DECAY OF THE EARTH'S MAGNETIC MOMENT AND THE GEOCHRONOLOGICAL IMPLICATIONS

THOMAS G. BARNES*

It is now known, but not well publicized, that the earth's main magnetic field is decaying relatively rapidly. This paper considers a physical basis for this decay and experimental determinations that support it. The conclusion is reached that it is an exponential decay and that the half-life is 1400 years.

This rate of decay is assumed to have been constant since the origin of the magnetic field. It is then shown that the life of the earth's magnetic field should be reckoned in thousands, not millions or billions, of years. It is also shown that the stronger magnetic field in the past and its shielding effect would alter radio carbon dates, reducing the previously held dates.

Magnetic Moment: Source of the Earth's Main Field

The earth's main magnetic field has been shown to be due to a *magnetic dipole.*[1] The strength of a magnetic dipole is called its *magnetic moment.* The magnetic moment is due to circulating currents.

In the case of the earth these currents probably reside in the earth's core, which is thought to consist of hot liquid metal, perhaps iron. These currents are extremely large. There is no known mechanism to sustain these currents.[2] So, as one would expect, the earths magnetic moment is decaying.

This paper considers the experimentally determined decay of the earths magnetic moment. It is a surprisingly large decay rate for such a large scale phenomena.

The earth's magnetic dipole (Figure 1) is located about 300 kilometers from the center of the earth with the magnetic axis making an angle of approximately 11.5° with the rotational axis of the earth.[3] The magnetic dipole moment, M, points southward, yielding a magnetic field that points *outward* at the South Magnetic Pole and *inward* at the North Magnetic Pole.

The field due to this magnetic moment is symmetrical about its axis and may be represented by two orthogonal components, B_θ and B_r, as shown in Figure 2. These components can be derived from the magnetic moment, M, by the following equations:[4]

$$B_\text{ø} = \frac{\mu M \sin \text{Ø}}{4\pi r^3} \qquad (1)$$

$$B_r = \frac{\mu M \cos \text{Ø}}{2\pi r^3} \qquad (2)$$

where m is the *permeability,* a magnetic property of the medium. The value of m is usually taken as $4\pi \times 10^{-7}$, its value in free space, unless the medium contains an appreciable amount of magnetic material.

In order to have up-to-date units the "Systeme International d'Unites" (called SI for short) is

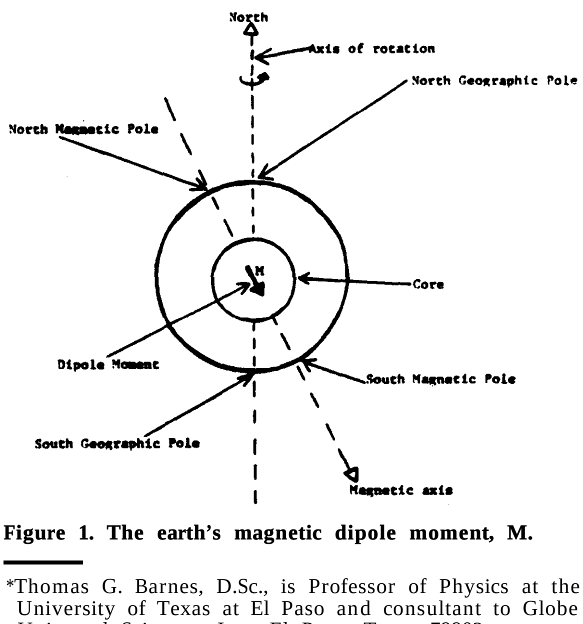

Figure 1. The earth's magnetic dipole moment, M.

