ARTICLES

CARBON-14 DATING MODELS AND EXPERIMENTAL IMPLICATIONS

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WHAT THIS ARTICLE IS ABOUT

Eight categories of models for converting carbon-14 dates into real time are discussed. Six of these models are based on a creation as described in Genesis and a short age of life on earth. Differences between the models are specified, especially those that are subject to experimental testing. Such features include (1) differences between ring years and radiocarbon years in trees that should be immediately postdiluvian by creationist theories, (2) the accuracy, or lack thereof, of the dendrochronological radiocarbon calibration curve in the historical era, and (3) the possible existence of carbon-14 in antediluvian fossil material. Suggestions are offered for experimental projects that would resolve these uncertainties.

In this paper I will discuss eight categories of carbon-14 models and their experimental implications. Six, or three-quarters of these, are creationist models. The purpose of this paper is to stimulate thinking and to argue for an experimental perspective.

CONSTRAINTS

Any model of carbon-14 dating must satisfy certain constraints. First, since carbon-14 dating is objective and reproducible, it cannot be ignored. One cannot simply dismiss it out of hand; there should be an explanatory model for the data. Second, it has been validated at least back to 300 B.C. by comparison with many other reliable dating methods.[1] Therefore, any model must account for this data, and it is not reasonable to consider carbon-14 dating completely unreliable before that point, particularly when used as a relative dating method.

Another universally recognized constraint is the level of carbon-14 in geologically old material. Although the existence of a very low level of carbon-14 in ancient or antediluvian fossil material, for example Pennsylvanian coal (conventional age ~350,000,000 years) is controversial

(see discussion below), it is universally agreed that the level of carbon-14 in such materials is at least very low, if not non-existent.

There are five other less universally accepted constraints that determine which of the eight categories of models will be chosen:

1. Strict uniformitarianism
2. The evolutionary time scale
3. An invariant decay constant for carbon-14
4. The dendrochronological carbon-14 calibration curve prior to around 300 B.C.
5. The date of the Flood, and its presumed consequences

How important one considers each of these constraints determines which category of model will be most appealing.

THE UNIFORMITARIAN MODEL

The first category we will consider is models that assume strict uniformitarianism. The model initially proposed was strictly uniformitarian (Libby 1955). This simple model is no longer supported by any worker in the field. It is of interest as an object lesson in the fallibility of strict uniformitarianism.

However, because of its mathematical simplicity, it is still used, even though it is known to represent only general trends. A simple translation can be made between model age and percentage of carbon-14. Citations of uncalibrated carbon-14 dates in the professional literature use this model by convention. It roughly approximates the evolutionary model.

The uniformitarianism model assumes that the ratio of carbon-14 to ordinary carbon (the $^{14}C/C$ ratio) in the atmosphere has always been constant at its present value (100 percent modern carbon, sometimes written as 100 pmc). According to this model, plants that get their carbon from the atmosphere would incorporate carbon with a constant $^{14}C/C$ ratio. The carbon in animals that eat these plants might be around 2 years "old", which is negligible in terms of radiocarbon dating. The carbon in carnivores would be slightly "older" but still of negligible "age". A dead plant or animal, or wood produced by a plant, does not exchange carbon with the environment (if the sample is chosen with sufficient care), and the $^{14}C/C$ ratio gradually decreases exponentially, with a half-life of 5568 years. One simply measures the $^{14}C/C$ ratio and compares that to the present ratio, using the formulas in Table 1. For those who find graphics more understandable, the graph in Figure 1 may be used. The

