RADIOCARBON, DENDROCHRONOLOGY, AND THE DATE OF THE FLOOD

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ABSTRACT

Radiocarbon and tree-ring data are evaluated in light of current creationist understanding of the impact of the Flood on global geophysical systems to deduce a most probable date for the Flood. A date within a few thousand years of 12,000 B.C. is found. This date is tentatively accepted, and a creationist model for the increase in global ^{14}C specific activity following the Flood is derived using it. The model readily explains the long-term past behavior of atmospheric ^{14}C recorded by approximately 9000 year continuous tree-ring sequences in Europe and America. This seems to provide strong support for the validity of the model (and, hence, the approximate date for the Flood upon which it is based) as well as the legitimacy of these long dendrochronologies. The model implies that conventional radiocarbon dates in excess of about 11,000 B.P. greatly exceed the true dates. It provides a rational basis for calibrating conventional ^{14}C dates, thus providing creationists with an objective and universal radiometric chronometer for determining the chronology of earth history from the Flood to the present.

INTRODUCTION

For purposes of scientific investigation, the Biblical account of earth history conveniently and naturally divides into two distinct periods. These are the pre-Flood and post-Flood worlds; the historical event which divides them is the Genesis Flood. These two periods are not equally amenable to scientific analysis. The pre-Flood world was brought into being by supernatural activity during the initial creation week. It was totally destroyed by the Flood so that the geophysical systems which were in operation during this period are nowhere preserved today. These two facts – the supernatural character of creation week, coupled with the paucity of empirical data from the pre-Flood period – conspire to render any effort to model pre-Flood geophysical processes and systems highly speculative at the present time. In contrast to this, the post-Flood world was brought about by the catastrophic processes accompanying the Flood and the natural consequences of that cataclysm. The resulting geophysical processes and systems are operative today, and extensive records of their past behavior have been left in sediments, tree growth-rings, ice cores, etc. Consequently, there is an abundance of data available for empirically based scientific investigation of this period. The overwhelmingly (though not exclusively) naturalistic character of the post-Flood period, coupled with the plethora of available data conspire to render it ideal for study and analysis using the usual methods of scientific investigation. Thus, it has seemed prudent to me to focus attention on the Flood itself and the post-Flood world in seeking to further develop the creationist model of the past.

There are two problems which must be solved before substantial progress can be made in the quantitative development of this most important portion of the model. The first and most obvious problem is that of ascertaining the *date* of the Flood. This date fixes the time scale within

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which the geophysical aftermath of the Flood develops and post-Flood history unfolds. The second problem is the elucidation of a suitable, objective scientific chronometer. In the absence of an objective scientific chronometer, the scientific and archaeological data bearing on the past can be assembled in a nearly infinite number of permutations, greatly impeding discovery of the correct arrangement. Radiocarbon may provide a very nearly ideal tool for the solution of both of these problems.

About a dozen creation scientists (too many to be reviewed here) have grappled with various aspects of radiocarbon dating in the past. Several different models for the past global behavior of radiocarbon, displaying a wide range of quantitative rigor and geophysical plausibility, have been proposed by these researchers. The earliest work which I have been able to find was published in 1961 by Whitcomb and Morris in *The Genesis Flood* (1). This analysis was perspicuous and contained what still stands as an essentially correct analysis of the probable effect of the Flood on radiocarbon. It effectively predicted the imbalance between the global production and decay of ^{14}C, while being apparently unaware that Libby (2) had already observed this imbalance and that Cook (3) had been arguing for the geophysical reality of Libby's observations since 1956. It failed to consider the effect of the Flood on the active terrestrial reservoirs of stable carbon (a necessary consideration, since it is the *specific* activity of ^{14}C which is of interest for radiocarbon dating purposes, and this is the ^{14}C activity per unit weight of stable carbon in the sample being dated), so wrongly predicted that radiocarbon dates would appear uniformly too old beyond about 2000 B.C. (Dendrochronology has subsequently suggested that radiocarbon dates are uniformly too *young* from about 1000 B.C. to the maximum tree-ring range of about 7000 B.C. See Figure 1.) Subsequent mainstream creationist efforts directed toward understanding radiocarbon have attempted to build upon this fine foundation, though there has been surprisingly little progress. The impediment, in my opinion, has been the almost unanimous a priori commitment of creationist researchers working on this problem to an Ussher-like date for Creation and the Flood. The work described in this paper breaks with these earlier attempts in this regard.

DATING THE FLOOD

The date of the Flood should not be very difficult to determine scientifically. A cataclysm of the magnitude of the Flood would necessarily profoundly perturb most of the geophysical systems operative on the globe. These systems would then inevitably go through a period of transition to new steady state conditions following the Flood. A good example is the "ice age" which is generally perceived by creationists as being a transient artifact of these sorts of post-Flood transition phenomena (4). Some of these transitions would require thousands of years to reach steady state and should still be evident today, unless the date of the Flood is exceedingly remote. By determining the probable initial state of these geophysical systems immediately following the Flood as well as their current rate of change and distance from steady state, it should be possible to deduce the probable elapsed time from the Flood to the present. Several independent analyses of this sort should make the date of the Flood quite conspicuous. Two such analyses follow.

Date of the Flood Using Global ^{14}C Build Up

Of the possible geophysical systems with potential application to dating the Flood, the global radiocarbon system is probably the most elegant. The global inventory of ^{14}C is governed by the equation:

$$\frac{d^{14}C^{g}(t)}{dt} = \overline{Q}(t) - \lambda^{14}C^{g}(t) \qquad (1)$$

where $^{14}C^{g}$ is the total number of ^{14}C atoms in the active radiocarbon reservoirs (i.e. atmosphere, oceans, and biosphere), $\overline{Q}(t)$ is the rate of production of ^{14}C by cosmic rays in the atmosphere, and λ is the decay constant for ^{14}C (1.21×10^{-4} per year). Careful analysis of the function $\overline{Q}(t)$ (5) indicates that for the purpose of ascertaining the date of the Flood it can be reasonably approximated by the time independent quantity $\overline{Q}$, the value of which has been determined to be

$$\overline{Q} = (3.5 \pm 0.6) \times 10^{26} \ ^{14}\text{C/year} \qquad (2)$$

by modern-day measurement (6). Given this substitution for $\overline{Q}(t)$, equation 1 can be solved

