Reversals of the Earth's Magnetic Field During the Genesis Flood

D. Russell Humphreys, PhD,
9301 Gutierrez NE, Albuquerque, New Mexico, 87111, USA.*

*current address: Institute for Creation Research, PO Box 2667, El Cajon, California, 92021, USA.

Presented at the First International Conference on Creationism, Pittsburgh, Pennsylvania, August 4–9, 1986. Published in: Proceedings of the First International Conference on Creationism, *R.E. Walsh, C.L. Brooks, & R.S. Crowell (Eds.), pp. 113–123, 1986.*

Abstract

Strong convection in the Earth's core during the Deluge would rapidly reverse the magnetic field while the fossil layers were being laid down. Afterwards the field would fluctuate for several thousand years and then begin decaying steadily. This young-earth model explains the paleomagnetic and archeomagnetic evidence better than old-earth "dynamic" theories do.

Keywords

Earth's Magnetic Field, Earth's Core, Field Reversals, Electric Currents, Mantle Conductivity, Sun's Magnetic Field Archeomagnetic Data

Introduction

Fossil layers all over the earth contain strong evidence that the earth's magnetic field reversed its polarity many times during the period the strata were being formed. Evolutionists (Dalrymple, 1983, pp. 124–132) and old-earth creationists (Young, 1982, pp. 117–124) think of these reversals as being spread over millions of years. Many of them assume that processes in the earth's core have always been ponderously slow, and that it is physically impossible for the field to reverse itself in less than a few thousand years. Consequently, they explain archeomagnetic and historical evidence showing a steady decay for the past 1,500 years as being just another reversal in progress. They support this view by pointing out other archeomagnetic evidence that in earlier times the field fluctuated and then slowly increased to a maximum about the time of Christ.

On the other hand, young-earth creationists have accumulated a lot of evidence that the earth is much younger than millions of years. Such a short timescale suggests that planetary magnetic fields could just be remnants of their original fields at creation, that the fields are essentially caused by freely decaying electric currents in the conductive cores of the planets. The predominantly dipole (two poles, north and south) shape of the earth's field and its apparent exponential (constant percent per year) decay for the last 150 years (Figure 1) (Barnes, 1973, pp. 222–230; Humphreys, 1983, pp. 89–94) are just what nineteenth-century theorists predicted for free decay in a conducting sphere (Lamb, 1883, pp. 519–549). Moreover, the observed decay rate gives a reasonable value for the electrical conductivity of the earth's core, 40,000 mhos/meter (Barnes, p. 228). This value agrees with estimates of the conductivity of likely core materials at core temperatures and pressures (Stacey, 1967, pp. 204–206).

The simplicity of the free-decay theory is an advantage over the complexity of the "dynamo" theories which advocates of an old earth must invoke to explain the field. Unfortunately, the free-decay theory as it stands now does not explain numerous past reversals. One would think that young-earth creationists would try to modify the free-decay theory;

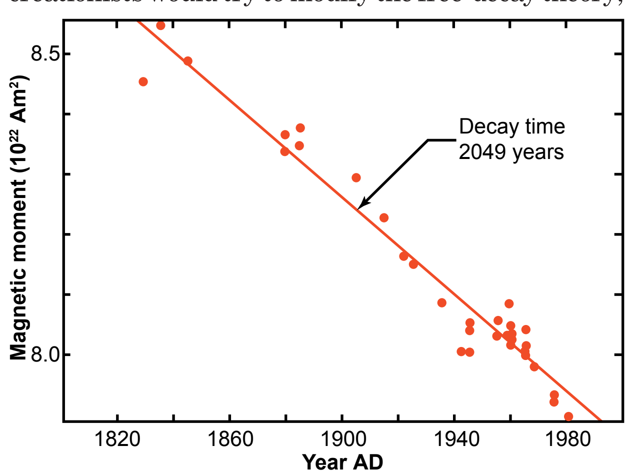

Figure 1. Measured decay of the earth's magnetic dipole moment during the last 150 years (Barnes, 1973, pp. 222–230; Humphreys, 1983, pp. 89–94.)

instead we have tended to dismiss the reversal data as being unconvincing (Barnes, 1972, pp. 47–50). But how compelling is the evidence?

Evidence for Reversals

For the past few years I have been studying many books and articles on paleomagnetism, talking to experts, gathering and measuring a few samples of my own, and preparing a review article for the *Creation Research Society Quarterly*. The evidence comes from field and laboratory studies of hundreds of thousands of samples taken from thousands of sites and reported by hundreds of authors over the past 50 years (Jacobs, 1984; Merrill & McElhinney, 1983). Fully half of all the samples are reversely magnetized (Jacobs, pp. 47–48). In most cases the magnetic directions from a single site are not randomly distributed, but cluster around a specific set of directions. There are clear correlations in the sequence of reversals from sites all over the world. Recently several sites have been found which record reversal transitions in detail, continuously tracking both direction and strength in small steps (Bogue & Coe, 1984, pp. 10341–10354; Prevot et al, 1985, pp. 230–234).

Several critiques of the field reversal hypothesis have appeared in creationist literature (Barnes, 1972, pp. 48–60, 1984, pp. 109–113). In my article for the *Quarterly*, I have listed all the specific criticisms I know of, and I have found adequate answers for all of them. For example, the often-repeated possibility of self-reversing rocks reflects a concern of paleomagnetists nearly 40 years ago. Since then, a number of careful field, laboratory, and theoretical studies have shown that self-reversal cannot explain more than a small percentage of the reversely magnetized samples (Jacobs, 1984, pp. 29–38; McElhinney, 1973, pp. 108–111). Another frequent criticism is that samples from different locations are not known to be simultaneous enough to allow us to map out the exact shape of the field at any particular time (Barnes, 1983). While the statement is probably true, it is irrelevant to the question of whether reversals occurred or not. Right now there is no place on earth (except perhaps the polar regions) where the field points south instead of north. The existence of even one genuine sample showing a southward field is proof that the field was drastically different at one time. The existence of over 100,000 reversed samples from many different strata all over the world shows that this "difference" was frequent and widespread. There are similarly simple answers for the other criticisms; in general, the critiques do not do justice to the sheer volume and variety of the positive evidence for field reversals. That evidence is too strong for me to dismiss. I conclude that field reversals at the earth's surface have occurred.