TABLE 1
Formulas for Carbon-14 Dating

$$(^{14}C/C) = (^{14}C/C)_0 \, e^{-kt}$$

$$t = \ln [(^{14}C/C)_0 / (^{14}C/C)] / k$$

$$\text{where } k = \ln (2) / t_{½}$$

$$t_{½} = 5568 \text{ years}$$

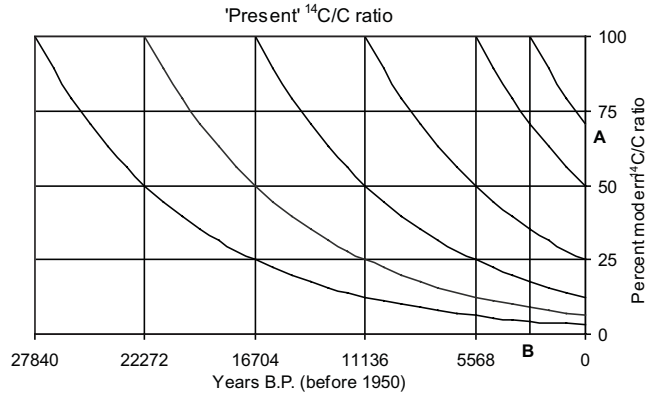
$$T / t_{½} = -\log_2(\text{pmc}/100)$$

pmc = percent modern carbon [=^{14}C/C ratio expressed as a percentage of that found in the "modern" (1850) biosphere]

formulas themselves are non-controversial. The graph associates every measured ^{14}C/C ratio with an age (for example, Age B, or Ratio A).

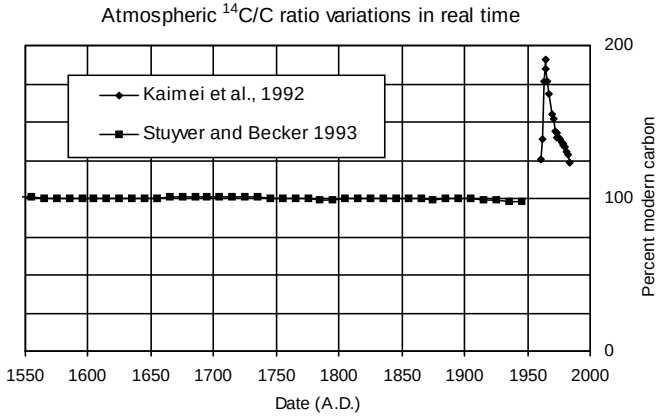
This model has been supplanted because it has been demonstrated that the ^{14}C/C ratio in the biosphere has varied during the recent past, and there is evidence that it has also varied in the more remote past. When massive amounts of carbon-14 were produced in the Northern

FIGURE 1



Hemisphere by nuclear explosions in the 1950s and 1960s the ^{14}C/C ratio in the atmosphere nearly doubled (see, for example, the data from Kaimei et al. 1992, shown in Figure 2). Since nuclear explosions in the atmosphere have been discontinued, this ratio has gradually decreased toward the ratio found before the nuclear age. The ^{14}C/C ratio in the biosphere had been slowly dropping over the 100-200 years prior to the nuclear age, apparently due to the introduction of essentially "dead"

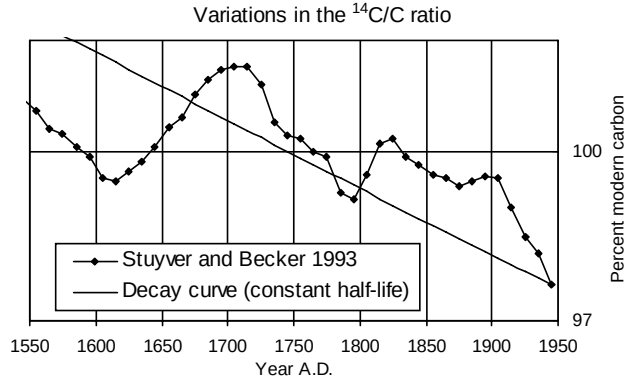
FIGURE 2



carbon from the use of fossil fuels (coal, oil, natural gas, etc. See Figures 2 and 3, especially Figure 3). The $^{14}C/C$ ratio of a 1945 sample from the biosphere actually is lower (and the specimen therefore "older") than that of a sample from 1850, or even 1700 (see Figure 3).

One may be tempted to say that the above variations were manmade, and that nature, if left alone, would be uniformitarian. But these are not the only documented variations in the $^{14}C/C$ ratio. For example, the decrease of the $^{14}C/C$ ratio between 1535 and 1615, or the increase between 1615 and 1705, has not been correlated with any causative human activity.

FIGURE 3



Recent, more precise measurements of the half-life of carbon-14 are closer to 5730 years than to the 5568-year half-life used in earlier calculations. So the conventional uniformitarian model would need minor modification, even if the assumption of a constant $^{14}C/C$ ratio in the biosphere were correct.