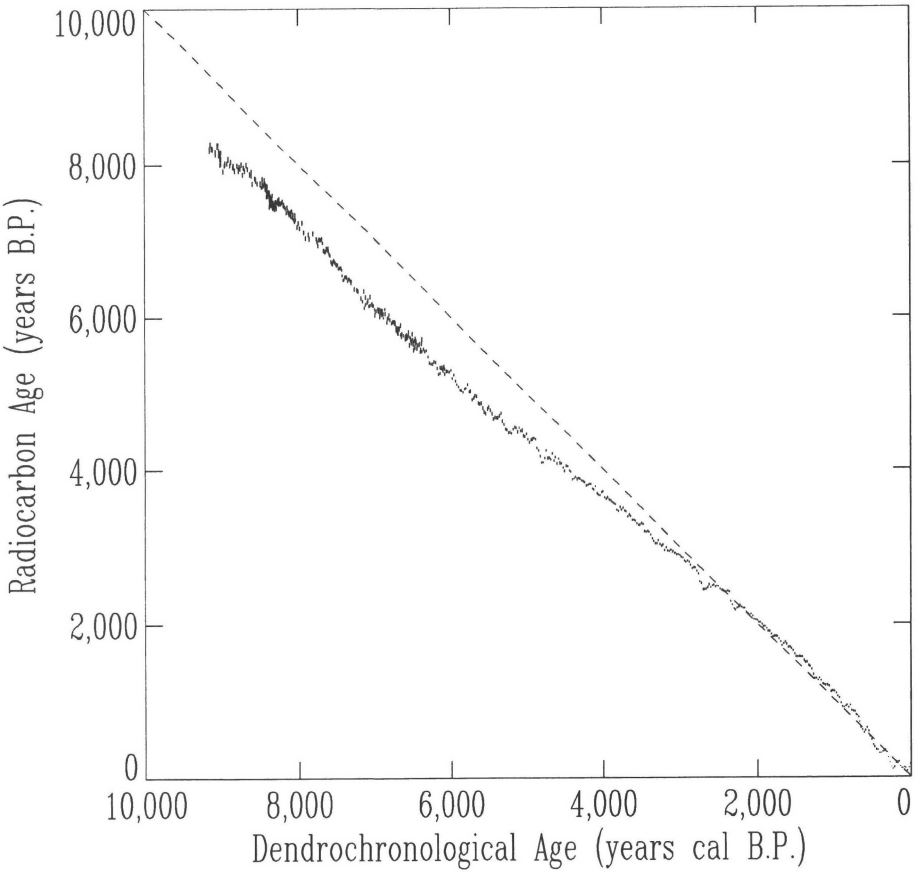

Figure 1: Dendrochronological calibration of radiocarbon. The dashed line corresponds to the prediction of the conventional steady state model.

uniquely once an initial condition is specified. Because of the apparent massive loss of carbon from the active global carbon reservoirs by burial in sediments at the time of the Flood (7), the global ^{14}C inventory in the atmosphere, oceans, and biosphere was probably reduced to near zero following the Flood. Hence, the appropriate initial condition is:

$$^{14}C^{g}(t_F) = 0 \tag{3}$$

where t_F corresponds to the year following the Flood. The solution of equation 1 for constant ^{14}C production and the initial condition specified by equation 3 is

$$^{14}C^{g}(t) = \frac{\overline{Q}}{\lambda}[1 - exp(-\lambda(t - t_F))] \quad \text{for all } t > t_F. \tag{4}$$

To use this equation to determine the elapsed time from the Flood, t_F, to the present, t_p, it is necessary to substitute t_p for t and rearrange as follows:

$$t_p - t_F = -\frac{1}{\lambda} ln(1 - \frac{\lambda^{14}C^{g}(t_p)}{\overline{Q}}). \tag{5}$$

It only remains to determine the value of $^{14}C^{g}(t_p)$ to obtain the desired elapsed time. From Grey (8) this quantity can be determined to be:

$$^{14}C^{g}(t_p) = (2.4^{+0.20}_{-0.05}) \times 10^{30} \ ^{14}C \text{ atoms}. \tag{6}$$

When the values for $\overline{Q}$ and $^{14}C^{g}(t_p)$ together with their associated error estimates given above are used in equation 5, an elapsed time between the Flood and the present of $14,000 \pm 7,000$ years is obtained. The large uncertainty in this quantity results principally from the uncertainty in the determination of $\overline{Q}$. The uncertainty in this parameter may not be as large as that which has been given by Lingenfelter and Ramaty (6) (which I have used); estimates of $\overline{Q}$ taken from a fairly comprehensive survey of the literature in the years between 1950 and 1980 yield a standard deviation of 0.26 (from seven determinations) compared to Lingenfelter's error estimate of 0.4. This reduces the uncertainty in the elapsed time from 7,000 to about 5,000 years. In any event, the most probable date for the Flood which is calculated by the build up of radiocarbon is 12,000 B.C.

Date of the Flood Using Dendrochronology

It is also possible to obtain an estimate of the date of the Flood from dendrochronology. This method is outstanding for its simplicity of application. In recent decades very long tree-ring chronologies have been constructed for use in calibrating the conventional steady state radiocarbon time scale which Libby (9) initially proposed. The most recent such calibration is shown in Figure 1. As can be seen, the dendrochronologies upon which this calibration is based (10) currently extend to about 7000 B.C. Since it is most unlikely that any trees survived the Flood in their place of growth, and since it seems quite impossible that any trees could do so without considerable indication of trauma in their growth-rings, the Flood seems to pre-date 7000 B.C. on the basis of the extent of these dendrochronologies alone.

Some creationists have been skeptical of dendrochronology in the past [see (11) for example]. I have scrutinized the methodology of dating using tree growth-rings over the course of a number of years and can no longer find any adequate scientific grounds for rejecting the results of this technology. Though it is not my purpose to attempt to answer all of the questions which might be raised about the tree-ring dating methodology here, the reader needs to be aware that considerable progress has been made in this field in recent decades so that many of the old objections are no longer valid. The hypothesis of multiple growth-rings per year as a significant source of error in these dendrochronologies currently has very substantial empirical evidence against it (12). In the initial phase of the application of dendrochronology to radiocarbon only one long tree-ring chronology existed. In recent years a second, independent, long chronology has been constructed (13). This dendrochronology uses an entirely different species of tree (oak as opposed to bristlecone pine) with entirely different growth characteristics. The two types of trees grew on different continents under different environmental conditions, and the dendrochronologies have been constructed by separate groups of researchers. Yet, the two long dendrochronologies agree in essential detail when compared via ^{14}C analysis of decade or bi-decade samples (10). This seems to exclude the possibility of significant error in these dendrochronologies.