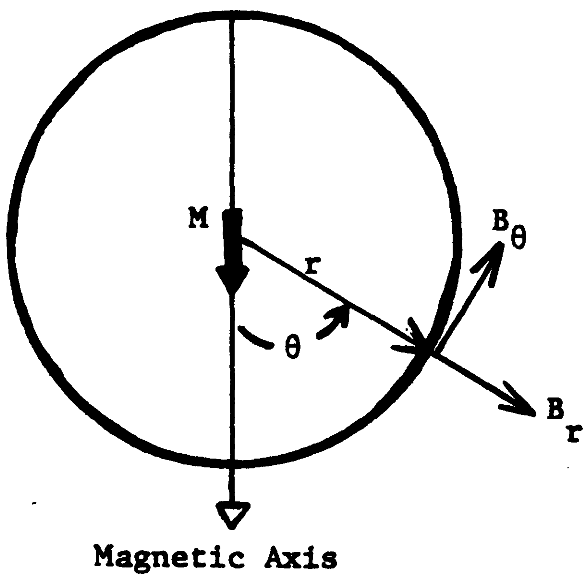

Figure 2. Field components due to the magnetic moment.

*Thomas G. Barnes, D.Sc., is Professor of Physics at the University of Texas at El Paso and consultant to Globe Universal Sciences, Inc., El Paso, Texas 79902.

Magnetic Moment M and Equitorial Magnetic Field B_0 of the Dipole. 1835 to 1965
(Earth radius = 6.371 x 10^6 meter)

Scientists	Year (Epoch)	M (amp meter²) $\times 10^{22}$	B_0 (tesla) $\times 10^{-5}$
Gauss	1835	8.558	3.309
Adams	1845	8.488	3.282
Adams	1880	8.363	3.234
Neumayer	1880	8.336	3.224
Fritsche	1885	8.347	3.228
Schmidt	1885	8.375	3.239
Vestine, et al	1905	8.291	3.206
Vestine, et al	1915	8.225	3.181
Dyson-Furner	1922	8.165	3.157
Vestine, et al	1925	8.149	3.151
Vestine, et al	1935	8.088	3.128
Jones-Melotte	1942.5	8.009	3.097
Vestine, et al	1945	8.065	3.119
Afanasieva	1945	8.010	3.097
U.S.C. & G.S.	1945	8.066	3.119
Fanselau-Kautzleben	1945	8.090	3.128
U.S.C. & G.S.	1955	8.035	3.107
Finch-Leaton	1955	8.067	3.120
Nagata-Oguti	1958.5	8.038	3.108
Cain, et al	1959	8.086	3.127
Fougere	1960	8.053	3.114
Adam, et al	1960	8.037	3.108
Jensen-Cain	1960	8.025	3.103
Leaton, et al	1965	8.013	3.099
Hurwitz, et al	1965	8.017	3.100

employed. In this system the unit of B is the *tesla* (equal to 10^4 gauss, the unit most often found in the literature) and M has the units *amp meter*^{2} (reminding us that it consists of circulating *amperes* of current enclosing *meter*^{2} of area).

The net field, B_0, at any point on the magnetic equator reduces to the B_θ component and may be written as

$$B_0 = \frac{\mu M}{4\pi r^3} \qquad (3)$$

because sin 90° = 1. Letting the earth's radius r = 6.371 X 10^6 meter and $m = 4\pi \times 10^{-7}$, the equatorial value of B at the surface is

$$B_0 = 3.687 \times 10^{-28} M \qquad (4)$$

This example illustrates how Equations (1) and (2) enable one to compute the earth's main field at any point (r, θ) on earth, or above the earth, if the earth's magnetic dipole moment is known.

Historical Values of the Earth's Magnetic Moment Indicate the Decay

The study of the earth's magnetism led Gauss to develop a magnetometer for making *absolute* measurements of B and to develop a mathematical method (spherical harmonic theory of potentials) for analyzing the magnetic surveys of the earth.[5] Gauss was then able to determine the magnetic dipole moment of the earth. His determination for the year (epoch) 1835 is M = 8.558 x 10^{22} amp meter.[2] This value of M and the date 1835 are taken as a key historical reference from which the decay in the earths magnetic moment has been measured.

Table 1 contains the values of the earth's magnetic dipole moment, the net field value B_0, the year (epoch), and the scientists who made the determination. The source for the magnetic moment values is a recent U. S. Department of Commerce ESSA publication[6] produced by the Institute for Earth Sciences, Boulder, Colorado.

Values in that table were given in cgs units and have been converted to SI units through the conversion factor for magnetic moment, namely 1 unit of $M_{SI} = 10^3$ units of M_{cgs}.