Since the $^{14}C/C$ ratio has varied in the recent past, one cannot relate measurements to the "modern" level without specifying which modern level. By convention, "modern" carbon is the $^{14}C/C$ ratio that existed in 1850, before most of the industrial revolution and well before the nuclear age. Thus the carbon in our bodies has a $^{14}C/C$ ratio of roughly 110-120 "percent modern carbon", which sounds a bit strange but makes sense once one understands the convention.

Since carbon-14 dating is an inaccurate measure of real time without some sort of calibration, uncalibrated carbon-14 dates are usually reported on the basis of the old (less accurate) 5568-year estimate of the half-life. As calibration is necessary, the correction for the wrong half-life can be included in the calibration. This makes it unnecssary to recalculate all the old published dates, or worry about which half-life has been used. By convention all uncalibrated carbon-14 dates are reported using the 5568-year value for the half-life. Those who use the 5730-year value are supposed to explicitly state that they are doing so.

THE EVOLUTIONARY MODEL

The next model we will consider, the evolutionary model, in common with all the other models except the uniformitarian model, uses a calibration curve to convert radiocarbon years to real-time years. In order to construct a calibration curve one must either have a model of how radiocarbon dates should correlate with real time, or one must have some specimens which can be securely dated by some other method and for which radiocarbon dates may be obtained. In the case of the evolutionary model, the latter is attempted.

The fundamental data on which the evolutionary model is built is the dendrochronological radiocarbon calibration curve. This calibration curve is based on work in which tree rings from Irish oak specimens were matched to each other to create a master sequence (Stuiver & Pearson 1993; Pearson & Stuiver 1993; Stuiver & Becker 1993; and Pearson et al., 1993; see also Kromer & Becker 1993). There may be circular reasoning in this process, as the specimens were apparently

first radiocarbon dated to give an approximate time-range estimate before detailed ring matching was attempted.[2] Specimens from defined 10-year or 20-year intervals were radiocarbon dated. A given radiocarbon date from a specimen with unknown calendar age is then matched with the radiocarbon date from one or more of these 10-year or 20-year specimens, and the real-time date for the unknown specimen is assumed to be the same as that of the specimen or specimens which it matches. The shape of the calibration curve, and uncertainties in the measurement of the unknown radiocarbon date may lead to a range of possible dates.

There is a belief that multiple lines of evidence support the master Irish Oak calibration curve. However, the curve derived from German oaks (Becker 1993) is incomplete, especially at 500 B.C. (Kromer et al., 1996). Bristlecone pine calibration disagrees with the Irish oak calibration from 600-300 B.C.[3] A calibration based on varves (sedimentary layers laid down in lakes and assumed to be deposited yearly) disagreed with the Irish Oak calibration in the range of 1,000-10,000 B.C. (Tauber 1970). Radiocarbon dates on archaeologically dated material (which will be the subject of another paper) disagree with the dendrochronological calibration curve at 614-612 B.C. The present standard of the conventional scientific and historical community for the period from the present to 6,000 B.C. is the Irish oak dendrochronological calibration curve.

For ages greater than the maximum age of the dendrochronological calibration curve, there is rough agreement between various investigators that the $^{14}C/C$ ratio has ranged from the present value to twice the present value. While there is disagreement among various estimates, the data of Bard et al. (1990) appear to have had a stabilizing influence on the interpretation of the data.

CREATIONIST MODELS

There are at least 6 different major groups of models from which creationists may choose. They may be grouped as follows:

1. Masoretic Flood, constant decay
2. Masoretic Flood, variable decay
3. Septuagint Flood, constant decay
4. Septuagint Flood, variable decay
5. Ancient Flood, constant decay
6. Ancient Flood, variable decay

The choice among these models hinges on the date postulated for the Flood, and the assumption of constancy, or variability, of the carbon-14

decay constant. The first row of models is based on a placement of the Flood 4,300 to 4,500 years ago, depending on the length of the sojourn of the descendants of Israel in Egypt (an interesting and potentially important point for other purposes, but one which is of minor significance here). This placement of the Flood is derived from the numbers in Genesis 11 as given in the Masoretic Text. The next row of models assumes a Flood roughly 5,500 years ago, in accordance with the numbers in Genesis 11 as given by the Septuagint. The final row places the Flood at a point usually between 10,000 to 30,000 years ago, and require major gaps in the genealogy of Genesis 11. The precise point is usually not specified by any biblical, archaeological, or geological data. The most defensible suggestion for a date for the Flood from this perspective is given by Aardsma at 12,00 B.C. (1991).