Researchers continue to extend these dendrochronologies and are "cautiously optimistic" that they may eventually reach beyond 8,000 B.C. (14). The maximum extent of these dendrochronologies is not expected to coincide with the termination of the Flood, however, but with the termination of extensive glaciation of the regions from which the living and dead trees which comprise these dendrochronologies have been obtained (15). Oard (4) has proposed that the ice age was a post-Flood phenomenon driven by the cooling of the oceans following the Flood. Using global heat balance considerations he concluded that it is not inconceivable that the post-Flood ice age might have transpired in as little as 600 years. I am not aware of any geophysical argument which shows that the post-Flood ice age *must* have been limited to this brief period of time, however. It seems to me from other geophysical considerations, such as the time required to remove excess heat from the oceans, that the post-Flood ice age may have lasted one to two millennia. Such considerations lead to an estimated date for the Flood within a few thousand years of 10,000 B.C., and seem to exclude dates more recent than about 8000 B.C.

The date of the Flood which is implied by the extent of the long dendrochronologies is thus found to be concordant – within the current limits of uncertainty – with that which is determined from ^{14}C build up. I will tentatively adopt the 12,000 B.C. date for the following analysis. The reader should bear in mind, however, that other dates within as much as about four thousand years of 12,000 B.C. would still be consistent with the analysis to this point.

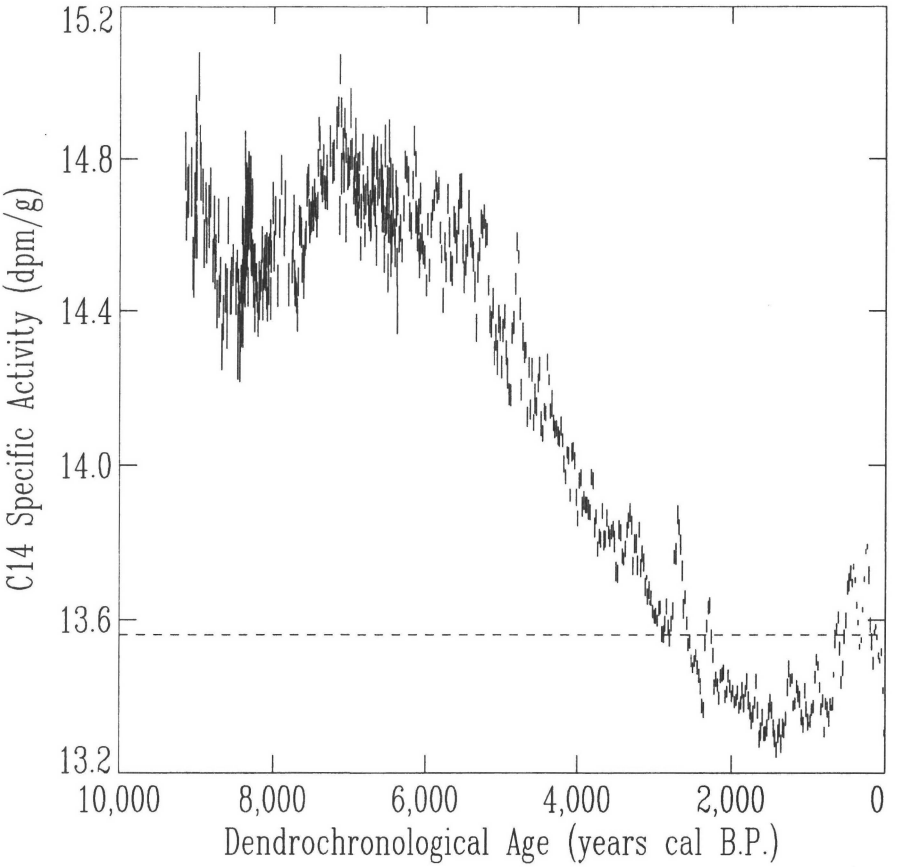

Figure 2: Atmospheric specific activity of radiocarbon (in units of ^{14}C disintegrations per minute per gram of stable carbon) versus time. The dashed line corresponds to the constant initial radiocarbon specific activity assumed by the conventional steady state model.

A CREATIONIST MODEL FOR PAST GLOBAL ^{14}C SPECIFIC ACTIVITY

The principal goal of my radiocarbon research has been to determine how the Flood affected radiocarbon, for the purpose of constructing a reasonably accurate quantitative model for the behavior of terrestrial ^{14}C inventories following the Flood. A knowledge of this behavior is necessary to correct conventional radiocarbon dates and thereby render radiocarbon dating of service to creationists. Detailed analysis of this problem (5) results in the conceptually very simple, analytic, two parameter model for the global behavior of the specific activity of ^{14}C from the Flood to the present given below.

$$\frac{\lambda^{14}C^g(t)}{C} = \frac{\overline{Q}[1 - exp(-\lambda(t - t_F))]}{C^g(t_F) + \alpha \times (t - t_F)} \quad \text{for all } t > t_F. \tag{7}$$

The numerator on either side of this equation is simply the global decay rate of ^{14}C in the active radiocarbon reservoirs at time t. It derives directly from equation 4. The denominator is the global *stable* carbon inventory in the active radiocarbon reservoirs following the Flood. The actual behavior of the global stable carbon inventory in the post-Flood period has never previously been determined that I am aware of, and does not appear to be derivable from independent geophysical considerations. Thus, it was necessary to determine this behavior from the model itself in the usual trial and error fashion. Accordingly, I chose a linear equation

