Evolutionary Explanations for Anomalous Radiocarbon in Coal?

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Abstract

The simplest explanation for radiocarbon presence in coal is that it was there when the coal formed. Radiocarbon dates of coal are typically 40,000 years, which obviously conflict with typical carboniferous coal geological ages of 300 million years. The viability of various evolutionary motivated explanations for the anomalous radiocarbon ages are considered, and the effects are demonstrated to be several orders of magnitude too small to account for the observed radiocarbon concentrations. The only reasonable explanation is the radiocarbon was incorporated at the time of formation, the geological ages are fictitious and the methodology of the 170 year-old Lyellian geological column is flawed.

Introduction

Evolutionists and those that believe in an ancient earth understand that radiocarbon presence in coal in measurable levels is a problem for the established geological timescale. Indeed, Hunt's (2002) website succinctly states:

> Accelerator mass spectrometry (AMS), a sensitive radiometric dating technique, is in some cases finding trace amounts of radioactive carbon-14 in coal deposits, amounts that seem to indicate an age of around 40,000 years. Though this result is still too old to fit into any young-earth creationist chronology, it would also seem to represent a problem for the established geologic timescale, as conventional thought holds that coal deposits were largely if not entirely formed during the Carboniferous period approximately 300 million years ago. Since the halflife of carbon-14 is 5,730 years, any that was present in the coal at the time of formation should have long since decayed to stable daughter products.

From an evolutionary perspective, the presence of C-14 in coal requires an explanation. One explanation given on the Talk.Origins website is that the C-14 in coal is the result of radioactive decay of the uranium and thorium decay series. Another explanation considered, but the website discounts it as unlikely is the infiltration of modern C-14 into the coal environs that contaminates the "ancient" coal with the new C-14. This "widespread contamination" explanation is also considered unlikely (Hunt, 2002).

The simplest explanation for the presence of the C-14 in coal is that it was there when the coal formed and it was formed recently, on the orders of thousands, not millions of years ago. This paper will show that the levels of natural uranium-thorium radioactivity in coal are not sufficient to generate the amount of C-14 necessary to give the "apparent" C-14 ages of 20,000 to 40,000 years that are typically determined for coal. We will also consider the possibility of contamination of the "ancient" coal by modern C-14 and demonstrate this possibility is untenable.

Question: Can the observed levels of C-14 in coal result from the uranium or thorium decay chains?

To answer this question we will consider these decay chains. Uranium consists of uranium-238 and its progeny, and uranium-235 and its progeny. Natural uranium consists of 99.2745% by weight U-238, 0.720% U-235 and 0.0055% U-234 (Kinsey, 1999). Often, uranium and thorium are near secular equilibrium with their daughters. Secular equilibrium occurs where the parent nuclide has a half-life much greater than any of the progeny and a sufficient time has elapsed for the progeny to build up/decay to near

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the same activity level of the parent. Figure 1 displays one molecular weight (mole) of natural uranium and Figure 2 shows one mole of thorium in secular equilibrium with its progeny.

In the 1980's, new types of radioactivity were discovered involving the emission of C-14, Ne-24, Ne-25, Mg-28 and other nuclei (Greiner and Sandulescu, 1990). It is thought that Ra-223 is the nucleus with the largest probability for emitting a C-14 nucleus, with Ra-226, Ra-224 and Ra-222 also exhibiting measurable radioactivities of this type. They are called cluster radioactivities. Normally, the most stable combination of particles that can be emitted is an alpha particle, the nucleus of helium-4, consisting of two neutrons and two protons. However, the theoretical and experimental efforts of the 1980's showed that other cluster emissions, although rare, do in fact occur. In the case of radium-223, the probable mode of decay is the emission of an alpha particle, but in nearly one out of a billion decays, a carbon-14 nucleus is emitted instead.

Now, C-14 is generated in natural uranium and thorium through the radium-226, radium-223 and radium-224 decays. The branching ratios for these nuclides to form C-14 is very small, for radium-226 it is 3.2 x 10^{-9} %, for radium-223 it is 6.4 x 10^{-8} %, and for radium-224 it is 4.0 x 10^{-9} % (Kinsey, 1999). The equilibrium concentration of C-14 is also displayed in the diagrams for the uranium and thorium decay chains. One mole of uranium is 79.4 microcuries (μCi) U-238, and 3.70 μCi U-235 with various concentrations of the progeny as shown. Note in particular, that one mole of uranium generates an equilibrium concentration of 2.5x10^{-9} μCi C-14 from the U-238 and 2.4x10^{-9} μCi C-14 from the U-235 decay chains for a total of 4.9x10^{-9} μCi C-14. Another way of expressing this is that one gram of uranium in equilibrium with its daughter has 2.1x10^{-5} picocuries (pCi) C-14 per gram of uranium.