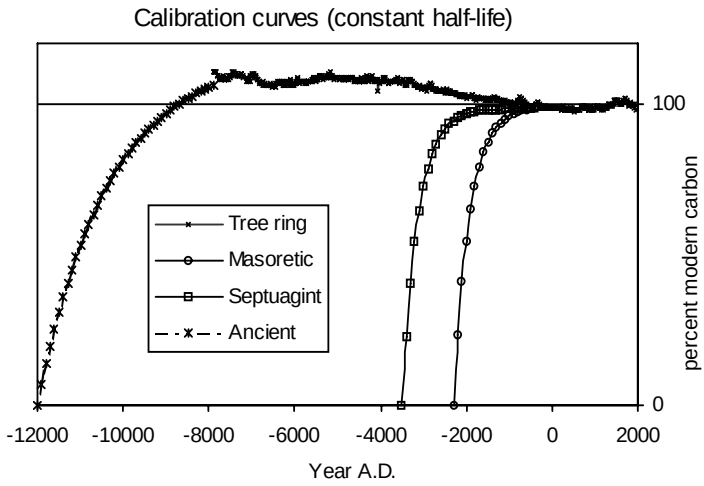
All six categories of creationist models require a rapid rise of the apparent $^{14}C/C$ ratio during the period immediately following the Flood, the left three explaining this by ordinary geophysical processes, and the right three by invoking a change in the radioactive decay constant of carbon-14. Both the constant decay and variable decay models make, in most cases, precisely the same predictions in terms of present-day measurements of the $^{14}C/C$ ratio and their correlation with real time. If we could have measured the $^{14}C/C$ ratio at a given time in the past, for example 4,000 B.P. for the Masoretic Flood models or 13,000 B.P. for some Ancient Flood models, the constant decay models predict a $^{14}C/C$ ratio much lower than the evolutionary model would predict. In contrast, the variable decay models can account for an initial $^{14}C/C$ ratio near, at, or even greater than that predicted by the evolutionary model. However, both models predict the same carbon-14 date for a given historical date, and so the variable decay models cannot be distinguished from the constant decay models by their predictions for carbon-14 dates for a given historical date. Where the predictions of the constant decay models and the variable decay models converge, I will use the term "apparent $^{14}C/C$ ratio" to describe this convergence.

Testable Prediction #1: Discrepancy Between Tree-Ring and Radiocarbon Years

It is obvious that the models based on the Masoretic Text and those based on the Septuagint require a rapid rise in the apparent $^{14}C/C$ ratio immediately after the Flood.[4] Measurements of carbon-14 in presumably

antediluvian fossil material consistently are less than 1% of the modern $^{14}C/C$ ratio. Even if one disregards the data from the dendrochronological calibration curve before 450 B.C., it is still necessary to go from a very low or zero apparent $^{14}C/C$ ratio at the time of the Flood to near the present ratio in less than 3000 years (see Figure 4). But what is not always appreciated is that the same is true for the ancient flood models. They have been designed specifically to agree with the dendrochronological calibration curve until its maximum age. In the model proposed by Aardsma, if the dendrochronological calibration curve at 11,000 years B.P. requires a $^{14}C/C$ ratio approximately 110% of that at present, and if the Flood occurred at 14,000 years B.P. (12,000 B.C.), then we still have only 3,000 years to reach that level (see Figure 4). No matter how it is constructed, any reasonable creationist model must have rapidly rising apparent $^{14}C/C$ ratios after the Flood.