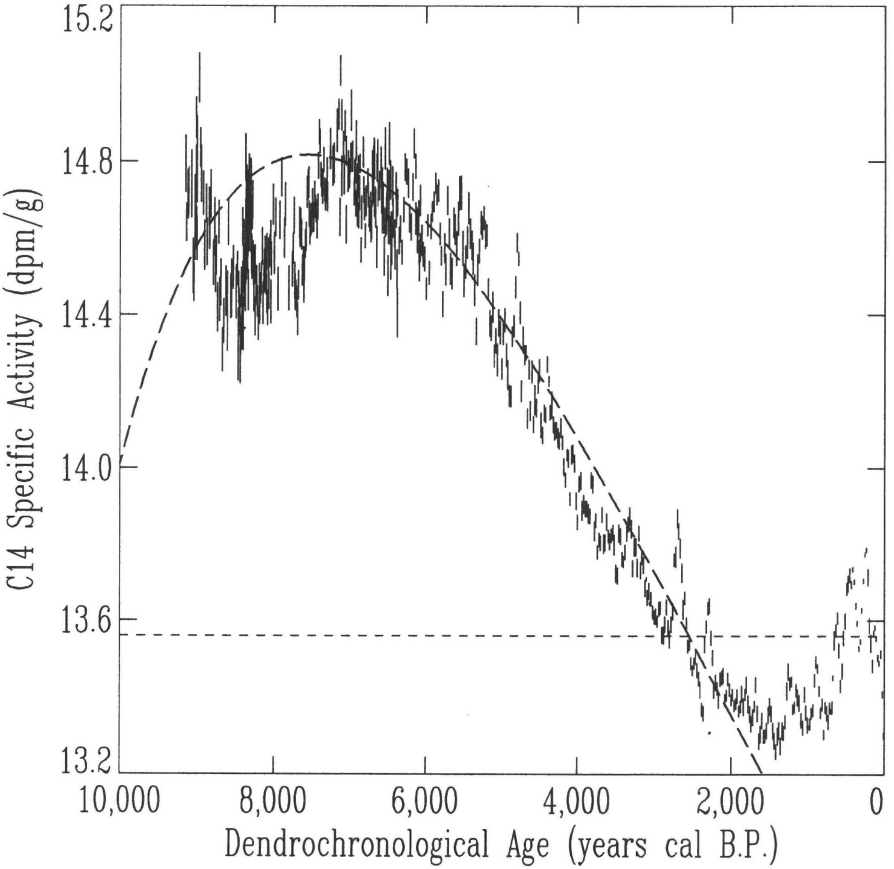

Figure 3: Demonstration of the match between the tree-ring data and our simple transition model. The heavy dashed line is the result of the transition model with $C^g(t_F) = 8.25 \times 10^{18}$ grams and $\alpha = 2.49 \times 10^{15}$ grams per year. The horizontal dashed line is the result of the conventional steady state model.

to describe its behavior since this is the simplest function consistent with the knowledge that it is most unlikely that this inventory came out already in steady state following the Flood. This gave rise to the two parameters of the model which are the initial quantity of stable carbon remaining in the active reservoirs following the Flood, $C^g(t_F)$, and the constant rate at which stable carbon atoms are assumed to have been added to or lost from these reservoirs, α.

The Model Confirmed

It is possible to use the radiocarbon calibration data shown in Figure 1 to obtain a record of the atmospheric specific activity of radiocarbon in the past as shown in Figure 2. Since radiocarbon mixes fairly rapidly between the various active carbon reservoirs, these data should provide a very good approximation to the average global specific activity of ^{14}C in the past. The model derived above (equation 7) should show at least some similarity to the actual long-term behavior of the global specific activity of ^{14}C shown in Figure 2 if it is correct. I have found it impossible to apply this model successfully to these data when constrained by the assumption of an Ussher-like date for the Flood. In sharp contrast to this, I found immediate and substantial progress resulted when the date of the Flood deduced above was tentatively adopted.

When I fit the model to the tree-ring data using standard non-linear least squares techniques and assuming a 12,000 B.C. date for the Flood the remarkably good fit shown in Figure 3 was obtained. The ability of this creationist model to fit these data so closely is especially significant since no adequate explanation of these data has, so far, been found within the conventional non-Flood view of the past (16).

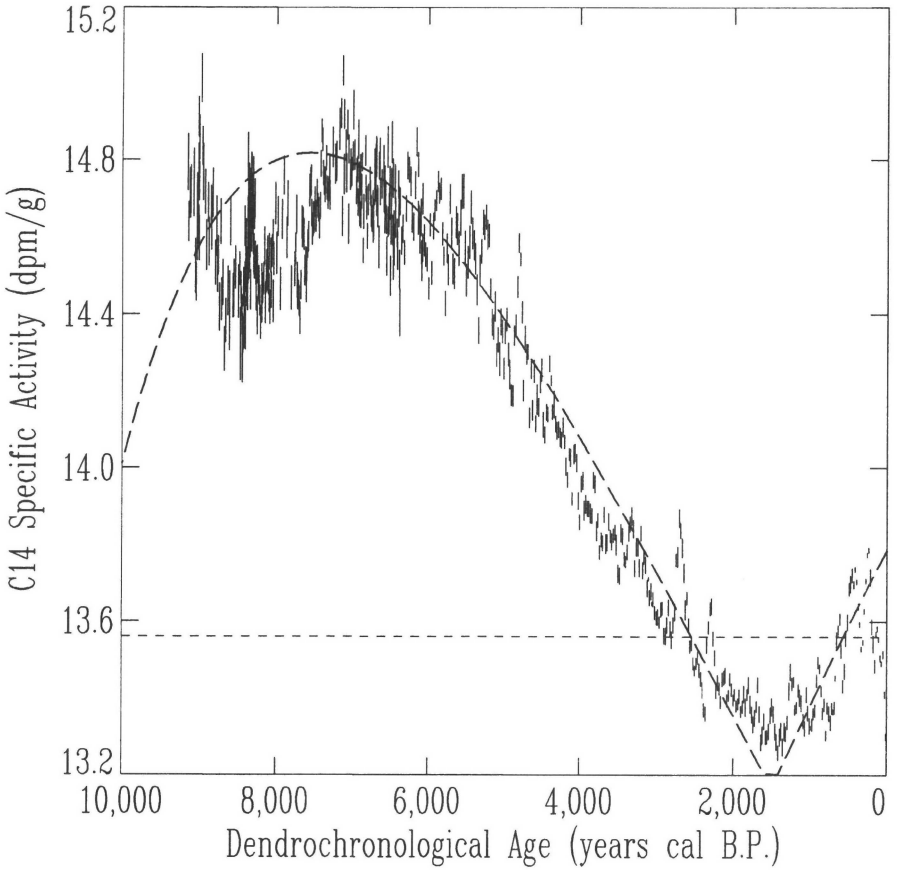

Figure 4: Demonstration of the match between the tree-ring data and our simple transition model when saturation of the oceans with respect to calcium carbonate is allowed for.