But I do not have the space to discuss the evidence in more detail here. What I want to do in this paper is to demonstrate that *reversals are possible within a young-earth framework*. First, I want to consider the basic physical requirements which would constrain any creationist reversal model. Next, I will review what astronomers have observed concerning the 22-year reversal cycle of the sun's general magnetic field, using those reversals as an example of how the earth might have done it. I will not try to develop a detailed explanation of the reversal mechanism in this paper. Instead I will show how the general features of my non-specific model explain both the amplitude and the frequency of the paleomagnetic data. After that, I want to show how a simple generalization of the free-decay theory can explain the archeomagnetic data showing large fluctuations in the field in prehistoric and historic times. Last, I will summarize what I am saying by outlining a general history of the earth's magnetic field from Creation to now.

Basic Physical Constraints

Since the field reversals are recorded in the fossil strata, the reversals must have happened when the strata were being laid down. Most young-earth creationists (including myself) are convinced that the Genesis Flood produced most of the fossil layers in a single year. Therefore, since roughly 50 reversals are recorded in the rocks, our model must average about one reversal per week (one full cycle every two weeks). Such changes are very rapid compared to the ponderous thousand-year or million-year timescales usually imagined for large changes in the field. If the reversals were indeed rapid, we can immediately deduce several things about the reversal mechanism and conditions during the Flood.

Mantle Conductivity

One deduction concerns the 2,700-km thick mantle (shell) of solid rock which supports the thin 30-km granite crust beneath our feet; in turn, the mantle floats atop the dense fluid core of our planet. There is much evidence that the mantle can conduct electricity, though not nearly as well as the core. This would make the mantle act like a screen, an electrical filter, slowing down and attenuating changes in the field as they move upward to the surface. A layer of thickness x and conductivity σ will attenuate a sinusoidally-varying field of period T by the following factor (Knoepfel ,1970, pp. 53–59)

$$A = \exp\left(-\sqrt{\mu\sigma x^2 / T}\right) \quad [\text{SI units}] \qquad (1)$$

(where μ is the magnetic permeability, $4\pi\times410^{-7}$ H/m). The higher the mantle conductivity, the slower the field changes we could observe at the surface. The fastest large change observed to date has been the 1969 "geomagnetic jerk," a sudden acceleration in the westward drift of the field. The change took about a year to complete, which implies that σx^2 for the conducting layer is of the order of 10^{13} mho/m, corresponding to an average mantle conductivity of about 100 mho/m. The exact value is a matter of vigorous debate among geomagnetic analysts at present (Courtillot & Le Mouel, 1984, pp. 706–716).

From this model, then, we would expect the average field at the earth's surface to be smaller during the reversals at the time of the Flood than it was just before the reversal started. A convenient measure of the strength of the field's source is its magnetic moment (explained in more detail in the next section). According to the free-decay theory, the earth's magnetic moment just before the Flood would have been more than 8.6 times the present value of 7.9×10^{22} A/m^2. But magnetic intensities at the earth's surface when the fossil layers were being formed were "abnormally low" (Merrill & McElhinney, 1983, pp. 195–196), corresponding to magnetic moments (in units of 10^{22} A/m^2) between 0.5 and 6.5 and averaging about 3.5. The reduction implies a mantle attenuation factor of 0.05, which would be produced by a σx^2 of 2.7×10^{12} mho/m. This value is within an order of magnitude of the present estimates, which are not well established yet.

Currents at the Top of the Core

A second implication of rapid reversals is that they could only be produced by electric currents in the outermost layers of the earth's fluid core. Using the core conductivity I mentioned in the introduction, 40,000 mho/m, in Equation 1 shows that a field reversing with a period of two weeks would be attenuated by a factor of 0.37 as it diffused up through about 3 km of core fluid. Such a small "skin depth" means that electric currents and magnetic flux deep within the core cannot produce rapid reversals directly. Any such deep flux would have to be carried up by flows of the conducting fluid, where it would then produce electric currents at the surface.

This simple consideration drives us to the following picture of the reversal process: a relatively thin layer at the top of the core produced a reversing magnetic field which was stronger than the much more slowly changing field contributed by deeper layers of the core. The field at the earth's surface, which is simply the sum of the two components, could then reverse rapidly.

The shape of the earth's field is mostly dipolar. The magnetic moment (mentioned in the previous section) of a dipole field is proportional to the current circulating in the source and the area encircled by the current. The magnetic moment M_s of a thin spherical shell of radius R conducting a current I_s is:

$$M_s(t) = \frac{2}{3}\pi R^2 I_s(t) \quad \text{A/m}^2 \tag{2}$$

The magnetic moment M_i of a freely-decaying current I_i in the interior of a complete sphere of radius R is (Barnes, 1973, p. 228)

$$M_i = 1.080 R^2 I_i \quad \text{A/m}^2 \tag{3}$$

The field at the earth's surface is determined by the total magnetic moment M:

$$M_{(t)} = M_s(t) + M_i \tag{4}$$

Comparing Equations 2 and 3 shows that the shell current is about 1.94 times as effective in producing magnetic moment as is the interior. That means, for example, that a three-billion ampere current flowing eastward on the surface of the core could cancel out the earth's present magnetic field, which is produced by a six-billion ampere current flowing westward throughout the core (according to the free-decay theory). If the surface current were six billion amperes, the earth's field would be just like our present one, only with an opposite polarity. So a core surface current can override the effects of the interior current, and it can do so rapidly.

The inductance (a measure of a circuit's resistance to changes in current) of the electrical path along the surface of a sphere of radius R is:

$$L = \frac{2}{27}\pi\mu R \quad \text{henry} \tag{5}$$

Using a radius of 3,470 km gives an inductance of 1.02 henry for the core. The electromotive force V required to change the current I flowing through an inductance at a rate dI/dt is:

$$V = L\, dI/dt \quad \text{volts} \tag{6}$$

To build up a current of billions of amperes through an inductance of one henry within days requires an electromotive force of the order of a hundred thousand volts.

So now, we have the basic electrical requirements of our reversal mechanism. It must be capable of applying roughly a hundred kilovolts of electromotive force around the outer perimeter of the core, and it must be able to maintain several billions of amperes through the circuit. This requires a power handling capacity of the order of a hundred trillion watts (10^{14} W). That may sound like a lot of power, but it is much smaller than the geologic power at work during the Genesis Flood. But is such a mechanism really possible?

