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CREATIONIST COMMENTARY ON AND ANALYSIS OF TREE-RING DATA: A REVIEW

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ABSTRACT

This paper 1) reviews the creationist literature concerning the use of tree growth rings in determining the ages of long-lived trees, developing post-Pleistocene chronologies, calibrating radiocarbon dates, and estimating past climates, and 2) suggests positive research directions using these data to develop creationist models of biblical earth history. Only a single author attempted to use tree-ring data to model pre-Flood climate zonation. However, most commentaries and studies focused on dendrochronology and using it to calibrate radiocarbon dates. Of these, most authors either 1) accepted conventional use of rings as annual indicators but rejected cross-matching with dead logs to produce master tree-ring chronologies extending to a date that may predate the Flood, or 2) proposed multiple rings per year reducing the dates to post-date the Flood, or 3) some combination of 1 and 2, or 4) accepted annual rings and cross-matched master chronologies but extended the date of the Flood prior to those chronologies via biblically acceptable gaps. All authors concerned with radiocarbon dating accepted it as reproducible but disagreed concerning the calibration provided by master chronologies, especially that of the bristlecone pine. The main issues raised by those objecting to calibration is that master chronologies are unreliable and the radiocarbon production rate has varied widely from the Flood until now. This paper calls for research into six areas (biblical studies, physiology of tree growth, C-14 flux through time, possible C-14 contamination, geologic and climatic context of Flood/post-Flood, and biogeographic history of dated trees) to attempt to resolve some of these disagreements and unknowns in order to build a consensus dendrochronology calibration model to convert radiocarbon dates into real time. This paper also calls for research to build creationist models of past environments, but this largely depends on first resolving the dendrochronology issues.

KEY WORDS

tree growth rings, tree-ring dating, dendrochronology, C-14 dating, paleoecology, C-14 flux, bristlecone pine, climate

INTRODUCTION

In botany class a student learns that as trees grow in girth they produce a characteristic growth ring in the wood that marks one annual increment. The inner circumference of the ring is light-colored, forming in the rapid growth of spring and early summer; the outer circumference is darker and denser, formed during the slower growth of late summer and completes the ring as the tree goes dormant for the winter. Thus, from the outer margin of the dark wood of one ring to the outer margin of dark wood of the adjacent ring is one year's growth. Of course, this is only a generalization that must be fine-tuned with accurate knowledge of the particular tree species and particular location: mid-season drought can cause a tree to stop and then start growth, making more than one ring in that annual increment, whereas trees in the wet tropics usually grow continuously and have no distinct rings. All this would be of little interest from a creation biology standpoint if it were not for the ability of trees to give a measure of time and past conditions on the earth. This is especially true because certain trees are old enough to potentially support or contradict a Biblical chronology derived from the Pentateuch, Joshua, Judges, and Kings.

Dendrochronology, the science of using tree rings to obtain ages of trees, assumes the growth rings are annual increments unless there is some compelling reason to verify otherwise. Dendrochronologists also generate composite tree-ring chronologies by finding dead trunks and cross-matching rings in their outer parts with rings in the inner parts (i.e., from the earlier formed rings) of living trees or of younger dead trunks. The purpose is to determine the age of, for example, timber used in ancient buildings and, hence, the age of the buildings themselves. Assumptions are also made about the effect of weather conditions on the characteristics of the rings and about extrapolating present conditions into the past. Besides using tree rings to estimate tree ages and obtain extended chronologies, these data are used to interpret past climatic conditions.

Interestingly, two events converged to make this all relevant to creationism. In 1961 *The Genesis Flood* (Whitcomb and Morris 1961) was published and initiated the resurgence of young earth creationism among evangelicals. A few years before this, dendrochronologists discovered and counted the supposedly oldest living tree, an individual of a bristlecone pine (BCP) species (*Pinus longaeva*, the Great Basin BCP) called "Methuselah," in the arid White Mountains of southeastern California near tree line (Earle 2018). It has over 4,600 rings, which, if these represent years, is close to the time when many creationists would date the Flood. Thus, creationists began to think of ways to use dendrochronology to support biblical chronologies and model past environments. However, later in the 1960s dendrochronologists began generating a composite BCP tree-ring chronology called the master BCP's chronology that now extends to about 9,000 years before present (BP). This is a serious challenge to a Biblical chronology developed from a straight-forward reading of either the Masoretic Text (MT) or the Septuagint (LXX).