Uranium and thorium typically are found in coal at concentrations of 1 to 4 parts-per-million (ppm) with maximum concentrations in United States coals rarely exceeding 20 ppm of either element (USGS, 1997). Can this level of radioactivity in the coal produce anything near the levels of carbon-14 to give radiocarbon ages of 20,000 to 40,000 years? No, because the number of atoms of uranium (N_U) divided by the number of atoms of carbon (N_C) or for the thorium chain must be

$$\frac{N_U}{N_C} = \frac{1}{8.0 \cdot 10^{-17}} \cdot \left(desired \frac{C-14}{C} ratio \right)$$

$$\frac{N_{Th}}{N_C} = \frac{1}{1.6 \cdot 10^{-17}} \cdot \left(desired \frac{C-14}{C} ratio \right)$$

For instance, if the desired C-14/C ratio were 1x10^{-14} (corresponding to 40,000 years), then the coal would need 125 uranium atoms per carbon atom. This "coal" would be 99.96% by weight uranium, which most people would call uranium and not coal. Thus, we need so much uranium or thorium to produce the desired C-14/C ratio, that it is practically impossible for C-14 generated from the uranium or thorium chains to produce the observed C-14 concentrations in coal.

Another possibility is that the C-14 is not primarily produced by the radium decay in the uranium/thorium in the coal, but by the surrounding uranium and thorium deposits. This can be dismissed readily based upon the following consideration:

> Consider a layer of coal of density ρ_{carbon} and thickness d_{carbon}. This is covered by a layer of uranium of density ρ_U and thickness d_U. Making the liberal assumption that all of the uranium series generated C-14 moves immediately to the coal layer, how thick must the uranium layer be in order to sustain the observed C-14/C ratio in the coal layer? Actually, much of the C-14 will never make it to the coal layer and we are making this assumption because it is simple and even with this assumption it demonstrates how difficult it is to produce the observed C-14/C ratios observed in coals. The minimum thickness required is

$$d_U = \frac{1}{8.0 \cdot 10^{-17}} \cdot \frac{\rho_{carbon}}{\rho_U} \cdot \frac{238}{12} \cdot d_{carbon} \left(desired \frac{C-14}{C} ratio \right)$$

> where the densities are densities of carbon and uranium, and not the contaminants. For a density of carbon of 1 g/cc, density of 18.95 for uranium, a one-meter thick coal layer and a desired C-14/C ratio of 1x10^{-14} (corresponding to 40,000 years), we get a thickness for the uranium layer of 130 meters of pure uranium metal.

On the basis of the above analysis, we can conclude that C-14 generated from the decay of radium through the uranium or thorium decay chains requires too much uranium or thorium to produce the observed C-14/C ratios. See Table I for the expected C-14/C saturation ratios.

As can be seen in Table I, the calculated ratios in are far below the observed ratios seen in coal.

Could some C-14 be generated from the spontaneous fission of some of the nuclides in the uranium/thorium decay chain? The spontaneous fission rates for the parents and progeny are a fraction of a percent, being 0.00005%, 1.7x10^{-9} %, 7.0 x10^{-9} %, and <1.0 x10^{-9} % for U-238, U-234, U-235 and Th-232, respectively (Kinsey, 1999). Most fissions of uranium produce two unequal fragments with several neutrons. In one out of 200 to 300 fissions, a third