The equatorial values for the field were computed by means of Equation (4). These computed values of B_0 check with those values which are listed in an early table by Sidney Chapman; after application of the conversion factor between SI and cgs units, namely, 1 tesla = 10^4 gauss.

It is clear from Table 1 that *the magnetic moment and the earth's main magnetic field have been decaying relatively rapidly since 1835.* Sidney Chapman states in his monograph *The Earth's Magnetism,*[8] in which he had compiled the data up to 1945,

these results certainly suggest a decrease

> of a few per cent. in H_0 and the earth's magnetic moment during the last century. When the great scale of the phenomenon is considered, this must seem a remarkably large and rapid secular change, not paralleled for any other worldwide geophysical property.

Chapman used the symbol H_0 instead of the symbol B_0, used in this paper, but it refers to the same magnetic field.

Additional confirmation of the rapid decay rate of the earth's magnetic moment can be seen in the following quote from the aforementioned ESSA publication,[9]

> Since the time of Gauss' measurements the earth's dipole moment has decreased, sensibly linearly, at approximately the rate of 5% per hundred years. Assuming these rates to persist, our analysis discloses that the dipole moment will vanish in A.D. 3991.

Exponential Decay of Earth's Magnetic Moment

One would expect the magnetic moment of the earth to decay exponentially because it is produced by *real* currents that dissipate energy through Joule heating. The magnetic moment of the earth is *not* produced by *amperian currents* (dissipationless currents), such as those that exist in permanent magnetization of material.

Permanently magnetized material has been rejected as the source of the earth's magnetic moment for two reasons: (1) It would require greater intensity of magnetization than has been observed in the crust of the earth, and (2) No magnetization exists in the core material, because the high temperature there would destroy the magnetization.

The temperature of the earth increases with depth to such a degree that it has exceeded the Curie point. For example at 25 kilometers the temperature has reached the Curie point for iron, viz 750°C, as reported by Jacobs.[10]

The earth's magnetic moment being due to a system of circulating real currents will undoubtedly have associated, with its loops of current and its imperfect conductors, an inductance, L, and a resistance, R. Since there seems to be no dynamo or other energy source in the earth that can generate these currents, the current that does exist in the core must be decaying exponentially. This means that the magnetic moment will also be decaying exponentially.

It is comparable to the freely decaying current in a simple series circuit in which the time to decay to e^{-1} of its initial value is equal to the ratio of the inductance, L, to the resistance, R. The problem is complicated by distributed inductance and resistance instead of the simple lumped elements of circuit theory, but the fundamental physics of the decay process is the same, namely exponential.

To be sure, the original magnetic energy contained in the inductive field of the earth was phenomenal to have been decaying as long as it has and still have such a sizeable amount of magnetic energy left. But, by no stretch of the imagination could it have been decaying continuously like this for billions of years.

Evolutionists will not accept this continuous decay process, because of the consequences it has on their preconceived ideas of billions of year age for the earth. But they have yet to propose any acceptable alternative explanation of the earths magnetic field and its decay.

Note how the excellent work of Horace Lamb is rejected in a recent survey article on the Earth's Magnetic Field,[11]

> H. Lamb showed in 1883 that electric currents generated in a sphere of radius a, electrical conductivity *s* and permeability *m*, and left to decay freely would be reduced by electrical dissipation by Joule heating to e^{-1} of their initial strength in a time not longer than $4\sigma\mu a^2/\pi$. This time is of the order of 10^5 years, whereas the age of the earth is more than 4×10^9 years.

No other reason is given for excluding this theory. But note the futility of all other attempts to explain the earth's main magnetic field as expressed in this same article:

> There has been much speculation as to the cause of the earths main field and no completely satisfactory explanation has as yet been given. . . .
>
> It seems that rather extreme assumptions are necessary to make any theory satisfactory—either an extreme geometry or extreme and implausible values of the physical properties of the material in the core and lower mantle.

It is this author's contention that Lamb's solution for the earth's main magnetic field is reasonable as a first approximation; that freely decaying currents are the source of the earth's main magnetic field. This makes sense because the data for the last 130 years indicate that the earth's main magnetic field is decaying at a rate that is at least as great or greater than one would predict with Lamb, that rate being dependent upon what assumption has been made for the value of the conductivity in the core—a value that is not easy to determine.