The values of the two parameters obtained from the least squares analysis indicate that stable carbon was being added fairly rapidly to the active reservoirs for many millennia following the Flood. This implies a large net uptake of $CaCO_3$ by the oceans from carbonate Flood sediments on the sea floor following the Flood. Modern measurements of $CaCO_3$ concentrations in the oceans (17) show them to be in steady state at present. This implies that the constant rate of uptake of $CaCO_3$ by the oceans following the Flood which the model implies must have ceased at some point in the past. This prediction is also confirmed by the model, which begins to diverge significantly from the tree-ring data at about 1500 years ago suggesting that this was when steady state was achieved. When the model was upgraded to take these additional data and insights into account (by the simple expedient of holding the stable carbon inventory constant from about A.D. 500 to the present time), harmony between the model and the tree-ring data was obtained for the past 1500 years as well (see Figure 4).

The prediction that the dissolved carbonate in the oceans may have increased rapidly following

the Flood, only achieving steady state about 1500 years ago is novel. It has important implications for the pH of the oceans and CO_2 concentration in the atmosphere which remain to be fully explored.

CORRECTING CONVENTIONAL RADIOCARBON DATES

These results indicate that radiocarbon can be used by creationists as an objective scientific chronometer suitable for determining the chronology of earth history from the Flood to the present. To do this it is necessary to correct conventional radiocarbon dates, which are derived without proper regard for the impact of the Flood. Figure 5 provides a convenient graph for this purpose. Since the date of the Flood is still uncertain within a few thousand years,

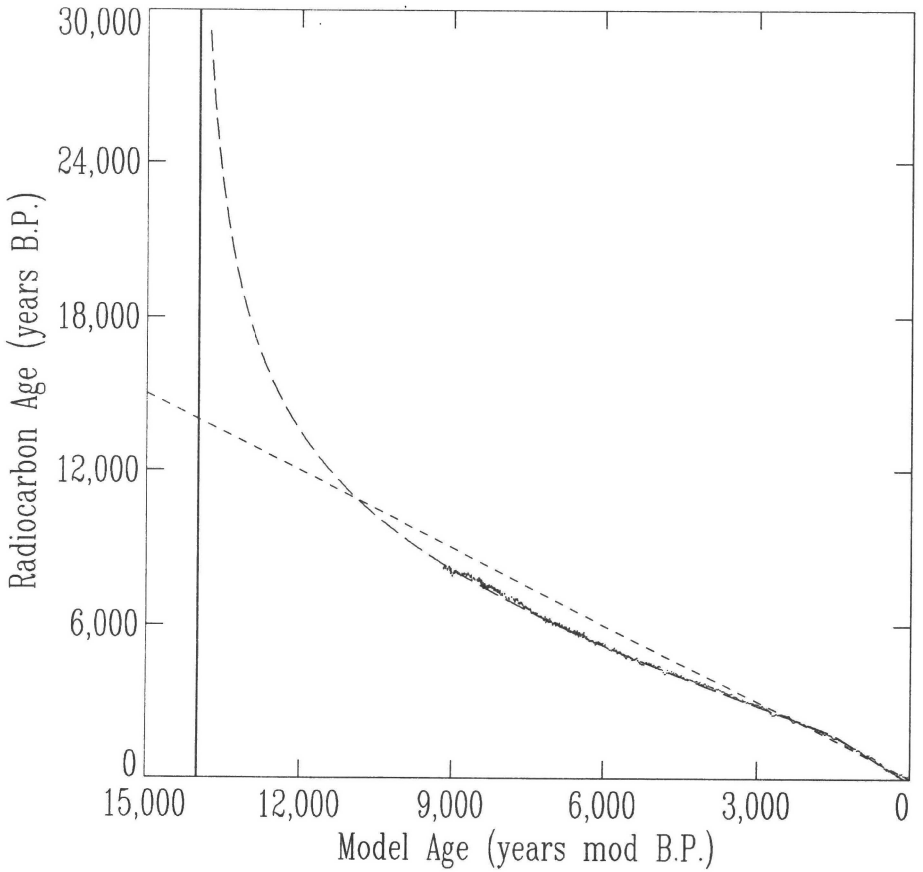

Figure 5: Curve for converting between conventional radiocarbon dates and dates predicted by the transition model (long dashes). The heavy vertical line marks the date for the Flood (14,000 years ago) which was used in constructing the model. The straight line drawn with short dashes is the prediction of the conventional steady state model. The tree-ring calibration data is also shown.

an absolute dating error near this magnitude will necessarily apply to dates approaching that of the Flood. This does not detract significantly from radiocarbon's usefulness as an objective chronometer in this remote period as relative dates should still be correct. It is anticipated that the date of the Flood will be refined considerably in the near future from independent considerations. If so, the absolute dating error for artifacts which derive from the first few

millennia following the Flood may be reduced from several thousand to several hundred years.

It is clear from Figure 5 that conventional ^{14}C dates are much too old for samples derived from the early millennia following the Flood. This helps explain the inordinate duration of the Pleistocene which the conventional geologic time scale exhibits (18).

CONCLUSIONS

In summary, four important conclusions result from this work:

1. The date of the Flood is indicated to be within a few thousand years of 12,000 B.C.
2. The integrity and validity of the long dendrochronologies used to calibrate conventional radiocarbon dates is affirmed by their ability to be explained within a Flood framework.
3. The concentration of dissolved carbonate in the oceans may have increased rapidly following the Flood, not achieving steady state until about 1500 years ago.
4. Radiocarbon can be used by creationists to date historical and archaeological artifacts by correcting conventional published dates using Figure 5.

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DISCUSSION

For a first approximation in an effort to obtain a ^{14}C age for the Flood it is appropriate to assume a constant ^{14}C generation rate equal to that determined by modern-day measurement (Equation 2), but the author has not established limits for the range of uncertainty concerning this rate between the end of the flood and the formation of the oldest ^{14}C datable artifacts that can be given precise and unquestioned historical age assignments. The validity of his conclusions depend critically on the magnitude of this uncertainty. There is paleomagnetic data which indicates that ^{14}C production during this period may have reached 40% greater than its modern level. (Bard, et al., *Nature*, May 31, 1990, pp. 405-410.)

The appropriateness of the $14_C g(t_F)=0$ (Equation 3) assumption depends on the nature of the subsequent analysis and on the additional assumptions that are taken into consideration. From some considerations it may be just as appropriate to assume a date for the Flood and proceed to a determination of $14_C g(t_F)$.

From the data given the equilibrium, or infinite age, ^{14}C concentration may be determined to be $\overline{Q}/\lambda=(2.9\pm0.5)*10^{30}$ ^{14}C atoms. According to Equation 6 the present concentration is probably within the range 2.4 to 2.6 x 10^{30}, or totally within the range of uncertainty for the infinite age value. From my viewpoint the best that can be said from a comparison of these values is that the contemporary ^{14}C concentration is probably less than the infinite age value, but $14_C g(t_P)$ and the appropriate $\overline{Q}$ are not known with sufficient precision or accuracy to allow specification to t_p with any confidence.