Therefore, most of the attention on tree rings by creationists has

been on this BCP master chronology. However, some authors have commented on master chronologies based on other long-lived trees species. These long chronologies have attained even greater significance because they are used to calibrate radiocarbon dating, which began to be used widely in the 1960s to date artifacts of ancient cultures.

Therefore the purpose of this paper is to review and discuss this extensive creationist commentary on and analysis of tree-ring data in relation to modeling the biblical history of the earth.

REVIEW OF CREATIONIST PUBLICATIONS

1. Initial enthusiasm for dendrochronology

Whitcomb and Morris (1961) developed a general model of the Genesis Flood and post-Flood events that provided consilience from diverse lines of evidence. Their treatment of tree rings was limited because no master chronologies older than "Methuselah" had yet been published, and hence, they focused on the ages of living BCP trees as well as sequoias (Whitcomb and Morris 1961, pp. 392-393). They cited the BCP as evidence of the oldest living thing on the earth as not exceeding an age expected for the years since the Flood. They suggested that the uniform age class and vigorous growth of sequoias also pointed to a grove of trees sprouting at the same time without co-occurring parent trees as evidence of post-Flood recovery less than 4,500 years ago. This was also the approach followed by Beasely (1993), who cataloged all of the long-lived species of the world, and Lorey (1994) and Bates (2003), who wrote for popular audiences.

2. Biblical constraints on chronology

It became apparent to Whitcomb and Morris (1961, App. II) that, when harmonizing historical chronologies with biblical data, one must be aware of various factors affecting the biblical exegesis. They give a lengthy discussion why it may be appropriate to consider there to be gaps in the biblical chronologies totaling as much as three or four thousand years, bringing Creation to about 10,000 years ago. Aardsma (1990, 1993a, 1993b) uses similar reasoning to biblically justify a Flood date about 14,000 years ago.

Brown (1990), in discussing dendrochronology and calibrating carbon-14 dates, summarized the biblical constraints using the assumption of no gaps in the genealogies in Genesis 5 and 11, as follows. Ussher's chronology (Creation at 4004 BC and the Flood at 2350 BC) and others similar to it are based on the MT, as is the King James Version and many other modern language translations of the Bible. Gapless interpretations of the MT are the tightest chronologies and most difficult to reconcile with other data. The least restrictive gapless biblical chronologies are those based on the LXX with Creation at about 5600 BC and a Flood date at 3400 BC, which Brown prefers. (He does not discuss the Samaritan Text as it gives intermediate dates.) Brown argues that the Masoretic Jews were motivated to shorten the genealogies. Jews at the beginning of the Christian era believed the Messiah would appear during the sixth millennium since creation. According to the LXX, Jesus was born and taught in the last half of the sixth millennium. By reducing the chronology by 1,500 years, the MT has Jesus appear near the beginning of the fifth millennium. Brown also emphasized that the LXX was the text quoted by the New Testament and was the Bible for the early centuries of the Church. (For further details on the possible ranges of dates, see Hardy and Carter 2014; for further support of the LXX, see Smith 2017).

Most young-earth creationist scholars who have addressed the subject (Bates 2003; Humphries in Aardsma 1990; Lammerts 1983; Long 1973; Wiant 1977a; Woodmorappe 2001, 2003a, 2003b, 2004) have accepted chronology based on the MT without gaps. Some authors (mostly those of letters in response to articles, e.g., Forgay 1993; Heinze 1995; Taylor 1993; Whitelaw in Aardsma 1990) appear to be emotionally committed to an Ussherian chronology.