1400 Year Half-Life for the Earth's Magnetic Moment

When values of the magnetic moment, M, in Table 1 are plotted against time, t, on semi-log coordinate paper, the points lie approximately on a straight line as one would expect for an exponential decay of the earth's magnetic moment. This is also true of course for a plot of

B_0 against t. We therefore assume that the decay is exponential and write

$$M = M_0 e^{-t/T} \quad (5)$$

Where M_0 is the magnetic moment at some reference time, and M is the magnetic moment t years after that reference time. The *time constant*, T, is the time required for the magnetic moment to decay to e^{-1} of its reference value M_0.

Rearranging Equation (5) and taking the natural logarithm, the following is obtained:

$$\ln (M_0/M) = t/T \quad (6)$$

Specifying M_0 at its 1835 value, M at its 1965 value, and t at 130 years (the time lapsed between these two values), we have

$$\ln (8.558/8.017) = 130/T \quad (7)$$

Solving for T, we obtain the time constant of 2000 years, the time for the earth's magnetic moment (or its main magnetic field) to decay to e^{-1} of its reference value.

To find the half-life Equation (6) is evaluated for t with the ratio M_0/M set equal to 2 and T given its value of 2000 years,

$$\ln (2) = t/2000 \quad (8)$$

This gives a rounded value of 1400 years for the half-life of the magnetic moment of the earth.

This means that in the year 3371 A.D. the earth's magnetic moment will be down to half of its present value, and there will be less protection from cosmic radiation.

Going backward in time, assuming this same exponential function, the earth's magnetic moment doubles every 1400 years of prior time all the way back to its origin. Table 2 gives the equatorial value of the magnetic dipole field (main field) on the surface of the earth as a function of time.

It is computed on the basis of 1400 year half-life or what amounts to the same thing, a time constant of 2000 years, with the reference value of 3.1 X 10^{-5} tesla (.31 gauss) in 1965. Time, t, is years backward from 1965. The exponential equation is

$$B = 3.1 \times 10^{-5}\ e^{\ t/2000} \quad (9)$$

and for convenience in computation it is expressed in the base 10 making use of the relation $e = 10^{0.43429}$ to put it in the form

$$B = 3.1 \times 10^{-5} \times 10^{0.0002171t} \quad (10)$$

The table is carried back one million years to show the *absurdity* of that age for the earth, if its magnetic field is assumed to be historically associated with its present processes. The value of 3 X 10^{215} is impossible, of course. This means that the earth is not a million years old, if its magnetic field originated at the time of the earth's origin and followed its present type of decay processes thereafter.

Table 2. Value of the Magnetic Field at the Surface of the Magnetic Equator for Various Dates in the Past as Computed from the 1400 Year Half-Life Decay Rate Currently Observed.

Date	Magnetic Field (Tesla)
1965 A.D.	3.1×10^{-5}
1000 A.D.	5.0×10^{-5}
1 A.D	8.3×10^{-5}
1000 B.C.	1.4×10^{-4}
2000 B.C.	2.3×10^{-4}
3000 B.C.	3.7×10^{-4}
4000 B.C.	6.1×10^{-4}
5000 B.C.	1.0×10^{-3}
6000 B.C.	1.7×10^{-3}
10,000 B.C.	1.2×10^{-2}
20,000 B.C.	1.8
30,000 B.C.	2.7×10^{2}
40,000 B.C.	4.0×10^{4}
50,000 B.C.	5.9×10^{6}
100,000 B.C.	4.2×10^{17}
200,000 B.C.	2×10^{39}
1,000,000 B.C.	3×10^{215}

One cannot date the origin of the magnetic field because we have no way of knowing its initial value. However, it can be seen that this rapid decay process requires that it be a very "young" age. For example the magnetic field on the surface of the earth in 20,000 B.C., namely 1.8 tesla (18,000 gauss) is stronger than the field between the pole pieces of the most powerful radar magnets. It is not very plausible that the core of the earth could have stayed together with the Joule heat that would have been associated with the currents producing such a strong field.

