varepsilon=1.0$. Using these values in Equation (17) gives an effective velocity of about 0.004 cm/s. Using this value in equation (16) gives a period of roughly 3,000 years, not much different from the observed decay time of 2,000 years. Using the period above in Equation (14) tells us that the diameter of the upflows must be of the order of 1,000 km to be effective, roughly the same size as the contour plots indicate. In the absence of more detailed information about the flux-carrying efficiency of the convection flows, we cannot exclude (on the basis of this theory) the possibility that a reversal process is at work in the earth's core today.

There is some evidence for the feeble stirrings of such a process. Most of the energy of the earth's magnetic field today is in its dipole (two poles, north and south) component, and that energy is decreasing steadily (Barnes, 1971, pp. 24–29). However, a small part of the field energy is in non-dipole components (quadrupole, ocotopole, etc.), and that energy is presently increasing (McDonald & Gunst, 1968, pp. 2057–2067), showing that the core still has some magnetic activity. Some dynamo theorists interpret this activity as evidence that the present decay of the dipole field is part of the full-fledged reversal cycle in progress. If that were so, the non-dipole components at this stage of the alleged cycle would be strong, according to solar and paleomagnetic reversal data (Jacobs, 1984, pp. 65–72; Moffat 1978, pp. 101–105; Schneider & Kent, 1988, pp. 252–256). However, the non-dipole components are relatively weak. Another consideration is that there are no known polarity reversals in the archeomagnetic data, even though those data include a period after the Flood when the core convection would have been more vigorous than it is today. Thus it appears that the reversal process today is making only a minor contribution to the decrease of the field. But even if the reversal process were dominant today, the mechanism I depict in this paper would still, in the long run, dissipate field energy, not add to it.

Conclusion

Even though creationist explanations of planetary magnetic fields are still in their infancy, they appear to be more complete and successful than the 40 year old dynamo theories. Recent magnetic measurements by Voyager at Uranus and Neptune have confirmed the predictions of a creationist theory on the origin of planetary magnetic fields (Humphreys, 1984, pp. 140–149; in press), a theory which had already explained magnetic data in the rest of the solar system better than dynamo theories. Recent measurements cast doubt on a dynamo operating in the earth's core at present (Lanzerotti et al., 1985, pp. 47–49). As yet there is no dynamo theory which accounts for the extremely rapid variations reported by Coe & Prévot. Dynamo theorists acknowledge that their theories are incomplete, very complex, and not very successful at making predictions (Bagenal, 1989, pp. 18–19;

Dessler, 1986, pp. 174–175).

Early forms of the creationist free-decay theory were straightforward and mathematically complete (Barnes, 1973). They showed that if the earth's core had no internal motions (as if it were solid), the earth's magnetic field should always decrease. However, the real world is not as simple as that. The core is a fluid which has internal motions, and there is clear evidence that the field has gone through reversal cycles. Dynamo theorists have tried to use this evidence to support their view that the earth's field has persisted for billions of years. Until a few years ago they could claim this ground by default, but now my theory of reversals provides an alternative and (I think) better explanation. The theory accounts for fluid motions and explains the reversal data well, particularly the Coe & Prévot data. According to this theory, the energy (or during reversals, peak energy) in the earth's magnetic field has been decreasing rapidly ever since creation.

Such a decrease implies that the earth's magnetic field is not eternal, but is relatively recent. If we extrapolate today's energy decay rate back to the theoretical maximum energy at creation (Barnes, 1975, pp. 11–13; Humphreys, 1983, pp. 89–94), we get an upper limit for the age of the field: 8,700 years. However, the rate of energy loss would have been greater during and after the Flood, as I mentioned above. Figure 10 shows one scenario with about 90% of the field energy being lost during the Flood or shortly thereafter. This would make the age of the field about 6,000 years, thus allowing the tight-chronology Masoretic text age for the earth (Niessen, 1982, pp. 60–66). In summary, all the theoretical and observational information we have about the Earth's magnetic field supports the biblical record of a recent creation.