3. Critiques of assumptions and general methods of dendrochronology

As creationists realized that master tree-ring chronologies had been established, they developed two basic arguments against dendrochronology, in general, and the cross-matched master chronologies, in particular. 1) The counts are inaccurate because there are both missing rings and multiple rings per year (i.e., false rings). 2) Bristlecone pine growth rings are too thin and, thus, too similar to allow accurate cross-matching between wood pieces. The term for growth in which the rings are uniform is "complacent" as opposed to "sensitive," which indicates the development of distinctive patterns of thin and thick rings.

One of the earliest writers to relate dendrochronology to biblical history was Robert H. Brown; he also wrote extensively about radiocarbon dating. Brown (1968) concluded that tree rings established a precise and reliable chronology back to 59 BC but was less confident of earlier dates. He suggested that prior to 59 BC three ring counting possibly overestimates ages by 500 to 1,000 years. Later Brown (1990) related this to complacency and explicitly stated that BCP is not well suited to chronology. Sorenson (1976), Wiant (1977a), Gladwin (1978), and Setterfield (1986) also agree on the issue of complacent growth. Gladwin (1978) also notes that disjunct populations of BCP in southeast California, southwest Utah, and central Arizona do not yield the same ring patterns for the same years.

Sorenson (1976) and Setterfield (1986) added the argument that BCP have up to 30% extra false rings and up to 10% missing rings. Sorenson and Gladwin (1978) both were frustrated that the master chronology was the work of one lab (University of Arizona), which would not release its raw data for critical review. Gladwin, who took a workshop at the University of Arizona, discovered there was personal rivalry with researchers at the Carnegie Institution of Washington such that the lab director in Arizona was highly defensive of anyone questioning his work. Based on an earlier critique by Sorenson (1973), Raaflaub (1974) issued a call for interested members of the American Scientific Association to conduct research for publication on tree-ring dating.

Armstrong (1976) cited work on Scots pine showing cyclic variation in ring width. He argued that if this is true in trees of unknown age, this could cause errors in cross-matching.

In an effort to experimentally generate multiple rings in Rocky Mountain BCP (*Pinus aristata*), Lammerts (1983) raised seedlings in a growth chamber, inducing multi-week drought stress mid-season. The objective was to mimic the climate he assumed to prevail in the White Mountains shortly after the Flood when the climate was warmer and wetter with a longer growing season. In both cases he found that regrowth following drought produced an extra smaller ring. Citing conventional climate models, Lammerts argued that prior to 1200 AD, a "San Francisco rainfall pattern" with winter precipitation and late summer rains characterized the White Mountains. This should have produced two rings per annual increment in the BCP. If this pattern existed between 2350 BC and 1200 AD, then the BCP master chronology (7,100 years known in 1983) would be reduced to 5600 years. Lammerts' work has been cited by numerous authors (Aardsma 1993a; Beasley 1993; Johns

1993; Lorey 1994; Matthews 2006; Woodmorappe 2003a).

According to certain dendrochronologists, false rings have a "signature" of a "fuzzy" terminal edge instead of a sharp edge. However, Lammerts did not find the signature in his experimental plants and argues that false rings formed by the "San Francisco pattern" should not have the signature, as well. Matthews (2006) likewise found evidence that BCP largely lacked such signatures.

Matthews (2006) reviewed the conventional literature on BCP dendrochronology, especially those papers providing support for multiple rings per annual increment. He developed a novel perspective that appears to have merit. Matthews hypothesized that multiple rings per year is an adaptation to aridity in BCP trees that are under stress. That is, production of "late wood" (he calls "dark wood") serves to limit evaporative loss to just one narrow band of "spring wood" (he calls "light wood"). Of particular interest is his demonstration that, as part of the tree dies back to a narrower strip of cambium and smaller number of supported leafy branches, the wood cells immediately after die back are larger in diameter demonstrating reduction of stress to the cells remaining alive after die back. He, as well as Woodmorappe (2003b), also points to trees downslope in better watered and sheltered locations. These trees may be about the same actual age but have thicker rings that number only in the hundreds, not thousands, before dying.