Even now the currents in the core of the earth can be shown to exceed one billion amperes;[12] but, if the field at the surface of the earth were 1.8 tesla instead of its 3.1 x 10^{-5} tesla, the currents in the core of the earth would be more than 50,000 times greater than they are now. Joule heating in the earth is proportional to the square of the current, this means that the Joule heating in the core of the earth would have been 250 million times greater than it is now, a phenomenal amount of heating.

It would appear from these arguments that the origin of the earth's magnetic moment is much less than 20,000 years ago.

Secondary Magnetic Fields

It should be pointed out that there are many anomalies in the earth's magnetic field that are not associated with its dipole source. Anomalies are presumably caused by ferromagnetic deposits, telluric currents, and other more or less localized causes.

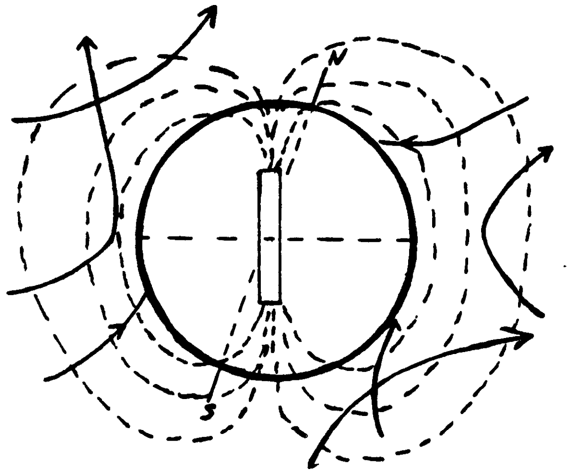

Figure 3. Earth's magnetic field tends to bend the paths of cosmic rays and to shield the earth.

Some of the anomalies may alter the earth's field over large regions of the earth. Sometimes the anomaly may cause a magnetic field that is larger than the dipole field in that region. However, when averaged over the whole earth, these anomalies are much smaller than the dipole field, otherwise the compass would not be classified as having *north-seeking* and *south-seeking* poles.

Solar winds, charges emitted from the sun, are considered to be the source of diurnal and other fluctuations in the earth's magnetic field. But these secondary fields are usually much smaller than the earth's dipole field strength. The main field of the earth is still the dipole field produced by the magnetic moment in the core of the earth.

It is the main magnetic field of the earth, the dipole field, that shields the earth from much of the solar wind. It also "guides" much of the radiation in toward the magnetic polar regions. It is this magnetic polar effect that locates the *auroral zones.*

It is this main magnetic field that shields much of the earth from some of the cosmic radiation. We shall next consider the influence of past stronger magnetic fields upon this radiation.

Effect of Strong Magnetic Field in the Past on Radio Carbon Dating

One of the consequences of the stronger magnetic field in the past was better shielding of the earth and its atmosphere from primary cosmic rays. This also reduced the rate of production of Carbon 14 in the atmosphere.

Primary cosmic rays interact with the atmosphere to produce neutrons which in turn transmute nitrogen atoms into Carbon-14. Hence, with the lesser number of cosmic rays striking the atmosphere per second, a smaller rate of production of Carbon-14 existed in the past. A smaller production rate of Carbon-14 in the atmosphere than has previously been assumed would reduce the age of Carbon 14 dates.

Primary cosmic rays consist of high speed positively charged atomic nuclei. The earth is constantly bombarded from all directions with these charged particles. The earth's magnetic field tends to bend the path of those particles away from the earth as shown in Figure 3. This magnetic force, F, is a function of the magnetic field, B; the charge, q, the particle velocity, v; and the sine of the angle θ between v and B, that is,

$$F = qvB \sin \theta \qquad (11)$$

Note that the shielding force is greatest when the particle motion is at right angles to the direction of the field B, and decreases as this angle decreases. Hence fewer cosmic rays reach the earths atmosphere in the lower latitudes than in the polar regions. Figure 4 shows the cosmic ray neutron intensity vs. geomagnetic latitude at 30,000 feet as determined by J. A. Simpson, Jr.[13]

The present magnetic field has already reduced the cosmic-ray neutron intensity in the equatorial region down to 22 percent of its value at 65 degrees latitude. Hence there is a limit to how much more it can be reduced by a stronger magnetic field. But the stronger field in the past must have caused some reduction in the rate of production of Carbon-14.