FIGURE 4



Herein lies the first experimentally testable difference between some creationist models and the evolutionary model for carbon-14 dating. Consider a tree that is perhaps 35,000 radiocarbon years old. It is not unreasonable to assume that, since according to Genesis 8:22, "seedtime and harvest,…summer and winter" were not to "cease"; "while the earth remains," the rings on such a tree must represent a close approximation of the number of years it grew. Since by hypothesis there is a

rapidly rising apparent $^{14}C/C$ ratio during this period, there would be a difference in the carbon-14 dates between the inside and the outside of this tree much greater than the number of real-time years. Therefore, according to any creationist scenario, a sufficiently old tree should have a significant difference between the carbon-14 dates for the inner and outer wood — much more than the difference predicted by standard evolutionary theory. For Septuagint models, the constraints are tighter than for Ancient Flood models; and for Masoretic Flood models, the constraints are even more severe. Wood that is 6,000 radiocarbon years old should have this feature for either Septuagint or Masoretic Flood models. In contrast, the predictions of most Ancient Flood models match those of the evolutionary model for specimens less than perhaps 11,000 radiocarbon years.

The simpler Masoretic and Septuagint models are more easily tested than one might think. Take for example a 250-ring specimen from Mt. Mazama (the Crater Lake region in Oregon), which blew up approximately 5,700 radiocarbon years ago. If one assumes a roughly exponential rise in the apparent $^{14}C/C$ ratio after the Flood, this specimen should have approximately 1,200 to 2,700 radiocarbon years' difference between the inside and the outside according to the Septuagint models. The exact difference depends on the rate of rise of the $^{14}C/C$ ratio in the post-Flood biosphere. According to the Masoretic models, there should be approximately 2,400 to 8,400 radiocarbon years' difference between the inside and the outside. An evolutionary or Ancient Flood model would predict roughly 150-250 radiocarbon years' difference between the inside and the outside (calculations available from the author; see Table 2).

It is important to note that the argument is not affected whether one accounts for the rapid rise of carbon-14 dates by dilutional effects, by changing production rates, by changing decay constants, or by any combination of these and/or any other factors. The simple fact is that if you wish to get from <1 percent modern carbon (pmc) to >97 pmc, the curve must slope upwards.

Some may wish to claim that this may not be true for all specimens. The plot of the atmospheric $^{14}C/C$ ratio versus time most likely is not completely smooth, and may even have occasional reversals. But for every part of the plot with no rise or with a reversal, the plot must have an even steeper section elsewhere. For a sufficiently long time period,

TABLE 2

Difference in Radiocarbon Years Between Inside and Outside of 250-Year-Old Tree with Bark Date of 5,700 ^{14}C Years

(Expected difference by evolutionary or ancient Flood models 180-230 radiocarbon years)

Mean life of ^{14}C in the upper biosphere	Expected age difference Septuagint Flood model	Expected age difference Masoretic Flood model
500 years	1,200 ^{14}C years	2,100 ^{14}C years
375 years	1,500 ^{14}C years	2,900 ^{14}C years
250 years	2,700 ^{14}C years	8,400 ^{14}C years

Mean life of ^{14}C in the biosphere at present = 375 years (Hesshalmer et al., 1994)

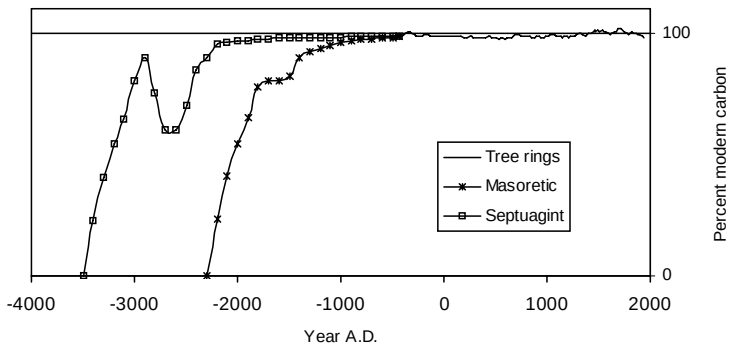
say 3,000 years, the trend mathematically must be observable (see Figure 5). Each of these creationist models is falsifiable.

Some creationist readers may resist the notion of testing our ideas. What if we are proved wrong? I would point out three significant benefits of falsifiability. First, testability places one indisputably in the field of science. Creationism can no longer be honestly disparaged as making no testable predictions. It is, or at least can be partly, scientific.