The dendrochronological calibration scale given in Figure 1 was developed by individuals who did their best to harmonize prehistoric time scale concepts from anthropology, archaeology, dendrochronology, and radiochronology that were developed independent of the chronological data in the Pentateuch. The disagreement between such time scale constructs and a time scale based directly on the chronological data in the Pentateuch indicates a possibility that such constructs are characterized by error that can become apparent only as indicated by historical data such as has been preserved in the Pentateuch. Each individual should evaluate for himself the evidence for the reliability of the affirmations in the Pentateuch.

The Biblical chronological data place the end of the Flood somewhere between about 4250 and about 5350 years before the AD 1950 zero reference point for the radiocarbon time scale. (4800 +/- 550 years.) [The uncertainty range is due to differences of interpretation regarding the Hebrew sojourn in Egypt, and to differences between Masoretic and Septuagint source material.]

If the ^{14}C age is greater than the true age, the characteristic biosphere ^{14}C level was less than it has been over the past 3000 years. If the ^{14}C age is less than the true age, as specified in Figure 1 for ages exceeding 3000, the characteristic biosphere ^{14}C level was greater than it has been over the past 3000 years, as indicated in Figure 2.

The validity of Dr. Aardsma's CREATIONIST MODEL FOR PAST GLOBAL ^{14}C SPECIFIC ACTIVITY depends on which is the most accurate representation of past events and conditions, the dendrochronological model represented in Figure 1, or a straight forward interpretation of the chronological data in the Pentateuch. If the chronological data is fictional, or requires indirect interpretation, how much else of the historical assertions contained there (a **universal** flood, e.g.) are subject to the same classification?

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Concerning this paper, Dr. Aardsma:

1) Does not appear to know that the case for the Biblical Flood, as to both scope and <u>date</u>, rests wholly upon Scripture.

2) Seems to forget that dendrochronology, at best, is a secondary dating method that demands confirmation at one point in any chosen sequence from some primary source, e.g. reliably recorded or otherwise proven (e.g. by radiocarbon), such as Libby used in dating cathedral trusses and Hatshepsut's Nile barge, etc.

3) Fails to employ (and reconcile) the well-established Biblical date of the Flood (very close to 3,000 years before Christ.

4) Ignores, or overlooks, some nine important published references by this reviewer pertaining to radiocarbon-dating of the Flood spanning over 20 years, as well as by other creationists. and

5) By arbitrarily endorsing a Flood-date of ca. 12,000 B.C., and without any showing of adequate grounds on which to so totally reject Biblical chronology, brings discredit upon Bible-science in this area and "gives the ball-game" to evolutionary thinking.

It should be obvious that when we abandon Biblical chronology as the 'benchmark' with which a Flood-date must agree we open the gate to human conjecture rather than Scripture! An unfortunate precedent for this is found in App. II of Morris & Whitcomb's *Genesis Flood* as early as 1961 where the authors dismiss Genesis 11 as chronology (for faulty reasons) and then proceed to speculate that to set the period between the Flood and Abraham at 5,000 years would be "stretching" it, while assuming 100,000 years (to accommodate some "evangelical scholars") would be "very hazardous" (pp.486-489).

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On the wall of Dr. Aardsma's office at the Institute for Creation Research, I once saw a quotation: "That which has been is remote and exceedingly mysterious. Who can discover it?" (Ecclesiastes 7:24, NASB.) It reminds me that unraveling the past is a tricky business, full of pitfalls for even the best of researchers. Dr. Aardsma is certainly one of the best of researchers, and he does a good job here of summarizing and explaining many things which we need to know about this complex topic. However, I think he has fallen into a pit concerning his very early date for the flood, 12000 B.C. It needs to be taken with a grain of salt, because two of the paper's key assumptions are, in my opinion, very questionable.

The first questionable assumption is that **the rate of production of ^{14}C, $Q(t)$, has been constant since the flood** [eq. (2)]. Dr. Aardsma cites [his ref. 5] an ICR monograph he is working on as giving the reason why he makes this assumption. In the April 1990 draft copy he sent me [pp. 41,42] he acknowledges that (A) a lower strength of the earth's magnetic field in the past could have caused a large increase in Q, and (B) archaeomagnetic data show just such a lower field strength for several millennia after the flood. He points out that the data show that the field was twice as high as the time of Christ as it is now, and apparently felt that this would cancel out the effect of the earlier low field. However, as I will show below, the effect of the low earlier fields would have been considerably greater. Further on, Dr. Aardsma appears to discount the archaeomagnetic data altogether because of one study of ^{10}Be in ice cores from Greenland [1]. The study suggests that the earth's magnetic field has remained constant for the past 5000 years.

But the ^{10}Be paper has a serious flaw: it assumes, with very little explanation, that snow "accumulation rates in Greenland probably did not vary by more than a few percent during the last 5000 years" [Ref. 1, p.383]. This assumption, as the authors acknowledge, has a strong effect on their conclusions. the authors did not specify any direct evidence in their ice cores which would justify their assumption, and I doubt that there was any. If snow accumulation rates were higher in the past, as one would expect in an ice age four to five thousand years ago [2], then the ^{10}Be data would be entirely consistent with the archaeomagnetic data. In fact it could mean that ^{14}C production rates were as much higher in the past as ice-age snowfall rates in Greenland exceeded present-day rates. A recent comment in *Nature* [3] agrees: "... it is extremely difficult to separate the climate signal and the cosmogenic-production signal imbedded in the ice cores."

The same paper [3] shows as archaeomagnetic field strength of less than 50% of today's value at a date which a corrected radiocarbon scale would probably put right after the flood. If the earth's field at that time had been dipolar, the ^{14}C production rate would have been 40% greater than now, assuming a constant flux of cosmic rays. However, my theory [4] of the post flood field fluctuations, and some data, suggests that the field then would not have been nearly as dipolar as it now is, but instead it would have had strong quadrupole and higher-order components. This would mean that $Q(t)$ would have been more than 40% greater.