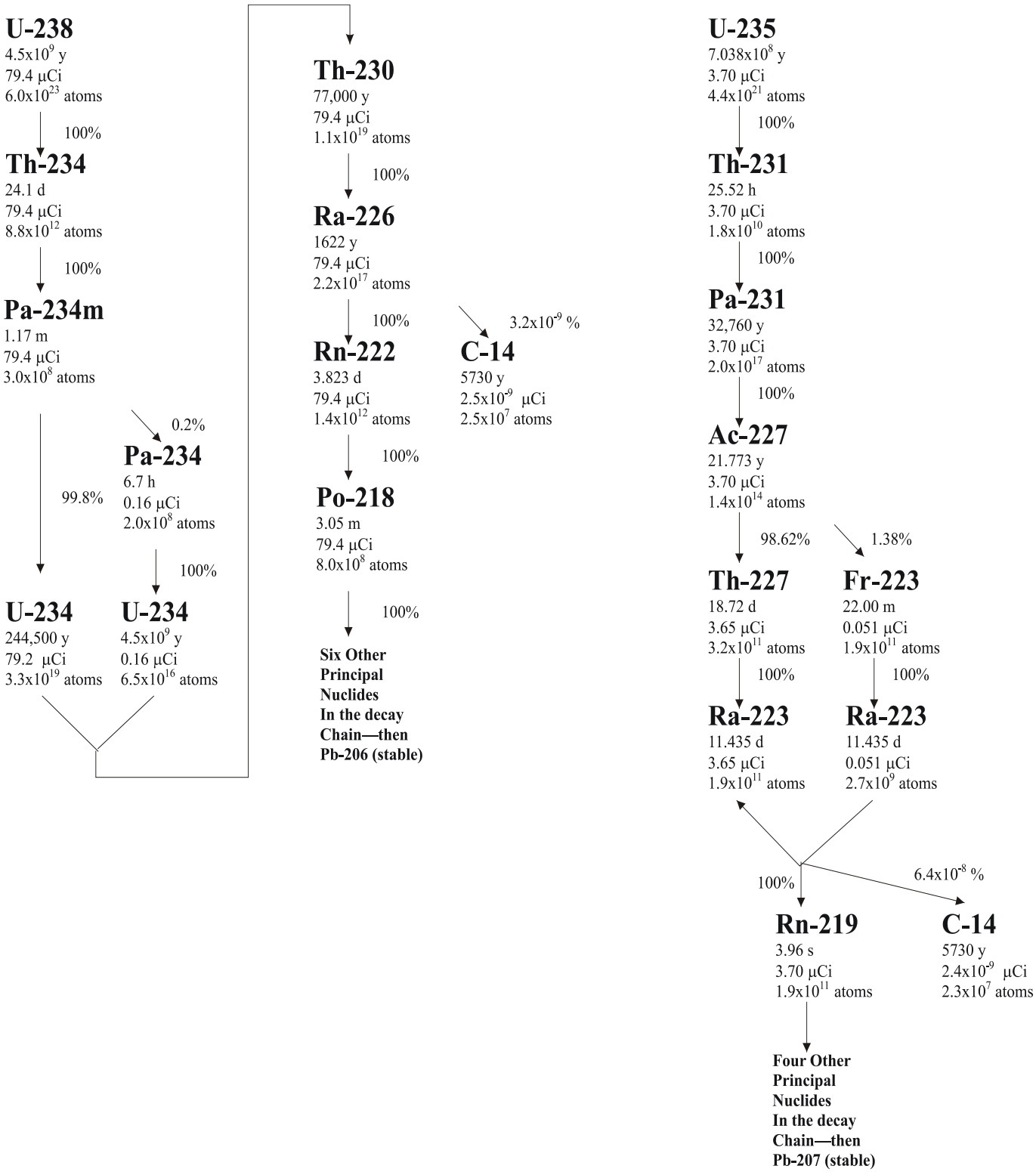

Figure 1. One mole of natural uranium (238.027 g) maintains under secular equilibrium 4.9 billionth of a microcurie of C-14 by the low probablility emission of C-14 nuclei from Ra-226 and Ra-223. This is 48 million atoms of C-14 per mole of uranium that corresponds to a C-14/U ratio of 8×10^{-17}. This diagram does not include the C-14 production by the neutron activation of nitrogen.