Reversals of the Sun's Magnetic Field

There is an object in nature which demonstrates that a large body can rapidly reverse it magnetic field—the Sun (Newkirk & Frazier, 1982, pp. 25–34). By studying it we can get some clues as to how the earth might have reversed its field during the Flood. Spectroscopic observations show that the sun reverses the polarity of its general magnetic field every 11 years, in synchronism with its sunspot cycle. When the number of sunspots is at a minimum, the observed field on a large scale is mainly dipolar, with the lines of force going mainly north and south. Then the strength of the north-south part of the field begins to diminish, the number of sunspots begins to increase, and an east-west part of the field begins to appear, having a complicated structure. In about 5.5 years, the north-south component has diminished to zero, the number of sunspots is at a maximum, and the east-west component of the magnetic field appears to be wound around the sun like a ball of twine.

Then things begin to happen in reverse. A south-north part of the field appears, in the opposite direction from its predecessor. The number of sunspots starts to diminish, and the east-west part of the field begins to unwind itself. After another 5.5 years, the number of sunspots is at a minimum, the east-west component has disappeared, and the field again has a dipole shape, just as it did 11 years previously. Now, however, the north and south poles of the field have switched places. In another 11 years the field reverses again, making a total of 22 years for a complete cycle.

Theorists do not yet have a complete explanation for this complex reversal phenomenon. However, the sun somehow manages to do it in a relatively short time for such a large body. The electrical conductivity of the incandescent gas at the sun's visible surface (the photosphere) is between 10 and 1,000 mho/m, depending on the depth. According to Equation 1, the current producing the 22-year cycle must be mainly in the upper few hundred kilometers of the photosphere. Since the sun is 200 times larger than the earth's core, the inductance it must overcome to reverse its surface currents is 200 times greater than the earth's Equation 5. If at the time of the Flood the voltage generating mechanism in the core was about as efficient as the sun's is now, the earth could reverse its field in about 20 days. Also, the earth rotates about 30 times faster than the sun. If the reversal mechanism is proportional to rotation speed, then the earth could conceivably have reversed its field polarity in even less time.

Dissipative Reversal Mechanisms

One reason dynamo theorists have had difficulty explaining the sun's reversals is that they have been looking for a mechanism which would not only reverse the sun's field, but also regenerate and maintain it for billions of years. But if the sun is relatively young, less than a few tens of thousands of years, there is no need for the regeneration requirement. The sun could merely be winding up and unwinding whatever magnetic field it had at creation, losing magnetic energy each solar cycle. Then its long-term behavior would be a steady decay modulated by the solar cycle of reversals. Such a process would probably not be very efficient. Much energy would be lost in the small-scale turbulence of the solar gas. Magnetic fields from the deep interior would eventually have to replace the losses. Energy-dissipative mechanisms could reverse the polarity of the field but not maintain its intensity.

At present, I have a good idea for such a mechanism, but I am still developing it. Basically it works as follows: (a) Convective updrafts (in the sun's photosphere or the earth's core) carry more magnetic flux to the surface than downdrafts can carry away from the surface. (b) Flux carried to the surface rapidly cancels the flux above it. (c) The work done by convection in pushing flux upward generates new electric currents which in turn generate new flux in the opposite direction. The cycle period is controlled by the time it takes for the new flux to diffuse down to the depth where the convecting updrafts start. The motive power for this mechanism comes from the heat which drives the updrafts. The new flux which is generated is opposite in polarity to the flux from the previous cycle, and slightly less intense due to resistive losses in the conductor. New flux floating up slowly from the deep interior must constantly replenish the flux lost at the surface. The reversals would only continue as long as there was a strong heat source to maintain vigorous convection.

To sum up, my theory suggests that a powerful source of energy was turned on in the earth's core during the Genesis Flood. One possibility I am considering is that God greatly increased the rate of radioactive decay during the Flood year, gradually tapering it down to the present rate. But whatever the cause, the energy would cause fast enough convection to drive reversals. So far, this mechanism is making sense quantitatively, but it needs more work.

Answers to a Critique

In 1982 a creationist published a brief letter (Montie, 1982, p. 196) suggesting that the sun's magnetic polarity reversals appeared to contradict Thomas Barnes' view that reversal cannot occur. The first two points of Dr. Barnes' reply (Barnes, 1982, pp. 196–197) were that paleomagnetic data are too localized and too unreliable to establish the existence of reversals. I have already dealt with those two points earlier in this paper. His second two points were that the sun's magnetic field is too complex for us to say (a) that it is dipolar, and (b) that it ever reversed.

It is true that the sun's field is very complicated on a "local" scale (less than 100,000 km). Its intensity varies from a few tenths mT (a few Gauss) in quiet regions up to several hundred mT (several thousand Gauss) in sunspots; it loops thousands of kilometers out of one sunspot and into another. But if we average the fields over larger areas of solar surface during sunspot minimum, a simple pattern emerges: about 10^{14} Wb (10^{22} Maxwells) of magnetic flux emerges from one polar region and enters the other, and the average intensity decreases from a maximum of a few tenths mT (a few Gauss) at the poles to lower values as one moves toward the equator. Because of such data one astrophysicist says (Sheeley, 1981, pp. 1040–1048):

> It is well known that near sunspot minimum the sun's large-scale field is very nearly a dipole field whose axis is aligned with the solar rotation axis. The strength of this vertical dipole decreases with the onset of sunspot activity, and its polarity reverses near sunspot minimum.