Second, to what is our ultimate allegiance due? Is it not to truth? If our beliefs are not true, then why hold them? One cannot ultimately evade the thrust of this question by saying that even if all the evidence

FIGURE 5

Effect of arbitrary irregularities in curves



is against our beliefs, they are still true. The claim of the Judeo-Christian (and Muslim) religious tradition is that our God is the God of the Universe. If the observable universe is truly understood, and does not match some part of our religious tradition, then that part needs modification or revision.

Third, and most importantly, if creationists are right, and the results of the experiments corroborate our theories while falsifying those of others, we provide an opportunity for anyone who is honest in heart to see that our theories are more correct than theirs. Let me state this in the negative. If we are right, but refuse to allow our beliefs to be tested, do we not give the message to our opponents, perhaps accurately, that we really do not believe — that we actually doubt? And do we not prevent them from ever finding out that we are right? I see the present situation, not as dangerous, but as a win-win situation. If we are wrong, we will find out. And if we are right, we will provide an opportunity to anyone who is honest in heart to see it. We should do the experiments.

One point to remember is that the Bible is not determinative for all knowledge. The Bible is not a good manual for automobile repair. The Bible does not even give a clear indication whether the sun moves around Earth, or vice versa. Such indication as was given seemed to the readers to be in favor of the former at the time when a major scientific dispute took place. The best Galileo could do was to argue that the Bible did not intend to address the question. It is certainly possible to read the genealogies of Genesis 11 as incomplete and not specifying the precise date of the Flood. Perhaps scientific data, including radiocarbon data, may help us determime this question.

Another point that deserves emphasis is that it is simply not true that whenever the mechanistic view of nature (usually mislabeled "science") conflicts with religion, science always wins and religion always loses. Specific cases in point that are now generally conceded are whether the universe has a beginning; whether the geologic record gives evidence of catastrophes; and, in the field of history, whether the numbers of First and Second Kings and First and Second Chronicles are accurate. Were it not for the fact that the question strikes at the heart of the mechanistic view, the same would be the case for the origin of life. In the case of Seventh-day Adventists, the same is true for the toxicity of tobacco. Thus religion is not destined to lose every time it stands up to the current majority scientific view. This means that religion should not surrender too quickly when challenged by what appears to be science.

Testable Prediction #2: Errors in the Calibration Curve in the Historical Era

A second difference in the predictions of our models deserves mention. The Masoretic and Septuagint models require a rising $^{14}C/C$ ratio during the historical era. This contrasts with the Ancient Flood and evolutionary models, and is testable in principle. The Masoretic and Septuagint models thus require the dendrochronological calibration curve to be grossly inaccurate in some portion of the historical era.

The most likely location at which to find the inaccuracy in the dendrochronological calibration curve, if there is such, is in the era between 450 B.C. and 765 B.C. Variations in the dendrochronological calibration curve in this region are unexplained geophysically. The Irish Oak data are irregular, and in two places the 10-year and 20-year curves disagree.[5] The bristlecone pine data disagree with both Irish oak curves in this area, as noted above, and the German oak data have a gap here. The dendrochronological calibration curve is not supported by the extant archaeological dates.

There is now direct experimental evidence that the dendrochronological calibration curve is incorrect in this region. Human bone archaeologically dated to 612 B.C. has a preliminary uncalibrated carbon-14 date of 720 ± 30 B.C. (± 1 S.D.). The probability of the date being this different by chance is $p<0.001$. At a later date I plan to discuss this carbon-14 date in detail.[6]

It may be argued that this would be only one area where the dendrochronological calibration curve is apparently in error, and is irrelevant to the larger question of whether the curve is fundamentally in favor of a short-age creationist or an evolutionary time scale. In one sense this is true. It would only substract around 300 years from conventionally calibrated dates, and the rest of the curve is not necessarily affected. However, once the conclusion is reached that the calibration curve is in error here, the question of further errors cannot be ignored, and it is entirely possible that the shape of a revised curve would be highly favorable to a short time scale.

The dendrochronological calibration curve appears to be an example of a data set that looked good at first but had significant problems on closer inspection. I think it is one of the duties of creationists to test this calibration curve, and to expose it as erroneous if it does not pass the test. This is especially true of those who subscribe to either the Septuagint or the Masoretic Flood models.