Downes (2010) summarized his research in tree physiology that demonstrates that the one-year-to-one-ring assumption cannot be accepted until verified by actual growth measured over known time. The main emphasis of the research was to understand the way known environmental factors affect tree growth and, thus, tree-ring structure. In particular, his work was aimed at testing global climate change models that use tree rings as proxies in place of direct measurements of climate, which are lacking from prior to the modern scientific era. Significantly, usable proxies must have annual periodicity, be dated with high confidence, and be sensitive to climate. He measured tree diameter in microns every 15 minutes for 4.5 years in *Eucalyptus*, a tropical tree with poorly defined ring structure. He found that trees after drought can respond to water application and reinitiate growth in as little as 30 minutes. By correlating trunk diameter changes with the record of environmental factors, he was able to show that *Eucalyptus* in his sample could have at least three wood density changes (i.e., obscure rings) per year, which corresponded to environmental changes. In a plantation of *Pinus radiata*, a species native to hot Mediterranean climate of Southern California and planted in humid, warm temperate Australia, the 18-year-old trees had between two and six false rings per year, and the annual increments could not be demarcated with confidence. Thus, these studies seriously challenge the use of tree rings to provide data for global climate models. They also challenge the use of tree rings for dating purposes.

Several popular apologetic articles argue for multiple rings per year, due largely to irregularities in the arid climate in which the BCP lives (anonymous author of response letter in Woodmorappe 2009b; Batten without date; Morris 2012; Snelling 2017; Thompson 2010, 2014). All of these authors rely on reports of tree physiology in non-BCP, some of which concern pine species and some species of unrelated trees. Morris specifically cites the forest physiology work related by Downes (2010; see above), but Downes was working with tropical *Eucalyptus* and Mediterranean climate *Pinus radiata*, which are not comparable to short season montane pines.

4. Critiques of computerized methods of dendrochronology

Wiant (1977a) reviewed the cross-matching methods. Apparently computer programs were just being developed to compare accurate measurements of ring widths statistically using correlation coefficients of all possible matches. Data were often transformed (e.g., normalized), but he argued that this would be valid only if there were no missing rings. He pointed out that complacent ring series can give high positive correlations. By analogy with pine species native to Mexico, he argued for multiple false rings in BCP when the climate should have been warmer after the Genesis Flood. False rings from drought or insect defoliation followed by regrowth become more frequent in the Mexican species the further south the trees grow. Of course, he assumes that BCP was in its current location almost immediately after the Flood. The same argument was used by Lorey (1994), Heinze (1995) and Bates (2003).

In a more recent paper, Brown (1995) argues likewise that positive correlation coefficients can lead to spurious cross-matches. He cites work on the development of a master chronology in Douglas fir in which computer analyses helped reduced the number of possible matches, but 66 different alternate matches with statistical significance still remained. Porter (1995) echoed the same objection in relation to the Irish oak master chronology. He also suggests that autocorrelation of rings (the growth in one year will affect the growth of subsequent years, see also Wiant 1977b) can cause incorrect cross-matches.

Using these same basic arguments as many of the authors above, Hebert et al. (2016) and Snelling (2017) emphasize the fallacy of numerous assumptions used to interpret tree rings in single trees, as well as the master chronologies. Both papers specifically criticize the BCP master chronology by citing the secular literature, with Snelling (2017, p. 58) saying, "The living trees account for only 1,200 years of the chronology, and the whole chronology depends on the accuracy of only two specimens—one living and one dead—where the growth rings appear to overlap. If any mistakes appear in the interpretation of these two specimens, the whole chronology crumbles." In noting the difficulty of correlating the very thin rings of BCP, Hebert et al. point out that "… a statistical computer program is [and should be] seen primarily as an independent confirmation of a visual match, rather than a replacement for the visual matching process" (2016, p. 349; my insertion implied by context).