Apparent Reversal Frequencies

This model explains a puzzling feature of the paleomagnetic data: abrupt changes in reversal frequencies. Figure 2 shows how the apparent frequency of reversals depends on the geologic age of the sample (Pal & Creer, 1986, pp. 148–150). By "apparent" frequency, I mean the number of reversals per unit of geologic time. By "geologic" time I mean simply the conventional age old-earth geologists assign to a sample, either by radiologic dating or by the fossils found nearby. If young-earth creationists are correct, geologic time x and real time t are quite different. However, since both are related to depth in the fossil layers, there should be a general correlation between them. If we call the number of reversals n, then the apparent reversal frequency dn/dx is related to the true reversal frequency dn/dt as follows:

$$\frac{dn}{dx} = \frac{dn/dt}{dx/dt} \qquad (7)$$

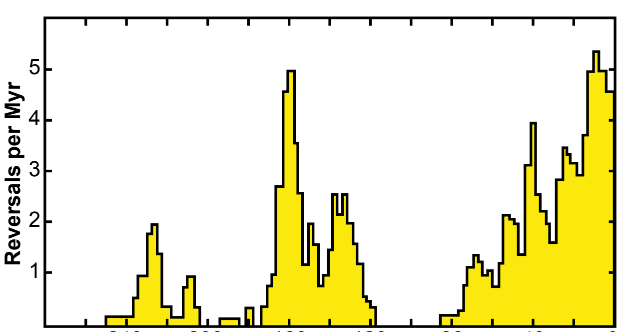

Figure 2. Apparent reversal frequency versus geologic "age" (Pal & Creer, 1986, pp. 148–150).

The quantity dx/dt, which I will call r, is the real-time rate of change of the geologic age parameter x. If x is roughly proportional to the depth of strata in any given location, then r is proportional to the deposition rate of the sediments forming the layers. Remembering that there are two reversals in a cycle of real-time period T, we can write the rate as:

$$r(t) = \frac{2}{\frac{dn}{dx} T(t)} \qquad (8)$$

If we make the crude assumption that T was constant throughout the Flood, we can use Equation (8) on the data of Figure 2 to see roughly how the deposition rate varied through the Flood. Figure 3 shows the result.

Figures 2 and 3 are two drastically different interpretations of the same data. The old-earth view (Figure 2) says that the reversal frequency fluctuated erratically over a hundredfold during the past, with two long dropouts in the upper Cretaceous and Permian, strong spurts in the lower Cretaceous, Jurassic, and Permian, and a fluctuating increase from the Paleocene to the Pliocene. The old-earth interpretation of these data requires at least nine or 10 large changes of power levels in the earth's core.

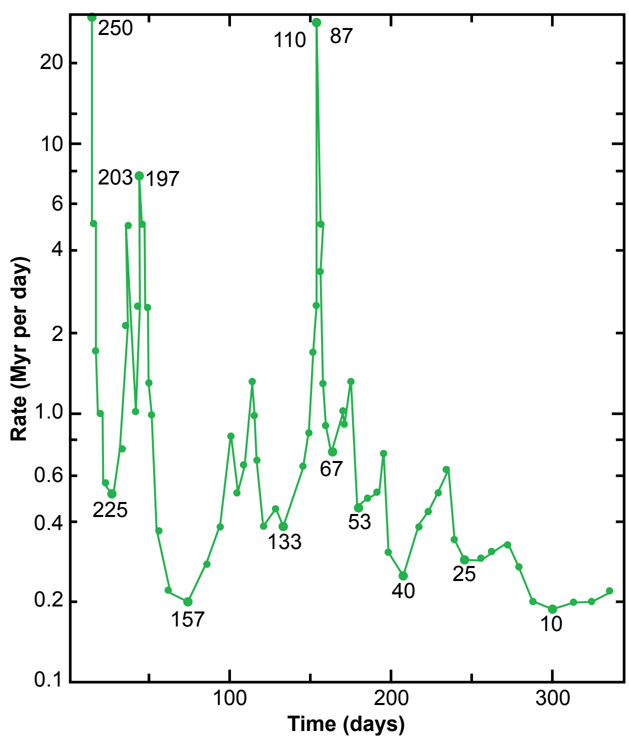

Figure 3. Sedimentation rate (rate of change of geologic "age") during the Flood, assuming twofold redundancy in reversal data and constant reversal period of four days. Numbers near large dots are corresponding geologic ages in Myr. Note that ages of the minima are very close to ages assigned to the boundaries of major strata, from Triassic to Pliocene. This implies that each stratum was formed during a burst of high sedimentation.

On the other hand, the young-earth interpretation (Figure 3) offers a simple explanation: most of the fluctuations in apparent reversal frequency would come from changes in deposition rate, not in the true reversal frequency. The dropouts would be periods of fast sedimentation, the spurts would be slowdowns of deposition, and the gradual increase in the upper strata would come from a tapering-off of sedimentation in the last stages of the Flood. Instead of many abrupt changes of power levels in the core, we would have only one. Sedimentation rates at the surface can change over a wide range, much more easily than energy levels in the core.

Field Fluctuations after the Flood

According to my model, the rate of energy release in the core jumped to a high level at the beginning of the Flood and gradually tapered off as the year progressed. Afterwards, the temperatures in the core and lower mantle would come to equilibrium and strong convection would stop. At that point we would expect the reversals to stop also. What would happen to the earth's magnetic field after that?

Higher-order Modes of Free Decay

Contrary to what we might expect, the field would not immediately start a steady exponential decay. In his 1973 paper re-investigating free decay in a conducting sphere, Barnes pointed out that the general solution was the sum of a number of different decay modes. However, since the higher modes would decay rapidly, he reasoned (correctly) that only the lowest mode would be important now. But the turbulence in the core during the Flood could put considerable energy into the higher modes, so we must consider their effect on the field right after the Flood. A freely-decaying magnetic field B in general depends on time t as follows (Parkinson, 1983, pp. 114–118):

$$B = \sum_{n=1} \left\{ \begin{array}{l} D_n \exp\left[-\dfrac{t}{T_d(n)}\right] + \\ Q_n \exp\left[-\dfrac{t}{T_q(n)}\right] + \\ O_n \exp\left[-\dfrac{t}{T_o(n)}\right] + \ldots \end{array} \right\} \qquad (9)$$

The terms D, Q, O, etc. are multipole orders, corresponding to $\neg = 1, 2, 3, \ldots$ in a standard spherical harmonic expansion. The index n is the degree of each mode of a multipole. Thus D_n represents the nth dipole mode, Q_n the nth quadrupole mode, O_n the nth octopole mode, and so forth. Higher-order multipoles have a more complex dependence on magnetic latitude and longitude than a dipole. All of these modes decay exponentially, each with its own decay time constant: $T_d(n)$ is the decay time of the nth dipole mode, $T_q(n)$ is the decay time of the nth quadrupole mode, etc. The decay times are all related to the conductivity σ and radius R of the sphere as follows:

$$T_\neg(n) = \frac{\mu\sigma R^2}{c_\neg(n)} \qquad (10)$$

where $c_\neg(n)$ is a constant which increases with increasing ¬ or n. For the modes of lowest order ($\ell = 1$), the constant is simply $C(n) = (n\pi)^2$. From the data in Figure 1, the present decay time of the earth's field is 2,049±79 years, which I assume is the time constant of the lowest dipole mode. Table 1 shows the time constants of some of the other modes.