There are also some creationist reasons to doubt the constancy of cosmic-ray flux. Nobody knows what the source of extra-solar cosmic rays is. What if they are connected to the flood events somehow? Then it is possible that cosmic-ray fluxes were higher after the flood. Solar flares also have a measurable effect on ^{14}C production. If the sun were more active during and after the flood (possibly relating to the speedup of radioactive decay I have suggested in previous papers), then ^{14}C production would again be higher after the flood (possibly relating to the speedup of radioactive decay I have suggested in previous papers), then ^{14}C production would

again be higher after the flood than it now is. In summary, there are many good reasons to suspect that ^{14}C production might have been much higher in the past.

What would be the effect of a variable $Q(t)$? Assuming a constant λ (perhaps good for the post-flood period), zero ^{14}C at time $t = 0$ right after the flood, and $Q(t) = Q_0 \exp(-\alpha t) + Q_1$, I get the following equation for the number $C(t)$ of ^{14}C atoms:

$$C(t) = \frac{Q_0}{\alpha - \lambda}(1 - e^{-\alpha t}) + \frac{Q_1}{\lambda}(1 - e^{-\lambda t})$$

Taking Q_1 as today's value and α as 0.001 yr $^{-1}$, I find that we would get today's inventory of ^{14}C in only 4300 years with a Q_0 of 3.2 times today's rate, it is quite easy to have the flood occurring 4300 years ago instead of 14,000 years ago.

In the denominator of eq. (7) Dr. Aardsma introduces a two-parameter time decrease of the amount of stable carbon C^9 in the global biosphere. He feels that the resulting fit to tree-ring specific activity of ^{14}C supports his model. However, it seems to me that a similar variability of $Q(t)$ with constant could easily produce the same degree of fit. Another thing to notice is that the specific activities shown in Figures 2 and 3 are *adjusted* on the basis of the assumed tree-ring age, not measured directly. For example, modern laboratory measurements of the bits of tree ring shown at 5700 years B.P. in Fig. 2 did not really give an average activity of 14.6 disintegrations per minute per gram. Instead, the measured activity was about 7.3 d.p.m./g, and some researcher multiplied that number by 2 to compensate for the amount of decay over the assumed 5700 years. Thus the shape of the specific activity curves are closely tied to the timescale one uses. If some correction were to shorten the timescale by a few thousand years, the left part of the curve would take a nosedive toward zero. So the curve that Dr. Aardsma produced a fit to is not necessarily the correct one.

The second questionable assumption in this paper is that **the tree-ring time scale is correct.** I do not yet feel competent in this field to fully judge it, but I have looked up the references Dr. Aardsma cited. I notice that most dendrochronologists appear to discount the possibility of more than one growth ring per year. They do so on the basis of a uniformitarian assumption: that worldwide climates over the past 10,000 years have not changed enough to significantly influence tree growth. But this assumption does not reckon with the possible effects of an ice-age climate, the details of which are not known. Scripture frequently refers to a seasonal "early and late rain" in ancient times (e.g., Deut. 11:14, Joel 2:23). Commentators try to relate this to present climatic conditions in Palestine, but perhaps it really refers to conditions which do not exist today. For example, suppose that during the ice age the general weather sequence in the temperate zones was this: spring rains; a hot, dry June; a cool, cloudy, wet July; and finally another hot, dry spell in August. This could produce two growth spurts and two rings per year. An experiment by Dr. Walter Lammerts [5] shows that more than one ring per year can be produced in young bristlecone pines by a two-week drought. If two or three rings formed routinely every ice age year, the tree-ring time scale would be shortened by nearly a factor of two.

I certainly don't want to reject *a priori* the possibility that the tree-ring chronologies are correct, especially in the light of my own experience about the reality of geomagnetic reversals [6]. However, what I found in that field was that uniformitarian biases had grossly stretched the paleomagnetic timescale, from one year to 500 million years. Can similar things happen in counting tree rings? I think what is needed is a detailed (tutorial) creationist review of dendrochronology, preferably by someone who has had hands-on experience in the field.

If the tree-ring chronologies are correct, then the flood probably does need to go much further back into time than young-earth creationists have thought. However, there are other data to be reckoned with. For example, my own paper at this conference [7] shows that the data strongly imply that the maximum age of the earth's magnetic field is 8700 years, implying a maximum date for the flood of about 5000 B.C. As another example, if we put the flood at 12,000 B.C., how do we explain the sudden appearance (or decrease of vagueness) of written human history [8] sometime around 3000 B.C.? What were we doing for the previous 9000 years?

Finally, there is the big question on everybody's mind: How can we fit a date for the flood of 12,000 B.C. into the Biblical chronology? One could conceivably squeeze an additional thousand years or so into the Septuagint (less credible but 1000 years longer than the Masoretic) chronology. But eight or nine thousand additional years beyond that just stretches my credibility to the limits. If tree-ring chronologies are correct, it looks as if either the Bible or the straightforward (Prov. 8:9) way young-earth creationists have interpreted it is incorrect (unless someone can find some plausible gaps in the scriptural chronologies). And yet a straightforward view of scripture has paid off handsomely in other areas of science. Which should we take at face value — tree rings, or scripture and the other scientific data? There

is a lot at stake in the questions posed by Dr. Aardsma's paper, and the questions deserve to be examined much more rigorously.

1.Beer, J., et al., "The Camp Century ^{10}Be record: implications for long-term variations of the geomagnetic dipole moment," NUCLEAR INSTRUMENTS AND METHODS IN PHYSICS RESEARCH, Vol. B5, 1984, pp. 380-384.

2.Oard, M.J., "An ice age within the biblical time frame," PROCEEDINGS OF THE FIRST INTERNATIONAL CONFERENCE ON CREATIONISM, Vol. 2, 1986, Creation Science Fellowship, Pittsburgh, PA, pp. 157-166.

3.Bard, E., et al., "Calibration of the ^{14}C timescale over the past 30,000 years using mass spectrometric U-Th ages from Barbados corals," NATURE, Vol. 345, 31 May 1990, pp. 405-410.

4.Humphreys, D.R., "Reversals of the earth's magnetic field during the Genesis flood,; PROCEEDINGS OF THE FIRST INTERNATIONAL CONFERENCE ON CREATIONISM, Creation Science Fellowship, Pittsburgh, PA 1986, pp. 113-126.

5.Lammerts, W.E., "Are the bristle-cone pine trees really so old?" CREATION RESEARCH SOCIETY QUARTERLY, Vol. 20, No. 2, Sept. 1983, pp. 108-115.

6.Humphreys, D.R., "Has the earth's magnetic field ever flipped?" CREATION RESEARCH SOCIETY QUARTERLY, Vol. 25, No. 3, Dec. 1988, pp. 130-137.