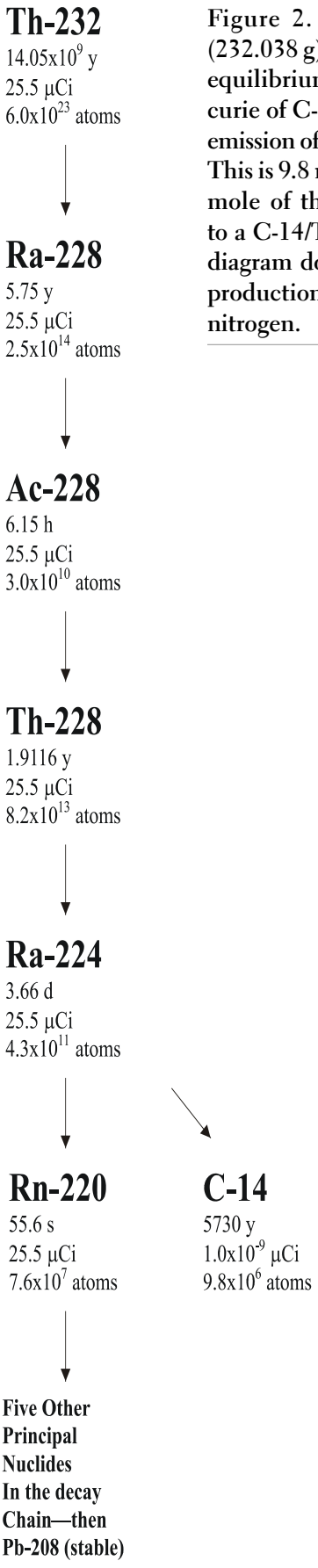

Figure 2. One mole of thorium (232.038 g) maintains under secular equilibrium 1 billionth of a microcurie of C-14 by the low-probability emission of C-14 nuclei from Ra-224. This is 9.8 million atoms of C-14 per mole of thorium that corresponds to a C-14/Th ratio of 1.6×10^{-17}. This diagram does not include the C-14 production by neutron activation of nitrogen.

fragment is emitted, a process called ternary fission. The most probable third fragment is an alpha particle, but other particles including C-14 nuclei are also possible. Vorobyov et al. (1972) measured the probability of a C-14 emission for neutron-induced fission of U-235, and found it to be 5.4 ± 0.6 carbon-14 nuclei per 10^4 alpha particles. Hence, the rate is at most 9.3×10^{-8} carbon-14 atoms per fission. The production rate for spontaneous fission production of C-14 would be the decay rate multiplied by the probability of spontaneous fission multiplied by the carbon 14 atoms per fission, which is a negligible rate of production.

Could some of the C-14 be generated in the coal be by neutron activation by the C-13(n, γ)C-14, N-14(n, p)C-14 and O-17(n,α)C-14 reactions? Yes, but consider the isotopic abundances and the cross sections for thermal neutron capture are shown in Table II.

Coal Type (% carbon)	Expected C-14/C ratio for 1 ppm U	Expected C-14/C ratio for 1 ppm Th
Anthracite (86–98%)	4.1 to 4.6 x 10^{-24}	8.6 to 9.8 x 10^{-25}
Bituminous (45–86%)	4.6 to 8.9 x 10^{-24}	9.8 to 19 x 10^{-25}
Subbituminous (35–45%)	8.9 to 11 x 10^{-24}	1.9 to 2.4 x 10^{-24}
Lignite (25–35%)	1.1 to 1.6 x 10^{-23}	2.4 to 3.4 x 10^{-24}

Table I. The expected C-14/C ratio for 1 ppm uranium or thorium due to C-14 in equilibrium (best case) with the U or Th decay chains.

Nuclide	Isotopic Abundance	Thermal (0.0253 eV) Neutron Activation Cross Section (barns)
C-13	1.11%	0.001
N-14	99.64%	1.827
0-17	0.039%	0.235

Table II. Isotopic abundances and cross sections for thermal neutron capture (T2 Nuclear Information Service, 2003.

If we had one mole of each element in the coal subject to the same thermal neutron flux, the O-17(n,α)C-14 reaction would produce 8.5 times as much C-14 as the C-13(n, γ)C-14 reaction and the N-14(n, p)C-14 reaction would produce 195 times as much. However, coal is primarily carbon so the isotopic fractions of N and O will probably be much less as shown in Table III with information for typical USA hard coal.