The initial values (right after the reversals stop) of any of these modes could be either positive or negative, depending on the direction of the various swirls of electric current left circulating in the core by the turbulence of the Flood. Can these extra decay modes explain the behavior of the earth's magnetic field since the Flood? Table 2 summarizes the results of 1,167 archeomagnetic field intensity measurements as equivalent dipole moments averaged over 500 or 1,000 year intervals "for the past 12,000 years" (Merrill, 1983, pp. 101–106), which I assume represents the post-Flood period. Figure 4 plots the number of samples/century versus age. Notice that the slope changes more than tenfold very abruptly at 3,500 years BP (1500 BC). It looks just as if the timescale abruptly changed at that point. If there was no particular bias in selecting the 1,167 samples, the change of slope strongly implies a problem in dating samples more than 3,500 years old—that the dating technique stretches out the timescale, giving much greater ages than it should.

Table 1. Time constants of free-decay modes. $T_\neg(n)$ from theory for various multipole orders (1) and various degrees (n), assuming that the observed decay constant (Figure 1) is the lowest mode.

Order		$T_\neg(n)$ in years for:		
		$n=1$	$n=2$	$n=3$
1	Dipole	2,049	519	228
2	Quadrupole	1,004	338	170
3	Octopole	609	244	133

Corrected Carbon-14 Dates

Almost all archeomagnetic samples more than a few thousand years old are either directly or indirectly related to radiocarbon measurements. However, as young-earth creationists have long been pointing out (Whitcomb and Morris, 1961, pp. 374–378; Whitelaw, 1970, pp. 56–71, 83), present carbon-14 dating techniques take no account of the strong possibility that the percentage of carbon-14 in the air was much smaller before the Flood.

Table 2. Archeomagnetic dipole moments. Summary of 1,167 worldwide results (Merrill, 1983, pp. 101–106).

Published Age (years BP)	Number of Samples	Dipole Moment (10^{22}) A/m²	95% Error
0–500	268	8.72	0.17
500–1,000	187	10.30	0.27
1,000–1,500	205	10.90	0.27
1,500–2,000	131	10.94	0.37
2,000–2,500	89	11.10	0.54
2,500–3,000	60	11.28	0.63
3,000–3,500	43	9.64	0.85
3,500–4,000	17	9.21	0.90
4,000–5,000	34	8.87	0.74
5,000–6,000	44	7.20	0.57
6,000–7,000	36	6.73	0.65
7,000–8,000	18	7.08	0.66
8,000-9,000	15	8.61	1.17
9,000–10,000	14	8.26	1.25
10,000–11,000	5	6.76	1.17
11,000–12,000	2	8.36	—

The issue is very complicated, depending on: (a) the existence of a water-vapor canopy shielding the Earth's atmosphere from cosmic rays (Dillow, 1981, pp. 175–179), (b) possible changes in radioactive decay rates (Setterfield, in press), (c) the amount of carbon in the air and biosphere (Morris, 1974, pp. 161–167), (d) changes in the Sun's output of protons, (e) the exact date of the Flood, and even (f) changes in the strength of the Earth's magnetic field (Merrill, 1983, pp. 106–109). Creationists have been considering these possibilities, but as yet there seems to be no timescale based upon a careful study of all six factors and an adequate amount of the existing data. Therefore, we must generate a very crude scale for a first cut at the problem.

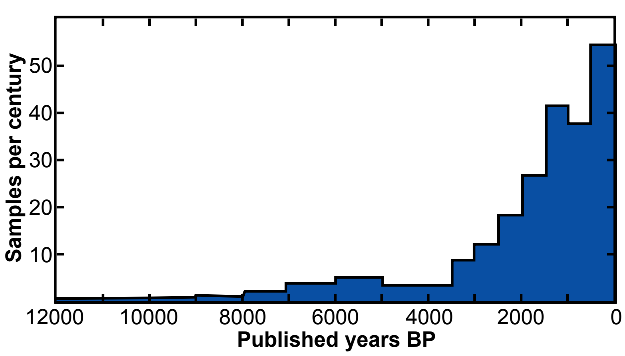

Figure 4. Number of archeomagnetic samples per century of published age, versus published (carbon-14) age. From Table 2 (Merrill, 1983, pp. 101–106).

For simplicity I assume (a) zero carbon-14 was in the air before the Flood, (b) the Flood occurred about 2450 BC (Niessen, 1982, pp. 60–66; Mauro, 1970, p. 20), (c) the percentage of radiocarbon in the atmosphere rose exponentially to its present value, and (d) that the rate of rise was fast enough to reduce the dating error by 1500 BC to less than 200 years. Assumption (d) requires a rise time constant of about 250 years, which could occur by a number of different combinations of factors 2, 3, 4, and 6. Table 3 lists the resulting correlations to the dates of Table 2.

Table 3. Corrected radiocarbon dates.
P = published age in years BP.
C = corrected age in years BP.

P	2,000	2,500	3,000	3,500	4,000	5,000	6,000
C	1,999	2,496	2,973	3,369	3,629	3,894	4,028
P	7,000	8,000	9,000	10,000	11,000	12,000	
C	4,111	4,168	4,211	4,245	4,271	4,293	

Figure 5 shows the archeomagnetic data plotted on my crude timescale. The solid line is a least-squares curve fit to the data using only the first and second dipole components and the first quadrupole component. The amplitudes of each component at 2450 BC are (in units of 10^{23} A/m²) 8.42, 9.23, and −15.5, respectively. The curve fits the general character of the magnetic data; it drops sharply after the Flood to a minimum of about three-quarters of the present field, and then it rises to a broad maximum at about the time of Christ. The quadrupole contribution seems to be necessary to get the broad maximum, because it has the next-to-longest time constant. This suggests that the older data should be re-analyzed allowing a quadrupole component. Several studies (Mauro, 1970, p. 20) confirm the existence of a significant quadrupole component in the paleomagnetic data from the upper fossil layers, so it is reasonable to look for such a component persisting into the period after the Flood.