7.Humphreys, D.R., "Physical mechanism for reversals of the earth's magnetic field during the flood," PROCEEDINGS OF THE SECOND INTERNATIONAL CONFERENCE ON CREATIONISM, 1990, Creation Science Fellowship, Pittsburgh, PA, in press.

8.Dritt, J.O., "Man's earliest beginnings: discrepancies in evolutionary timetables," PROCEEDINGS OF THE SECOND INTERNATIONAL CONFERENCE ON CREATIONISM, 1990, Creation Science Fellowship, Pittsburgh, PA, in press.

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CLOSURE

The bottom line of each of the reviewer's comments seems to be a feeling that a date for the Flood within a few thousand years of 12,000 B.C. violates a straight forward interpretation of Scripture. It is obvious that this issue must be resolved before serious consideration of the science can really begin.

I am in full accord with the assertion that we must maintain a commitment to a straight forward interpretation of Scripture and refuse to compromise its plain sense. It is for this reason that we understand that the world was supernaturally created and did not get here through any series of natural processes. It is for this same reason that we agree that the earth really was covered by water in the great cataclysm of Noah's day. The Bible is very explicit regarding these things so that they cannot be denied without doing violence to the plain sense of the divinely inspired record, in my opinion.

But Biblical chronology, unfortunately, does not resolve itself in such a simple fashion. Nowhere in Scripture, either in the Old or New Testament, is the date of the Flood ever explicitly given. Nowhere are we told that 2500 years would or did elapse between the Flood and the Messiah, for example. Dates such as these can only be obtained from Scripture by a process of deduction from numerous Bible references. And this process is not at all free from pitfalls of assumption and human finiteness in the unavoidable interpretive process.

When one studies the history of chronologies derived by various Bible scholars from the early centuries after Christ to the present, one is immediately struck by the fact that their results are by no means identical. In fact, they sometimes differ by more than 1,000 years. This does not result from addition errors or sloppy research, but from the fact that it is not always clear how the numeric information in a given reference is to be properly applied for chronological reckoning, compounded with the fact that different Old Testament manuscripts contain different readings at many of the key Biblical chronology passages.

The majority of discussion devoted to any study of post-Flood chronology has been, and always will be, necessarily focused on understanding the full intent of the genealogical list given in Genesis 11. As Dr. Whitelaw has pointed out, Drs. Whitcomb and Morris, both well-known and respected conservative creationist scholars, in Appendix II of *The Genesis Flood* — the book

which revitalized the modern creationist movement—present eight cogent reasons why one should not force a strict (i.e. no gaps) interpretation of Genesis 11. They conclude:

> In Summarizing the arguments of this entire discussion, we may say that the lack of an overall total of years for the period from the Flood to Abraham, the absence of Cainan's name and years in the Hebrew text, the symmetrical form of the genealogies of Genesis 5 and 11, the inclusion of data that are irrelevant to a strict chronology, the impossibility of all the postdiluvian patriarchs being contemporaries of Abraham, the Biblical indications of a great antiquity for the judgment of Babel, the fact that the Messianic links were seldom firstborn sons, and the analogy of "begat" being used in the ancestral sense allow the existence of gaps of an undetermined length in the patriarchal genealogy of Genesis 11. (p. 483)

Please note that this conclusion was reached by men whose commitment to a straight forward interpretation of Scripture cannot be denied.

Deducing correct dates from Biblical chronology is not a "straight forward" exercise in Biblical exposition. For this reason there has historically been, and will continue to be, a plurality of viewpoints on the date of the Flood within the recent creation camp. The date for the Flood which I have proposed is simply one more expression of this plurality.

The thrust of the comments relevant to the scientific content of the paper seems to be an assertion that alternate assumptions might produce a different model for radiocarbon which would keep the date of the Flood close to 2500 B.C. and still make good sense of the relevant radiocarbon, dendrochronological and other data from geophysics and archaeology. My own experience in modelling radiocarbon leads me to reject this claim. Though I have contemplated and attempted to quantify several possible post-Flood scenarios, constrained by various different dates for the Flood, the radiocarbon model which I have presented in this paper is the only means of integrating and harmonizing all of the pertinent data within a Biblical creationist, Flood model of earth history which I have been able to discover.

The fundamental difficulty is that there is just too much data to be squeezed into a time frame constrained by a 2500 B.C. date for the Flood. Consider the tree-rings for example. We are presented with a data set comprised of over 9000 tree-rings, each section of which is replicated by numerous physical sections (or cores) from real trees whose ring patterns match and overlap from sample to sample. Now, all creationists that I know of would grant the general validity of secular chronology (including tree-rings and radiocarbon dates) back to 1000 B.C.; this section of chronology harmonizes very nicely with the relevant Biblical data. Thus, we are all agreed on the most recent 3000 years of the tree-ring chronology, leaving the remaining 6000 tree-rings to be explained in the remaining 1500 years required to achieve a date for the Flood of 2500 B.C. This necessitates four growth rings per year on average! I maintain that this is an unreasonable requirement. Any post-Flood climatic scenario which one might imagine to bring about such extreme behavior in these trees would almost certainly not bring about four growth rings per year on average; rather it would almost certainly bring about replacement of these trees by other types of plants more suited to such peculiar conditions.

As one further example, consider the following archaeological data from Jericho. At one location in the ancient mound 26 buildings stages were excavated all belonging to the PPNB period. This data implies that a succession of 26 consecutive house building programs was undertaken at this site during the PPNB. Conventional radiocarbon dates imply that the PPNB lasted a little more than one millennium, roughly coinciding with the seventh millennium B.C. This leads to the conclusion that houses had to be rebuilt at Jericho about once every forty years—a conclusion which seems entirely reasonable. My model does not alter this conclusion. Now let us suppose that these radiocarbon dates are wrong and need to be rescaled to fit within a 2500 B.C. date for the Flood (this to be accomplished by assuming a markedly increased production rate of radiocarbon for some length of time after the Flood, for example.) Obviously, we will have to compress these 1000 radiocarbon years of the PPNB period into a much shorter number of "real" years. In fact, a rough graphical analysis of this problem suggests that it will be necessary to compress this time span into something on the order of 100 years. But this immediately leads to the seemingly unreasonable conclusion that houses had to be completely rebuilt during the PPNB at Jericho once ever four years! Even modern houses last longer than this!

In conclusion, the possibility that the Flood was significantly earlier than 2500 B.C. does not seem to be able to be ruled out Biblically and seems to be strongly implied by presently available radiocarbon, tree-ring, and archaeological data.

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