As can be seen, nitrogen would produce most of the C-14 via neutron activation. The following is a conservative order of magnitude estimate to determine an upper limit on how much C-14 can be produced in typical USA coals due to uranium in the coal:

Consider a layer of coal of area A and thickness d_c. With the following definitions

ρ_{cm}=density of coal media including noncarbon components (g/cm^3)

f_N=fraction of the weight of the coal media that is nitrogen

Component Element	% Weight	Percent Production Rate of C-14
Carbon	73%	0.03%
Oxygen	7.5%	0.08%
Nitrogen	1.4%	99.89%

Table III. Typical Hard Coal Composition and Percent Production Rate of C-14 by Neutron Activation (Öko-Institut, 1999).

f_U=fraction of the weight of the coal media that is uranium

f_C=fraction of the weight of the coal media that is carbon

f_{sf} = fraction of decays that are spontaneous fissions

A=area of coal layer of interest in cm^2

d_c=thickness of coal layer (cm)

SA_U=specific activity Becquerrels per gram (Bq/g)

N_{f-U}=average number of neutrons per spontaneous fission

the thermal neutron flux is less than

$$\varphi = f_U \rho_{cm} d_c (SA_U) f_{sf} N_{f-U}$$

and the number of target nitrogen atoms is

$$n = f_N \rho_{cm} A d_c \frac{N_A}{W_{M-N}}$$

so that the saturation activity per volume would be less than

$$\frac{\varphi \sigma n}{A d_{cm}} = f_U f_N (\rho_{cm})^2 (SA_U) f_{sf} N_{f-U} \sigma_N d_c \frac{N_A}{W_{M-N}}$$

and so the C-14/C ratio should be

$$\frac{C-14}{C} = \frac{f_U f_N}{f_C} \frac{W_{M-C}}{W_{M-U} W_{M-N}} \rho_{cm} \frac{\tau_{1/2C-14}}{\tau_{1/2U}} f_{sf} N_{f-U} \sigma_N N_A d_c$$

This shows that the saturation C-14/C ratio of the layer could be increased if the product of the fractional weights of uranium and nitrogen can be increased. It must be understood this was derived using a thin layer assumption. If d_c were too large, the thin layer assumption would not apply. If we adhere strictly to the above formula and if we use too large of a value for d_c, we would overestimate the C-14 to C ratio since most of the incident neutron flux would have been removed from the beam by attenuating processes and would not be available for additional activations. Using Figure 7.13 of Shleien, Slaback, and Birky (1998) a reasonable estimate would be $d_c < 25$ cm for a density of 1 g/cm^3 and using this the result for 1 ppm U, 1.4% nitrogen a C-14/C ratio of less than 3.3×10^{-21}. Even substituting in 20 ppm, we only get 6.6×10^{-20}, which is much less than the C-14/C ratio corresponding to 40,000 years. We have concentrated on uranium-induced activation of nitrogen since the fission rate is about 80 times higher than all of its progeny, U-235 progeny and Th-232 progeny. When there is more than one nuclide that undergoes spontaneous fission, then sum over U for the various nuclides.

The above analysis has been for neutron activation due to U/Th dispersed within the coal. For neutron activation of the coal from outside, the neutron activation would be expected to penetrate only about 25 to 50 cm of the coal.

	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Decay Chain	Radium Generated C-14 Emission	Spontaneous Fission Neutron Activation of Nitrogen	Be(α,n) Neutron Activation of Nitrogen	B(α,n) Neutron Activation of Nitrogen	Be(γ,n) Neutron Activation of Nitrogen	B-11(α,n)C-14 Generation of C-14
U (1 ppm)	5.5×10^{-24}	1.2×10^{-20}	7×10^{-24}	3×10^{-24}	5×10^{-24}	1.2×10^{-23}
Th (1 ppm)	1.2×10^{-24}	1.5×10^{-25}	2×10^{-24}	7×10^{-25}	7×10^{-25}	3.0×10^{-24}

Table IV. Upper Limits of Saturation C-14/C Generation by U or Th Decay Chains.

So the interface coal would be neutron activated, but the coal within would not be neutron activated. Further, coal contaminated primarily with thorium would be expected to produce very little neutron activation compared to the same concentration by weight of uranium.

Besides spontaneous fission, another source of neutrons could be generated by beryllium and boron in the coal that could produce neutrons via the Be-9(α,n), Be-9(γ,n), B-10(α,n) or the B-11(α,n) reactions. There are a number of commercially available neutron sources that produced neutrons by these reactions (Cember 1996). The source of alphas or gammas is from the uranium/thorium progeny. However, beryllium, boron and uranium are found in trace concentrations in coal in the parts-per million range (Swaine, 1990) making this an insignificant source of neutrons compared to uranium's spontaneous fission neutrons. So five modes for C-14 production in coal for the uranium and thorium decay chains are displayed in Table IV.