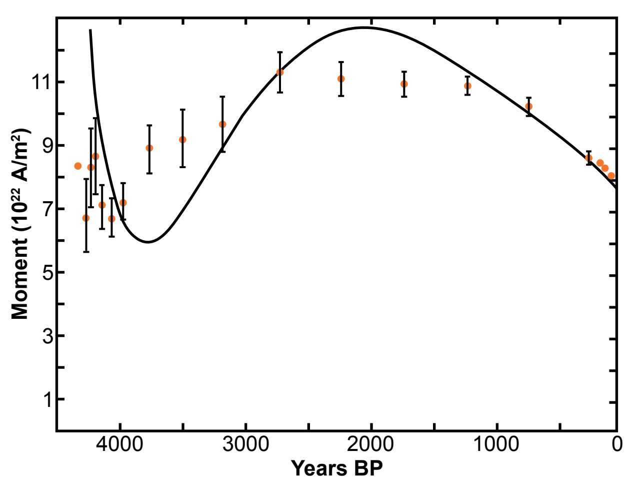

Figure 5. Archeomagnetic data.

Conclusion

Figure 6 summarizes what I think is the history of the earth's magnetic field. We can divide it into five episodes: (1) *Creation* of the field along with the earth, (2) *Steady decay* for nearly 2,000 years until the Flood, (3) *Rapid reversals* during the year of the Flood, (4) *Large fluctuations* continuing for several thousand years after the Flood, and (5) *Resumption of steady decay* from about the time of Christ to now. I have discussed Episode (1) in two previous articles (Humphreys, 1983, 1984, pp. 140–149) presenting a hypothesis about how God created planetary magnetic fields. The recent Voyager measurements of Uranus' magnetic field confirmed a prediction I made in the second article on the basis of the hypothesis. I have not discussed Episode (2) at all, but I would like to point out that its decay rate was not necessarily the same as the present rate. This paper mainly concerns Episodes (3) and (4), the sources of paleomagnetic and archeomagnetic data. As I mentioned earlier, the lower amplitude during Episode (3) comes from mantle screening and the fluctuations in Episode (4) come from higher modes of free decay. Dr. Barnes' analysis is based on the main features of the last century and a half of Episode (5).

The history I am outlining is more complex than Barnes' picture of a steady decay from creation to now, but it does not differ on the essential hypothesis: that the earth's magnetic field has freely decayed since its creation. I have merely made explicit two features which were always implicit in the free-decay idea: (a) that motions of the core fluid can perturb the field, and (b) higher-order modes of decay are possible. Both of these features have a firm basis in theory, experiment, and natural phenomena. The field reversals I am picturing differ in several essential ways from what dynamo theorists picture: (a) They were energy-dissipative. That is, the reversals did not add to the total energy in the magnetic field; instead they subtracted from it. (b) They did not involve the whole core; instead only the surface of the core participated. (c) They were the result of a single powerful even in the core rather than an ongoing process throughout the history of the field. In particular, the present decline of the field is not another reversal in progress; instead it is the last surviving free-decay mode.

This view of the earth's field appears to explain the major features of the paleomagnetic and archeomagnetic data fairly handily. Furthermore, it sheds light on the low intensity of the reversals and the erratic changes in their apparent frequency. And the hypothesis is testable: one way would be to look for strata which clearly formed within a few weeks and yet contain at least one reversal. For example, we could look for distinct lava flows thin enough that they would have to cool below the Curie temperature (500–700°C) within a few weeks. If any such flows contained a full reversal, they would be rejected as being unclear data by present paleomagnetic methods, so it is possible that the data we want already exists in the rubbish heaps and filing cabinets of paleomagnetic laboratories. However, the place to look for new data would be wherever there are many volcanos and long sequences of reversals already reported, such as Iceland. This would be a hard but exciting field project, if time, money, and trained people could be brought together on it. The results of such a search would certainly shed light on the subject of this conference, the age of the earth.

References

Barnes, T.G. (1972). Young age versus geologic age for the earth's magnetic field. *Creation Research Society Quarterly, 9*(1), 47–50.

Barnes, T.G. (1973). Electromagnetics of the earth's field and evaluation of electric conductivity, current, and joule heating in the earth's core. *Creation Research Society Quarterly, 9*(4), 222–230.

Barnes, T.G. (1982). Reply to Montie. *Creation Research Society Quarterly, 19*(3), 196–197.

Barnes, T.G. (1983). Earth's magnetic age: The Achilles heel of evolution. *Impact, 122*. El Cajon, California: Institute for Creation Research.

Barnes, T.G. (1984). Earth's young magnetic age: An answer to Dalrymple. *Creation Research Society Quarterly, 21*(3), 109–113.

Bogue, S.W. & Coe, R.S. (1984). Transitional paleointensities from Kauai, Hawaii, and geomagnetic reversal models. *Journal of Geophysical Research, 89*(B12), 10341–10354.

Courtillot V. & Le Mouel, J.L. (1984). Geomagnetic secular variation impulses. *Nature, 311*, 709–716.

Dalrymple, G.B. (1983). Can the earth be dated from decay of its magnetic field? *Journal of Geological Education, 31*(2), 124–132.

Dillow, J.C. (1981). *The waters above* (pp. 175–179). Chicago: Moody Press.

Humphreys, D.R. (1983). The creation of the earth's magnetic field. *Creation Research Society Quarterly, 20*(2), 89–94.

Humphreys, D.R. (1984). The creation of planetary magnetic fields. *Creation Research Society Quarterly, 21*(3), 140–149. On p. 146 I predicted: "In that case according to equation (3), (4), and (30), the present dipole moment of Uranus would be of the order of 10^{24}J/T." Voyager measured a dipole moment of 4×10^{27} Gauss/cm^3, which is 4×10^{24}J/T. (*Sky and Telescope*, April 1986, p. 335).

Jacobs, J.A. (1984). *Reversals of the earth's magnetic field.* Bristol: Adam Hilger Ltd.

Knoepfel, H. (1970). *Pulsed high magnetic fields* (pp. 53–59). Amsterdam: North-Holland.