5. Support and use of dendrochronology with creationist interpretations

Woodmorappe (2003a, 2003b, 2004, 2009a, 2009b) accepts the validity of the annual nature of rings in BCP in his thorough review of modern dendrochronology methods and biology of the BCP. In particular he explains stripbark growth in BCP, which is an adaptation to aridity and cold stress. That is, the tree increases in girth around its full circumference only until it reaches a certain size when the roots can no longer obtain the water and nutrient resources to support a full crown of leaves of an increasingly larger tree. At that point, much of the cambium dies except for a small strip on one side of the tree. The tree trunk then assumes a flattened shape, and only a few branches remain alive directly above the growing strip of wood.

Furthermore, Woodmorappe (2003b), in his field studies noticed that the "old" logs, which are supposed to have been lying in the elements for three to seven thousand years, do not look that old. Matthews (2006) adds the argument that even though a foot or more

of rock is supposed to have eroded away from underneath, they still are where they fell! Woodmorappe's (2003a, 2003b) studies convinced him that dead trunks did not exceed more than about 3,000 growth rings, with most having considerably fewer rings than the oldest livings trees. Woodmorappe (2003a) argues that cross-matching techniques appear to be valid. Thus, he developed a novel hypothesis that ring correspondence is due not to climatic, synchronous perturbations but to wave-like sequential localized soil perturbations. That is, rock and soil shifts during substrate creep over several year periods due to erosion and earthquake tremors would stress trees on a fault first, then the creep would spread to other trees over multiyear periods. Thus, trees of the same age would have time-staggered ring patterns making them appear to be of different ages. Using them for developing chronology would then greatly inflate the number of years measured. These types of perturbation would be expected to occur during the years of the Flood recovery.

6. Critiques of calibrating radiocarbon dating with dendrochronology

The physics and math of radiocarbon dating are beyond the scope of this paper, but this section attempts to provide the context of radiocarbon dating as it relates to dendrochronology. As one of the earliest creationists to attempt to correlate carbon-14 dates with a biblical chronology, Brown (1968, see also 1986, 1990, and Brown in Aardsma 1990), reviewed the basis of radiocarbon chronology. To calibrate the C-14 curve with the master chronology, wood segments for every 10 rings in the ring series are dated using radiocarbon dating. He concluded that the University of Arizona Dendrochronology Lab's BCP master chronology would require a 10% increase in C-14 flux before 3500 BP, which has largely been accepted by conventional science, or alternatively, as cited above, that the master chronology overestimates tree ages by 10%. Less than 10 years after Brown's initial assessment, Sorenson (1976) suggested that cross-matching is not valid because the dead tree segments are dated by C-14 before cross-matching even begins because the dead segments would cross-match with so many recent ring patterns in living trees. In a similar vein, Hebert et al. (2016) and Snelling (2017) recently argued that a common feature of dendrochronology is circular reasoning by assuming tree dates to calibrate C-14 dates, which are then used to advise the selection of cross-matched alternate correlations to obtain master chronologies.

Two other early authors working with Egyptian artifacts expressed concerns about the impact dendrochronology calibration of C-14 dating had on archeological dating. Long (1973) lists a long series of specific artifacts along with their C-14 dates, archeological dates, tree-ring calibration of the C-14 date, and the biblical chronology date. In most cases the C-14 date is the youngest, the archeological often close to 1,000 years older, and the calibration date intermediate between the other two or sometimes the oldest by a few years. The biblical chronology often was closest to or younger than the raw C-14 date. Tyler (1977) did not list dates of specific items, but did provide a chart summarizing the C-14 curve, the tree-ring ages plotted against the C-14 curve, and plotted artifacts dated by C-14. He found that the carbon-dated tree rings and carbon-dated artifacts were significantly different for the years 600 BC to 1900 BC, and, hence, the dates were incompatible.

Long's (1973) main argument was that C-14 concentrations vary geographically due to 1) erratic changes in the atmosphere, 2) changes of intensity of the cosmic ray flux, 3) higher altitudes receiving less protection from cosmic rays, and 4) and absorption of C-14 in "dead" rings because the tree is still alive. Therefore he concluded that the BCP calibration curve was not valid for other locations, and that a separate curve would have to be calibrated with different species occurring at low elevation and as close to Egypt as possible.