Table IV pertains to the Öko-Institut referenced coal with a density of 1.47 g/cm^3. The neutron activation effect is conservatively overestimated by assuming all neutrons are thermalized where the N-14(n,p)C-14 production rate is maximized. This coal's macroscopic total cross section for thermal neutrons is > 0.98 cm^{-1} and for 1.66 to 2.6 MeV gammas the range is 0.055 to 0.070 cm^{-1} (ash contribution excluded). Calculated results are for a thick coal layer, and a thin coal layer would produce a smaller result with edge effects unless a similar distribution of alpha, gamma emitters and attenuating properties of the surrounding non-coal media existed. For comparison with neutron activation, the B-11(α,n)C-14 reaction produces radiocarbon directly with a saturation C-14/C ratio < 1.2 x 10^{-23} for 1 ppm B and U.

The Be(γ,n) mode of neutron production only occurs for gamma energies > 1.66 MeV and the uranium and thorium progeny have several gamma emissions in this range.

To use Table IV, columns 3–5 are increased by increasing either the decay chain concentrations or the Be or B concentrations.

For the beryllium or boron mixed with uranium and thorium to be a significant source of C-14 would require high concentrations of Be/B, U/Th, and nitrogen. Even with unrealistic concentrations of uranium, thorium, beryllium and boron in the 1% by weight range, C-14/C equilibrium concentration ratio does not approach 10^{-14} corresponding to 40,000 years.

Besides the (α,n) reaction neutron sources listed in Table IV, there are at least 50 other isotopic (α,n) sources of neutrons. The summed neutron flux from these sources in coal is similar in magnitude to the neutron flux from spontaneous fission of uranium. Neutron activation is not a likely explanation for the observed C-14/C ratios.

The concentrations observed in coal are at least a factor of 100,000 more than what could be generated by neutron activation within the coal, and this is the best case. There is just not enough C-14 generated by the low-probability radium decays, spontaneous fission or neutron activation of the coal. *The anomalous concentrations of C-14 in coal cannot be explained by any of these generating processes. So, where did it come from?*

Can the observed levels of C-14 in coal result from contamination from the atmospheric C-14?

To answer this question, we need to construct the differential equations that describe the contamination of the coal. Consider a plane of coal of thickness d_c and area A. The following variables are defined:

N_{14} = atoms of C-14 in plane of coal of area A and thickness d_c.

N_{12} = atoms of C-12 and C-13 in plane of coal of area A and thickness d_c.

p_{14} =atoms C-14 cm^{-2} s^{-1} entering the coal from the atmosphere.

p_{12} =atoms C-12 and C-13 cm^{-2} s^{-1} entering the coal from the atmosphere.

l_{14} =atoms C-14 cm^{-2} s^{-1} leaving the coal to the atmosphere.

l_{12} =atoms C-12 and C-13 cm^{-2} s^{-1} leaving the coal to the atmosphere.

The differential equations that describe the rate of change of C-14 and C-12 and C13 is as follows:

$$\frac{dN_{14}}{dt} = (p_{14} - l_{14})A - \lambda N_{14}$$

$$\frac{dN_{12}}{dt} = (p_{12} - l_{12})A$$

The solution for these differential equations for times much greater than the half-life is

$$N_{14}(t) = \frac{(p_{14} - l_{14})A}{\lambda}$$

$$N_{12}(t) = (p_{12} - l_{12})At + N_{12}(0)$$

Now the ratio $\frac{N_{14}(t)}{N_{12}(t)}$ is the observed C-14/C ratio observed in coal today.

The ratio $\frac{p_{14}}{p_{12}}$ will be less than or equal to the atmospheric ratio of C-14/C. We will make the liberal assumption that it equals this ratio.

The ratio $\frac{l_{14}}{l_{12}}$ will be equal to the coal ratio of C-14/C.