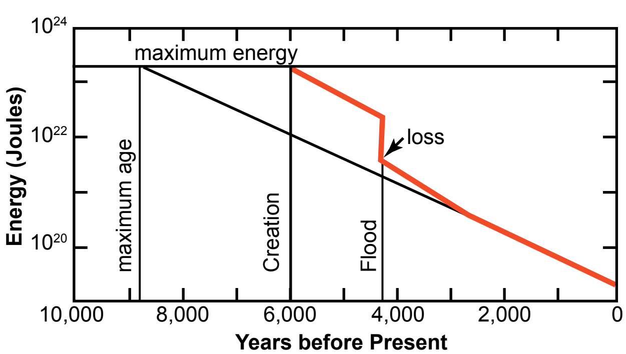

Figure 10. Energy in the earth's magnetic field.

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Wang, Y.M., Nash, A.G., & Sheeley, N.R., Jr. (1989). Magnetic flux transport on the Sun. *Science, 245*, 712–718. The fluid of the Sun rotates around its axis at different rates at various latitudes and depths. This "differential rotation" causes the north-south ("poloidal") flux lines to be stretched out in the direction of rotation, thus adding an east-west ("toroidal") component to the field. However, the existence of this part of the flux depends on the existence of the north-south flux, whereas the converse is not necessarily true. In the case of the earth's core, there is observational evidence (Lanzerotti, et al., 1985, pp. 47–49) that the east-west component is not very strong. In this paper I show a mechanism which reverses the north-south component without any dependence on an east-west component.

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Footnotes

1. Extrapolating today's decay rate for 1,656 years from the theoretical maximum created field (Barnes, 1973, pp. 11–13; Humphreys, 1983, pp. 89–94) gives a field strength before the Flood 30 times today's level, corresponding to a field energy of about 2×1022 J.
2. The field at a particular point fluctuates because of the different rates of decay of multipole components having different polarities, but in a free decay each component would steadily dissipate its energy into heat.

Discussion

Dr. Humphreys has, once again, demonstrated the fertility of creation science in his novel explanation of the magnetic field reversal data. The detailed theory presented in this paper warrants further, careful consideration by specialists in magnetohydrodynamics and geomagnetism.

For my own part, I am primarily concerned with the relationship of Dr. Humphreys' work to the age of the Earth question—a very minor portion of the present paper. Dr. Humphreys states that his theory implies an age for the earth's magnetic field of less than 9,000 years. This obviously conflicts with other geophysical data which strongly suggest a date for the Flood prior to 10,000 years ago [Aardsma, G.E., (1990). Radiocarbon, dendrochronology, and the date of the Flood. In R.E. Walsh & C.L. Brooks (Eds.), *Proceedings of the second international conference on creationism* (Vol. 2, pp. 1–10).] I am of the opinion that there is no real conflict of substance here, however, since the magnetic field data are not now, and have never been, definitive regarding the age of the earth. There is, of course, the obvious precariousness of such a large extrapolation of the relatively small amount of modern data into the distant past (to a starting value which cannot be determined experimentally) which is required to determine the age of the earth (actually the age of the magnetic field) in this way. But more fundamentally, there is nothing either implicit or explicit in the recent creation framework which rules out a dynamo magnetic field data—free decay *and* dynamo. Since these two theories do not share identical implications for the age of the magnetic field all conclusions about the age of the earth which are drawn from magnetic field data must be viewed as tentative.

Quite apart from the existence of an alternate theory for the origin and sustenance of the earth's magnetic field is the question of the actual boundary on the age of the earth within which a free decay theory can function. Dr. Humphreys has shown one possible scenario (Figure 10) for the decay of the field energy, consistent with a 4000BC date for creation. It would be very helpful if he would discuss other possible scenarios and the consequent range over which the date of creation might ultimately be found without falsifying his free decay theory. Specifically, does he feel that free decay would be ruled out if the true date of creation were found to be say 12000BC?

Gerald E. Aardsma, PhD,
Santee, California.

This review will be restricted to the physical mechanism for reversals of the earth's magnetic field. Dr. Humphreys has come up with a novel and physically sound approach to reversals of the magnetic field. He correctly employs the principles of magnetohydrodynamics, to the electrically conductive fluid in the molten core of the earth, in connection with heat and convection there.