Setterfield's (1986) perspective is colored by his model of the decay of the speed of light since Creation. In his model, cosmic radiation has varied widely, which in turn would cause wide deviations in the C-14 flux before, during and after the Flood. Thus, he suggests that calibration of C-14 by dendrochronology prior to AD 500 is spurious.

Tyler (1977) challenged the validity of the dendrochronology calibration of radiocarbon dates. He did accept conventional reports that C-14 equilibrates in the troposphere in weeks longitudinally and in a few years latitudinally. Even though the greater ocean surface flux in the Southern Hemisphere removes enough C-14 to make the ages there about 40 years "older," one would still expect the C-14 to be in equilibrium across North America, Europe, and the Middle East. To explain the discrepancies he, like Long (1973), suggested contamination on existing rings. He thought this could be due to food transport across sapwood or *in situ* conversion of cellular N to C-14 in these high altitude plants. He also suggested unusual climatic conditions about 600 BC and the possibility of chronological errors. He thought these more likely due to errors in the archeological methods than in the dendrochronology assumption as cross-matching appears to be valid for the time frame involved.

7. Creationist models harmonizing radiocarbon dating with dendrochronology

Most of the remaining creationist literature on C-14 calibration by dendrochronology centers on two competing creationist models by Brown and Aardsma and an extensive exchange between them. Brown (1986, 1990, see also Brown in Aardsma 1990) developed a mathematical model on the constant rate increase of C-14 post-Flood. Based on radiocarbon content in organic Flood deposits such as coal, he estimated the ratio of C-14 to C-12 as about 1/100th of that after 3500 BP. He (Brown 1986) suggested that C-14 flux was near zero at the time of the Flood due to low magnetic field intensity, shielding by a water vapor canopy, extraction of C-14 from the biosphere by fossil and carbonate deposits during the Flood. He supports the agreement of C-14 and real time from the present (i.e., pre-nuclear testing) back to 3500 BP, before which C-14 ages increase exponentially to a real-time asymptote of 5000 years BP (an approximate LXX date for the Flood).

In a response exchange (Aardsma and Brown 1991; Aardsma 1992), Aardsma pointed out that Brown's conversion would require a BCP living about 6000 BP to make 580 rings in 80 years, or 7 rings/year. Other cases would require up to 20 rings/year in ring series predating 3500 BP. He also said this would require 26 rebuildings of Jericho in 70 years instead of 1,000 years. Brown replied that Jericho at that time had much higher rainfall and the rebuildings were just 26 repairings. To this, Aardsma (1992) replied that he could not find any reference to the high rainfall, which Brown did not document.

Aardsma (1990) also developed his own C-14 conversion model based on dendrochronology. He accepted the University of Arizona BCP dendrochronology calibration as valid. The differential equation he used allowed him to match a constant rate buildup of C-14 after the Flood to the conventional calibration curve, which terminated at approximately 9500 BP. The formula generated a parabolic curve peaking about 8000 BP and dropping to near zero

about 1500 BP with an increase to modern levels as the oceans became saturated and reach equilibrium with the atmosphere. Extrapolating the parabola to the left, the curve intersected zero at approximately 11,500 to 12,000 BP. By allowing a period of one to two millennia for an Ice Age to cool the oceans to near current temperatures and allow for amount of C-14 in the ocean to build to the point of adding to the atmosphere after the Flood, Aardsma tentatively suggested a date of 14,000 BP for the Flood. Therefore his conversion curve follows the University of Arizona calibration curve back to 9000 BP, which dips below the uncalibrated steady-state line, begins curving upward just earlier than 9000 BP, crossing the steady-state line at about 10,500 BP from which point it increases exponentially to an asymptote of 14,000 years real time.