The constant $N_{12}(0)$ is the number of atoms of C in the coal layer of area A and thickness d_c at time t=0. If we assume for every carbon atom removed, one is added $(p_{12} - l_{12}) = 0$, then with these assumptions, we calculate the rate of replacement (loss) of carbon atoms to be

$$p_{12} = l_{12} = \frac{\frac{N_{14}(t)}{N_{12}(t)} N_{12}(0)\lambda}{A\left(\frac{C-14}{C} air - \frac{N_{14}(t)}{N_{12}(t)}\right)}$$

With this information, the time to replace the initial number of carbon atoms is

$$t_{replacement} = \frac{1}{\lambda}\left(\frac{\frac{C-14}{C} air}{\frac{N_{14}(t)}{N_{12}(t)}} - 1\right)$$

So in order for the coal to be the result of contamination from the atmosphere and for the coal deposit not to grow or shrink in size, it requires the average atom of carbon is replaced within the above time frame.

For the C-14/C ratio of air being 1.4 x10^{-12} and $\frac{N_{14}(t)}{N_{12\&13}(t)}$ ratios similar to those found in coal, namely 10^{-13} to 10^{-14} this means the coal would have its carbon replaced on the order of 0.1 to 1.1 million years. Replacement of the carbon atoms every 0.1 to 1.1 million years requires coal to be a very open system with atoms entering and leaving in order to contaminate the coal with new C-14. Thus, if the noted C-14 concentrations in coal were due to contamination from new C-14 from the atmosphere, and the coal is really 300 million years old, the carbon has replaced itself many times in the millions of years since its original formation. However, the magnitude of the variation due to contamination would be expected to vary by several orders of magnitude. Variation in the thickness, depth and porosity of the rock covering the coal would be expected to produce wide variations in the C-14/C ratio, much more than just two orders of magnitude. It is on the basis of an expected greater variation in the C-14/C ratio that we can reject the likelihood of the widespread contamination of the coal layers by the atmospheric C-14.

How can 40,000 year radiocarbon dated coal be reconciled with a literal interpretation of the earth being only 6,000 years old according to the Bible?

Some creationists would find it amazing that a staunch evolutionist would look at a Lyellian dated coal deposit of 300 million years, then look at the radiocarbon date of 40,000 years and say "It is still too old to fit into any creationist chronology, since there is a factor of 7 difference with your Bible." To which a creationist could state "Yes, but I can see several reasonable explanations and being off by a factor of 7 is better than a factor of 7,000!"

It is well understood that the Specific Production Rate (SPR) is greater than the Specific Decay Rate (SDR) for the earth's carbon inventory. What this implies is that equilibrium has not been reached in the earths carbon-14 system (Whitelaw, 1992). To understand what equilibrium is we write the equation that governs the formation of C-14 from N-14 and other targets in our atmosphere

$$\frac{dN_{C-14}}{dt} = \varphi\sigma n - \lambda N_{C-14}$$

where φ is the flux of neutrons (n/cm^2-s), σ is the activation cross section for the production of C-14 via the $N^{14} + n^1 \rightarrow C^{14} + H^1$ reaction (and any other C-14 creating reactions), n is the number of target N-14 atoms and λ is the rate of decay of C-14. The first term on the right side is the rate of production and the second is the rate of decay. The solution to this differential equation is (Cember, 1996)

$$\lambda N_{C-14}(t) = \varphi\sigma n\left(1 - e^{-\lambda t}\right)$$

And if the world were millions of years old, the saturation activity of C-14 in the earth system would definitely have been reached and would be $\varphi\sigma n$. One plausible reason for unsaturation (SPR>SDR) is the world may not be millions

of years old, but thousands, since the earth may have not had time to achieve saturation. For further discussion on the C-14 dating topic, see Whitelaw (1992).

Conclusion

The presence of C-14 in coal in measurable quantities is the strongest evidence that the geological ages proposed by Lyell in 1830 are pure fiction. As demonstrated, the uranium and thorium decay chains do not generate enough C-14 to explain the measured anomalous C-14/C ratios and widespread contamination of the coal by atmospheric C-14 should generate a greater variation in the observed C-14/C ratios than those found in coal. Evolution needs the millions of years that the Lyellian geological column provides, but radiocarbon dating of old carbon sources like coal clearly witness to evolutionary geologists that the Lyell geological column interpretation is misleading, it should no longer be taught as fact, and should be abandoned as a viable theory.