Lamb, H. (1883). On electrical motions in a spherical conductor. *Philosophical Transactions of the Royal Society of London, 174*, 519–549.

McElhinney, M.W. (1973). *Paleomagnetism and plate tectonics* (pp. 108–111). Cambridge: Cambridge University Press.

Mauro, P. (1970). *The wonders of biblical chronology* (p. 20). Swengel, Pennsylvania: Reiner Publications. Mauro's date

for the Flood is 2390 BC. The date I have used is midway between Mauro's and Niessen's.
Merrill, R.T. & McElhinney, M.W. (1983). *The earth's magnetic field*. London: Academic Press.
Montie, M. (1982). More study needed on magnetic fields. *Creation Research Society Quarterly, 19*(3), 196.
Morris, H.M. (Ed.) (1974). *Scientific creationism* (general edition, pp. 161–167). El Cajon, California: Master Books.
Newkirk, G. Jr. & Frazier, K. (1982). The solar cycle. *Physics Today, 35*(4), 25–34.
Niessen, R.(1982). A biblical approach to dating the Earth: A case for the use of Genesis 5 and 11 as an exact chronology. *Creation Research Society Quarterly, 19*(1), 60–66. Niessen's date for the Flood is 2518 BC.
Pal, P.C. & Creer, K.M. (1986). Geomagnetic reversal spurts and episodes of extraterrestrial catastrophism. *Nature, 320*, 148–150.
Parkinson, W.D. (1983). *Introduction to geomagnetism* (pp. 114–118). Edinburgh: Scottish Academic Press. I have simplified Parkinson's notation and terminology.
Prevot, M. et al. (1985). How the geomagnetic field vector reverses polarity. *Nature, 316*, 230–234.
Sheeley, N.R. Jr. (1981). The influence of differential rotation on the equatorial component of the Sun's magnetic dipole field. *Astrophysical Journal, 243*, 1040–1048.
Stacey, F.D. (1967). Electrical resistivity of the earth's core. *Earth and Planetary Science Letters, 3*, 204–206.
Whitcomb, J.C. Jr. & Morris, H.M. (1961). *The Genesis Flood* (pp. 374–378). Grand Rapids, Michigan: Baker Book House.
Whitelaw, R.L. (1970). Time, life, and history in the light of 15,000 radiocarbon dates. *Creation Research Society Quarterly, 7*(1), 56–71, 83.
Setterfield, B. (in press). Carbon-14 dating, tree-ring dating, and speed of light decay (a preliminary model). *Ex Nihilo Technical Journal*.
Young, D.A. (1982). *Christianity and the age of the earth* (pp. 117–124). Grand Rapids, Michigan: Zondervan.

Discussion

This is an interesting paper on the relationship between reversals of the earth's magnetic field and sedimentary layering. It certainly treats the problem from a novel perspective. It is important to remember that this paper presents a scenario permitting a "young-earth" view to be consistent with paleomagnetic data on field reversals. The plausibility of the scenario seems to depend upon satisfying physical laws and the inclusion of singular events, that is, miracles. I do, in fact, believe in miracles, but it is hard to know if such a model is consistent with physical principles because of its singular element. Dr Humphreys' idea of looking for rapid reversals in volcanic flows would greatly alleviate this criticism since it represents a test of the scenario.

Charles R. Carrigan
Albuquerque, New Mexico.

In general Dr. Humphrey's paper is coherent and clearly exposed. The evidence tending to show that the earth's magnetic field is decaying exponentially, in accordance with the model of free decay within a conducting sphere, surely disarms any evolutionist claim for an old earth age. Dr Humphreys claims that both paleomagnetic and archeomagnetic samples, collected from thousands of places around the planet, show evidence for magnetic field reversals. He argues that convection within the earth's core during the Genesis Flood would rapidly reverse the direction of the magnetic field, with the latter being registered by the fossil layers as these were being laid down. If these fossil layers, as probable evidence for magnetic field reversals, can't be ignored, what would be then a more specific mechanism by which core convection can perturb the earth's magnetic field, thus making it reversal? What would be the specific reasons the electric currents at the boundary of the earth's mantle and core would trigger a reversal of the earth's magnetic field? Can Dr. Humphreys expand the arguments for establishing simultaneity of formation among the vast paleomagnetic and archeomagnetic samples collected so far?

Francisco S. Ramirez, Avila, Iv,
Cd. Juarez, Chihuahua, Mexico.

I commend Dr. Humphreys on this excellent paper. His development of a nonregenerative reversal theory, associated with the Flood, provides a physically plausible explanation of worldwide magnetic reversals. We have different criteria for "proof" of dipole reversals, but his theory leaves the long-age creationists in a dilemma because he employs the raw data they depend on.

A weakness in his paper is the failure to give a strong refutation of the dynamo theory, such as that in my *Origin and destiny of the earth's magnetic field*, (2nd ed.), Institute for Creation Research, or "Earth's young magnetic age confirmed", *Creation Research Society,* Vol. 23, June 1986, pp. 30–33. That left some loose ends in his episodes (1) and (4). It raised the question: Does this change the age limit set in a previous paper? The answer: It lowers that limit because his reversal process is dissipative.

Thomas G. Barnes, PhD,
El Paso, Texas.

It seems to me that Dr. Humphreys has succeeded in his stated goal of demonstrating that "reversals are possible within a young-earth framework." If, as Dr. Humphreys suggests, young-earth creationists have previously dismissed the very convincing data suggesting that the earth's magnetic field (as well as the sun's) has reversed itself many times in the past, then this is an important contribution to this field. The objections to the simplified version of the "free-decay" theory are well taken, and the argument that field reversal evidence in the fossil layer is due to rapid fluctuation in higher order multipole terms of the earth's magnetic field requires a minimum of assumptions. Nevertheless, I have some problems with the proposed convective model for generating the required fluctuations of surface currents on the core. Why is this any more believable than some sort of dynamo model required by an old-earth hypothesis? Dr. Humphreys proposed what seems to me to be a colossal level of core turbulence to create these rapid fluctuations. Could mantle and crust survive the rapid pressure changes as well as the concommitant rise in temperature? Would such a high level of turbulence disappear in only 1,000 years? I trust Dr. Humphreys will continue this excellent work by addressing such questions in future publications.

Thomas Hussey, PhD,
Albuquerque, New Mexico.