Aardsma's paper (1990, pp. 12-14) includes a published discussion in which R. Humphries notes that Aardsma makes two assumptions: 1) C-14 buildup has been at a constant rate since the Flood, and 2) tree rings are close to annual. Humphries argued that data show that the magnetic field was very weak after the Flood allowing for a much faster buildup of C-14 after the Flood. When he adjusted the differential equation by varying the buildup rate, he obtained a parabolic curve with a beginning zero value close to a 4500 BP date for the Flood. In response, Aardsma (1990, pp. 14-15) argued that to fit the necessary rings in the 1,500 years to which most creationists would agree are the pre-correspondence years (i.e., calibration curve valid only since 3000 BP or 1000 BC) would require four rings per year. He is quite right in that if the climate were that warm and wet to allow that many rings based on short periodic droughts, the BCP would be replaced at that location by some other plant.

Aardsma (1993a) continued his research to attempt to answer such objections. He used C-14 dates of tree rings to test whether multiple or false rings could account for the disparity between dendrochronology and the biblical record. Tree-ring number was plotted against the deviation from the regression line of the radiocarbon age. The width of the deviation peaks (at midpeak) gives the number of rings associated with lower radiocarbon ages due to sunspot activity. He supported this by showing identical deviation peaks for Douglas fir in North America and Irish oak over the last 600 years. Since 3000 BP (when the BCP calibration curve is accepted as valid by most creationists) the widths fell into two size classes, 50 years and 100 years. To correspond to a MT Flood date, the widths should rapidly increase backward in time to a maximum of 400 and 2,000 rings in each class. However, the size classes are consistently 50 or 100 years over the time back to the earliest tree-ring dates, suggesting that growth rates have been annual throughout. Of course, this requires the assumption of uniformitarian conditions in sunspot activity and radiocarbon flux since the Flood.

Shortly afterward, Brown (1995) came to question the validity of cross-matching to extend chronologies. He argued that the BCP master chronology Aardsma had used for his conversion work was done before statistical computer programs had developed means to eliminate some of the many incorrect cross-matches (see also Brown in Aardsma 1990).

Other authors have argued for inaccuracies in the calibration curves. Beasley (1993) suggested that uptake of C-12 from the dolomite carbonates would dilute the radiocarbon ratio and increase the calculated ages. To this Aardsma (1993c) argued that contamination is unlikely in that carbon incorporation is via carbon dioxide in the air, not dissolved carbon dioxide in the sap. He also said that wood resins would keep groundwater carbonates out, and radiocarbon extraction methods remove all but the cellulose fraction. He pointed to the close match between the master chronology of Irish oak (alluded to by Johns [1993] in his letter supporting Aardsma [1993a]) and BCP to show that the patterns are not due to local conditions. Taylor (1995) countered by suggesting that the long tree chronologies could be accounted for by whole BCP trees floating and rerooting after the Flood. They should have many rings because they were created that way with the "appearance of age." Using the same reasoning, Lorey (1994) and Heinze (1995) naively suggested that the White Mountains persisted through the Flood and that the BCPs survived the Flood in place and resumed growth afterwards.

More recently, Woodmorappe (2001, 2003a) developed a novel explanation to account for the discrepancies between the dendrochronologically calibrated radiocarbon dates and biblical chronology. He cited conventional evidence of C-14 age anomalies in locations near modern volcanoes due to dilution by geologic "infinitely old" C-12 in the air. By extrapolating this to conditions shortly after the Flood, the intense volcanic activity should have actually counteracted the low magnetic field influence and caused exaggerated age in plants living in the early years after the Flood. He then coupled this with his hypothesis of time-staggered soil disturbances instead of synchronous climatic factors. To correlate the C-14 dates with the time-staggered ring patterns, he hypothesized that" infinitely old" C-12 was escaping from faults that were causing the sequential soil disturbances. That is, there was a gradient of localized diluted C-14 corresponding to each of the time-staggered cross-matching ring patterns. Thus, among simultaneously growing trees or groves of trees would be those with no age dilation, those with 1000 year dilation, those with 2,000 year dilation, and so on to those with 7,000 year dilation. He proposed a tectonic event that would end the C-12 escape, as well as kill the affected trees.