The total process is quite complex and will not be analyzed in this paper. However, one might make a crude estimate, on the basis of Figure 4, that the world wide neutron intensity might have been reduced by as much as 10 percent about 2800 years ago, back when the field was four times as strong. This would affect the experimental results of radiocarbon dating by reducing the age of the sample.

Melvin Cook has already pointed out that a non-equilibrium condition exists now that reduces the experimental results on radiocarbon dating. This reduction is progressively greater with the age. From his analysis he concludes that

> it reduces the computed age by an amount dependent upon the age of the sample by amounts increasing in time from about 20% in 1000 years, 30% in 4000 years and finally telescoping all the very long ages to 12,500 years or less.[14]

When the effect of the larger magnetic field in the past and the consequent lesser rate of production of Carbon-14 is included these ages will be telescoped still further.

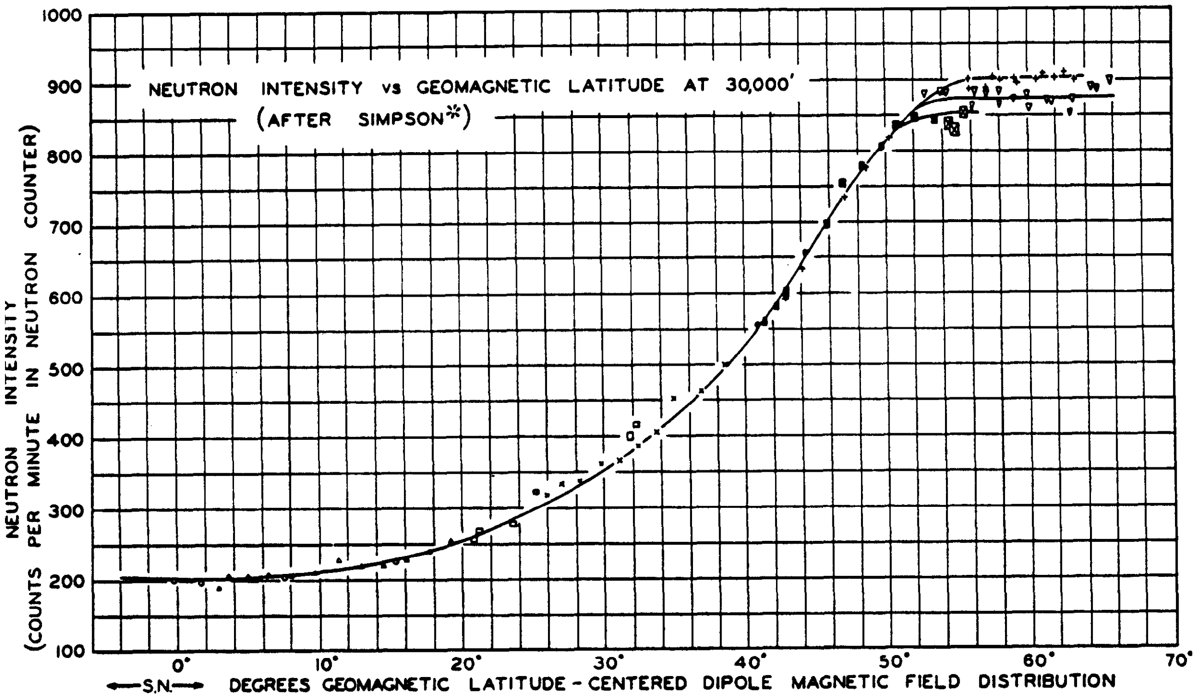

Figure 4. Variation of the cosmic ray neutron intensity vs. magnetic latitude at 30,000 feet. (Permission granted to use Figure 2 from *Radiocarbon Dating* by Willard F. Libby, Second Edition, p. 13. University of Chicago Press, 1955.)

Conclusion

The search for a physical explanation of the earth's main magnetic field and its decay rate seems to have been retarded by an evolutionary bias toward long ages. The physics seems inevitably to point to a much shorter age. It is believed that Horace Lamb's treatment of the freely decaying currents in a huge conducting sphere, such as the molten core of the earth, should be reconsidered as the source of the earth's magnetism.

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