One of the phenomenon in magnetohydrodynamics is magnetic diffusion. It is not dependent on fluid flow. The rapidity with which magnetic diffusion takes place is inversely proportional to the electrical conductivity. The author makes use of the fact that the mantle has a much lower conductivity than the core.

Making us of that great increase in rapidity of magnetic diffusion, along with some of his original development, yields a very plausible mechanism for rapid magnetic field reversals outside of the core. Dr. Humphreys is to be commended for this ingenious approach to magnetic field reversals during the Flood.

Thomas G. Barnes, DSc
El Paso, Texas

I can find no fault with the magnetohydrodynamic mechanism proposed by Dr. Humphreys to explain the earth's magnetic field reversal, nor do I dispute the timescale inferred for this field reversal, given the sudden onset of the worldwide turbulent flow described by Figures 8a–f. Dr. Humphreys correctly points out, however, that the onset of this supposed turbulent flow requires a postulated "powerful event." This postulated core temperature inversion, which must be both very intense and very uniform, seems to me to be as suspect as the steady-state dynamo theories. I recognize that Dr. Humphreys' theory is remarkably successful at explaining existing paleomagnetic data and should be taken seriously. I also accept his assertion that existing data on field reversal obviates steady-state dynamo theories. It seems intuitive that heating mechanisms such as tidal forces, radioactive decay, and joule heating would be non-uniform and not steady-state, so that a successful dynamo theory, if it is ever developed, would have to accommodate the physics that Dr. Humphreys has described in this paper.

Thomas W. Hussey PhD
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Closure

Dr. Aardsma brings up some good points in regard to using the earth's magnetic field to estimate the age of the earth. I agree with him that in principle, self-sustaining dynamo theories are available to the young-earth creationist as a possible option. However, I don't think they are a very good option, because (a) no complete or even plausible dynamo theory exists, and (b) recent observations weigh against a working dynamo in the earth's core today (Lanzerotti, 1985). So it is my judgment (which could be wrong) that a self-sustaining geodynamo is unlikely.

On the basis of the magnetic field data alone, I cannot completely exclude Dr. Aardsma's possibility of a creation in 12000BC, and free decay would not be ruled out by such a timescale. The problem is that we have no direct measurements of the core's electrical conductivity. So I cannot say that all of the present decrease is due to free decay; some of the decrease might be caused by a residual form of my dissipative reversal mechanism, as I pointed out in the second-to-last section of my paper. That would reduce the slope of the line in my Figure 10 and push the dates of the Flood and creation backward. However, as my comments on Dr. Aardsma's article show, I do not find the case for a Flood earlier than 5,000 years ago very compelling.

Several years ago Dr. Barnes was justifiably concerned about the idea of rapid reversals, because at that time I had proposed no physical mechanism showing how such reversals could take place. I wrote this paper to relieve such concerns. Therefore I am very glad that he has found no fault with the mechanism I have presented, and I am quite grateful for his commendation.

I'm glad that Dr. Hussey found nothing wrong with the mechanism I proposed, because much of his professional experience has been closely related to magnetohydrodynamics. Upon further discussion with him since the time he submitted his comments, he has decided that the temperature distribution required for my mechanism would not have to be uniform. As for the intensity required, I offer the following rough calculations:

The temperature gradient required for convection to occur in the core has been estimated at about 14 K/km [Stacey, F.D. (1969). *Physics of the earth* (1st ed.), p. 255]. The gradient could have been at or near that value before the events of the Flood. To overcome magnetic forces (viscous forces turn out to be negligible), a parcel 5 km in diameter only needs to be one or two Kelvin hotter than its surroundings. This means that to power 50 reversals, the average core temperature does not need to change by more than 100K during the course of the Flood. The corresponding amount of energy is consistent with either the radioactive heating or lower-mantle cooling models (Humphreys, 1986, p. 126). Thus the reversal mechanism I propose fits in quite reasonably with other events associated with the Flood.

D. Russell Humphreys PhD