Closure

I am glad to have Dr. Carrigan's comments because he has done some significant research on the Earth's magnetic field. He brings up a question deserving serious thought: What is the proper place of miracles in a scientific theory? If there is a chance that God has intervened miraculously in the workings of the physical universe, then it would be foolish and unscientific for us to ignore that possibility. On the other hand, a theory which introduces miracles on an ad hoc basis every time it runs into trouble would certainly be inferior. There must be an optimum way to treat miracles somewhere between the two extremes. I propose the following guidelines as a sensible constraint on our thinking with regard to an assumed miracle:

1. Does the available evidence suggest it?
2. Does the Bible suggest it?
3. Does it minimize intervention and maximize explanation?
4. Are there some scientific ways to check the hypothesis?

I think of the third guideline as an "economy of action" principle, since the Bible presents God as doing things with precision. Thus, for example, I might suggest that God caused most of the physical phenomena of the Flood simply by increasing the rate of radioactive decay for a short time. There are some scientific data and biblical passages which suggest such an event, and it explains a lot of things with a single action. But then the fourth principle would require us to seek additional physical evidence that the decay rate did indeed change in the past.

I enjoyed meeting Mr. Ramirez at the Conference and I respect his theoretical talent. Since I outlined a possible reversal mechanism in the paper, I assume he wants me to explain the third step, the most essential stage of the mechanism. The convective upflow I mentioned carries north-south magnetic flux B upward with velocity v, producing a Lorentz force per unit charge $v \times B$ in the east-west direction. The collective effect of all the upflows is a large electromotive force around the perimeter, gradually building up an east-west surface electric current through the inductance I mentioned. This current produces new north-south flux in the opposite direction as the previous flux, which was canceled out by the rising flux when it reached the surface. The new flux would be equal in magnitude to the flux of the previous cycle except for the fact that losses occur. I emphasize that I am still working on this possibility; it may or may not turn out to be a valid model. The important point to keep in mind is that the Sun somehow manages to do the job, heedless of our feeble theories.

I cannot expand upon arguments for simultaneity of the reversals, as Mr. Ramirez asks, because I made no such claim in the paper. I was only concerned with the *existence* of reversals, not with the question of whether each one occurred at the same instant all over the earth.

I am honored by Dr. Barnes' commendation, since he pioneered creationist work on the earth's magnetic field. Without him, the decay of the field and its simple explanation as a free decay would probably still be buried in obscurity, unknown to the average creationist. However, I must point out that his criteria for reversals are overly stringent. Even if the reversals were not dipolar or simultaneous worldwide, they were very unusual magnetic phenomena which we creationists cannot dismiss with a few critiques.

The reasons I did not more vigorously criticize the dynamo theories, as Dr. Barnes wishes, were simply that (a) my space was very limited and (b) other creationists, including Dr. Barnes, have done an adequate job in that area. However, most mainstream scientists are still not aware of the problems with dynamo theories, so I will briefly touch upon them in my response to Dr. Hussey below.

Dr. Barnes', third point refers to my 1983 paper (Humphreys, 1983, pp. 89–94), which estimates the initial strength of the earth's magnetic field from a simple hypothesis. There was an arbitrary constant $\underline{k}$ in the theory which could have any value from zero to one. I gave a plausibility argument for my choice of the value $\underline{k}=\frac{1}{4}$; with that choice the initial strength of the field would be about 18 times higher than it is today. I then showed that extrapolating the present decay back 6,000 years gives a value within 5% of the other value, well within the observational error limits. However, if $\underline{k}$ were to have its maximum possible value of 1 (which I would prefer for aesthetic reasons), the initial strength of the field would be four times higher than my 1983 estimate. This would allow a 75% loss of energy during the reversals or in Episode 4 while still keeping the 6,000-year timescale. If less energy were lost it might extend the time by an additional 2,000 years, but no more. So there was a limited amount of flexibility in my 1983 theory, and it turns out to be enough to accommodate my present one.

Dr. Hussey has done good theoretical work in plasma physics; he gets right to the root of the matter by asking why my model should be considered more plausible than the dynamo theories. The first reason is that the dynamo models are not very plausible even without competition. After four decades of work by hundreds of theorists and experimentalists, the theory is still incomplete. No one has yet proven that a self-sustaining dynamo can actually work in the earth's core, or even that it is reasonable to expect one (without assuming that the earth is old). A number of "anti-dynamo" theorems have eliminated all the simple possibilities, and the theories have steadily become more and more complex, which makes them harder to prove or disprove. In addition, the theories have had some major difficulties with observed magnetic fields in the solar system (Humphreys, 1984). If my model turned out to be as unsuccessful after an equal number of man-years' work by clever people, I would regard it as a failure.

A second reason is that my model is actually *less* catastrophic than the current models, a situation I find ironic. Pal & Creer (1986), for example, invoke at least eight or nine large asteroid impacts to account for the spurts in apparent reversal frequency. These impacts must be severe enough to affect the earth's core as well as surface conditions. My model, on the other hand, has only one core disturbance, and yet it explains the frequency and amplitude data and the worldwide character of geologic strata (Figure 3). Since my model explains more data with fewer assumptions, it should be considered more plausible than the dynamo models.

Dr. Hussey feels that unusually high levels of turbulence in the core are needed to produce rapid reversals. But until I or someone else quantifies a dissipative reversal mechanism, nobody can really know what flow velocities are necessary, so we cannot yet calculate the effects on core, mantle, and crust. However, it is not essential to heat the core to produce the convection. Dr. John Baumgardner's paper (Baumgardner, J. [1986]. Numerical simulation of the large-scale tectonic changes accompanying the Flood. In R.E. Walsh, C.L. Brooks, & R.S. Crowell [Eds.], *Proceedings of the first international conference on creationism* [Vol. 2, pp. 17–24]. Pittsburgh, Pennsylvania: Creation Science Fellowship) outlines a model which would *cool* the top of the mantle by many hundreds of degrees, thus producing strong convection without increasing the core pressure.

I was disappointed that Dr. Dalrymple did not respond to the Conference's request to review this paper, because he is one of the founding fathers of paleomagnetism. His silence is particularly significant in light of his strong criticism of Dr. Barnes (Dalrymple, 1983) concerning the subject of this paper, geomagnetic reversals.

D. Russell Humphreys, PhD.