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C-14/C Percent Modern Carbon (pmc) ± 1 S.D.	Material	Reference
0.44 ± 0.13	Anthracite	Vogel (1987)
0.42 ± 0.03	Anthracite	Grootes (1986)
0.358 ± 0.033	Anthracite	Beukens (1992)
0.3 ± ?	Coal	Schleicher (1998)
0.2 to 0.35* (range)	Anthracite	Aerts-Bijma (1997)
0.18 ± 0.01**	Anthracite	Nelson (1986)
0.142 ± 0.023	CaC_2 from coal	Gurfinkel (1987)
0.112 ± 0.057	Bituminous coal	Kitagawa (1993)
0.081 ± 0.019	Anthracite	Beukens (1992)
* Estimated from graph	** Lowest value of multiple dates	

Table V. Accelerator Mass Spectrometry (AMS) Measurements of Coal Samples Expected to be C-14 Dead. Results borrowed from Baumgardner (2003) and Giem (2001).

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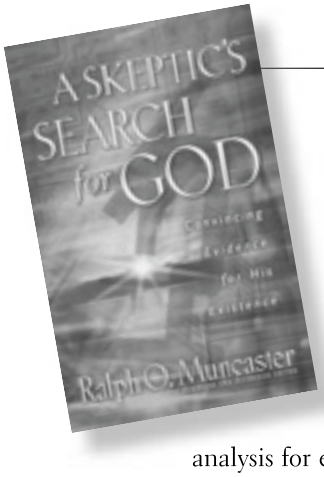

Book Review

A Skeptic's Search for God, Convincing Evidence for His Existence

by Ralph O. Muncaster
Harvest House Publishers, Eugene, OR. 2002, 283 pages. $11.99

This book is an autobiographical sketch combined with an analysis for evidence for the existence of God. The narrative begins with the author's early childhood belief in God and upbringing in the church. Through the early skepticism of an influential older friend, which was re-enforced by a secular college experience, Muncaster jettisoned any lingering belief in a Deity. Later in life Muncaster was confronted with a Christian who challenged him to actually try and disprove the existence of God and the accuracy of the Bible in a formal way. Muncaster picked up the gauntlet and devised an intellectually honest approach that combined consideration of analytical, statistical, and legal proofs. Muncaster approached each set of proofs from the perspective of both hard and soft evidence. He defined hard proof as the results of sciences like physics, chemistry, mathematics, and microbiology which can be measured, defined, and verified by repeated experiments. Soft sciences or "sciences of observation" include anthropology, general biology, botany, and geology. The writer used each type of proof to try to disprove the existence of God.

From this point the book is broken into three sections. The first section contains analytical proofs of God (pp. 67–121). He uses analytical proofs in an effort to show the origin of the first living cell by naturalistic evolution. The second section is on the statistical proofs for God (pp.125–194). Muncaster uses statistical analysis "to test the probability of his [God's] existence by testing for something only God could do...I could test his ability to foretell the future with perfect precision and accuracy"(p. 60). The third section consists of legal proofs of God (pp. 197–241). Legal proof has to do with eyewitness testimony, hostile witness testimony, corroborative reports, and circumstantial evidence. If analytical and statistical proofs point toward the existence of God as creator then legal proof would come into play to determine the validation of the truth claims of the various competing religious systems.

Muncaster begins with the origin of life issue that brought him into contact with the creation/evolution debate. Early on he encounters the claims of scientific creationists such as the Institute for Creation Research (pp. 73–74) and progressive creationists. The writer uses material from both sources in his quest. By using analytical evidence from the complexity of living cells, DNA and RNA studies, and the work of Michael Behe, he concludes that the origin of a single living cell could not have come about by chance and naturalistic evolution. The only alternative is creation by God.

Muncaster then uses the statistical method to test the accuracy of the Bible. "Only a God of the universe would be able to perfectly know the beginning from the end. Could the God of the Bible live up to that? How about the God of other holy books? What about other people?"(p. 129). He tests the accuracy of general Old Testament prophecies as well as specific Messianic prophecies and finds statistical evidence for both.

The author then proceeds to examine the legal evidence for the accuracy and trustworthiness of the Old Testament and New Testament documents. Included in this are the martyrdom of the apostles and early Christians, archaeological evidence, hostile witness testimony of events in Jesus' life, and the difference of the Biblical Christ contrasted to the Christ of Mormonism, Jehovah Witnesses, and Christian Science. The book is apologetic in nature and ends with an invitation to receive Christ as Savior (p. 259).

This book is written with the lay reader in mind, but also contains information making it a useful tool for the skeptics who are in our lives. *A Skeptic's Search for God* has several helpful appendices, a bibliography, endnotes, but no index.

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