Testable Prediction #3: The Existence of Carbon-14 in Very Old Fossil Material

Finally, there is the question of whether very old fossil material contains carbon-14. Views that allow alterations of the radiometric decay constants can account for the complete absence of carbon-14 in antediluvian or very ancient fossil material, matching evolutionary requirements. On the other hand, models that explain carbon-14 dates by ordinary geophysical processes without changing the decay constants are virtually required to predict that there is a small but now measurable amount of carbon-14 in antediluvian fossil material. This constitutes the third experimental difference in predictions between models.

Evidence for the existence of this small amount of carbon-14 in very old/antediluvian material will be discussed in another paper. This carbon-14 has five possible explanations. It could be machine error, contamination *in situ*, contamination during processing and/or measurement, nuclear synthesis *in situ*, or residual activity. Machine error can be largely eliminated experimentally. Nuclear synthesis can be essentially eliminated on theoretical grounds. So the carbon that is measured is apparently either contamination or true residual activity.

If this carbon-14 can be firmly proven to be residual, the entire evolutionary time scale would be invalidated. To have a residual activity of 1 atom after 1 million years requires starting with a mass of pure carbon-14 over 100 times larger than the earth.[7] Thus if there is residual carbon-14 in material that is supposedly 350 million years old, it is simply not that old. Further experiments in this area should be a high priority for creationists.

SUMMARY

To summarize, there are several testable creationist models for carbon-14 dating, which have implications for biblical interpretation and historical reconstruction. Testable areas include: 1) differences between ring years and radiocarbon years in trees that should be immediately postdiluvian by creationist theories, 2) the accuracy, or lack thereof, of the dendrochronological radiocarbon calibration curve in the historical era, and 3) the possible existence of carbon-14 in antediluvian fossil material. These models should be tested, so we may know which, if any, of them deserves our confidence.

ENDNOTES

1. The most specific examples are Dead Sea Scrolls which have reliable historical dates on them, which were dated twice (Bonani et al., 1992; Jull et al., 1995; see also Rodley 1993) with results that agree with the carbon-14 dates derived from dendrochronological calibration. Although there may be controversy over the accuracy of historical dates, and their matching with the dendrochronological calibration curve, in the era preceding 330 B.C. (see Testable Prediction #2), the accuracy of calibrated dates in the era from 330 B.C. to the present is secure.
2. This is known to have happened for Bristlecone pine. See Michael and Ralph (1981).
3. The difference averages over 100 years. The probability of this happening by chance is $p<10^{-24}$. Even if one allows for uncertainties in the data by expanding the standard deviations of the measurements on bristlecone pine by multiplying by 1.3 and adding 20 years to the measurements, the probability is still $p<10^{-14}$. See Suess (1978) for the data on bristlecone pine.
4. This has been noted by, among others, Brown (1979).
5. The 20-year calibration curve gives an uncalibrated radiocarbon date for 450 B.C (± 10 years) of 481 ± 13 B.C., whereas the comparable dates from the 10-year curve, at 445 (± 5) and 455 (± 5) B.C., are 522 ± 44 B.C. and 558 ± 30 B.C. respectively. The 20-year curve gives an uncalibrated radiocarbon date for 670 (± 10) B.C. of 554 ± 13 B.C. whereas the 10-year curve gives a date for 661 B.C. of 495 ± 25 B.C. The probability of either of these two happening is $p<0.05$.
6. The date itself has been reported, although in much abbreviated form, in Burky et al., 1998.
7. For details of the argument, see Giem (1997, p 175-188).

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EDITORIAL COMMENT

The editors feel this paper makes a valuable contribution to creationist writing, and we are pleased to publish it. However, we feel that a word of caution is in order. Historical theories are inherent difficult to test decisively, because one is attempting to reconstruct initial conditions, and the number of possibilities is, for practical purposes, infinite. Even if we can test a few possibilities, there may be too many variables to be able to disprove an idea completely. Furthermore, we have reservations about the power of science to test conclusively historical scenarios in which supernatural intervention is proposed. In historical science, tentativeness of conclusions is always appropriate, and more so when dealing with issues at the interface of science and Scripture. With this caveat in mind, we hope this article will indeed stimulate creationists to test their ideas wherever possible.