8. Tree-ring data to model past climates

As Downes (2010) has shown (see Point 3 above), tree-ring data are not reliable for determining the ages of trees and estimating past climatic conditions unless the actual growth increments and causes of ring width variation are understood for that particular species. Generally in most climate modeling studies using tree-ring data, too many assumptions are made resulting in the models being suspect. However, the comparison of ring development in tropical species versus temperate species is better established and less dependent on the knowledge of the particular species involved. Because of the lack of seasonality in the humid tropics, most species there lack growth rings or have them only weakly developed. Therefore inferences about climate regimes based on the presence or absence of ring structure are less fraught with assumptions.

Using this type of data, Wise (1992) has modeled the presence of seasonality in the pre-Flood world. He found that below Permian strata, there is only one sample of fossilized wood from high paleolatitude strata, and it shows seasonality (i.e., ring structure). The remaining numerous samples are all from low paleolatitudes and show tropical growth without rings. From the Permian upwards, there are abundant samples from both high paleolatitudes, all showing seasonality, and from low paleolatitudes showing nonseasonal tropical growth. Wise notes that where one places the Flood/post-Flood boundary will alter one's interpretation of the data. He concludes that, for all models placing the end of the Flood above the Permian, the pre-Flood world had a pronounced seasonal climate beyond 30 to 35 degrees north, including drought and late

frosts, although it may have been more moderate than today's climate. The data also support the conclusion that Flood transport was via very strong east-to-west currents paralleling latitudes rather than currents crossing latitudes. Tidal resonance of Flood waters would account for this, as well as flooding of equatorial regions before high latitudes. As a result, fossils higher in the column are more temperate and familiar looking and, thus, more "modern."

DISCUSSION

Tree-ring data offer creationist researchers with both opportunities and challenges in understanding and modeling biblical earth history. Wise (1992) has already taken advantage of tree-ring growth patterns relating to tropical versus temperate climates and the relatively few assumptions involved. This has allowed him to propose climatic zonation of the pre-Flood earth.

In theory when the tree-ring data are properly understood, creationists should be able to model detailed climatic conditions for various biogeographic zones in both the pre-Flood and post-Flood earth. Unfortunately, this type of modeling requires many more assumptions as pointed out by Downes (2010). However, if Downes' type of research is conducted on living trees that are also known as fossils, then causal growth factors can be better known in the fossils and fewer assumptions need to be made for modeling. For example, birch, alder, chestnut, and Southern beech are all known from pre-Flood sediments; many other living genera of trees are known from Paleogene and Neogene sediments (R. W. Sanders, unpublished compilation extracted from the paleobotanical literature). The closer these fossil species are in similarity to living species, the more accurately the tree rings can be interpreted based on the physiological responses of the living species. Because building models of past climates depend on the same physiological research as does interpreting time increments of tree rings, such studies are not likely to move forward until the chronology issues are resolved.

Indeed, relating tree rings to time has become a major challenge for creationists. After dendrochronology labs published master tree-ring chronologies, creationists realized that, if all the rings in the master chronologies represented successive years, then these chronologies were serious threats to accepting the biblical age of the Flood. Therefore, it is understandable why so much of the creationist literature has been focused on this issue. Furthermore radiocarbon dating became much more common about the time that the master tree-ring chronologies became available, and radiocarbon labs seized the opportunity to calibrate the C-14 dates by matching them to the master tree-ring chronologies. So not only were creationists trying to deal with relating master chronologies to real time, but then had to understand how this two-pronged assault on the biblical history could be addressed and converted into a biblically supporting model.

Giem (1997) reviewed the various creation models for converting C-14 dates into real time (Table 1). Given the creationist consensus that radiocarbon dating is objective and reproducible and is validated back to at least 300 BC by other dating methods, he found that the models differ in several assumptions, including 1) constant vs. variable C-14 decay rate (not the same as variable flux as discussed below) and 2) date of the Flood. As a result there are six basic conversion models, all of which require a rapid rise in C-14 after the Flood and each yielding a different assessment on validity of dendrochronological calibration prior to 300 BC:

Table 1. Giem's (1997) summary of the various creation models for converting C-14 dates into real time.

Flood Date	Constant Decay Rate	Variable Decay Rate
no genealogy gaps, MT Flood	Model 1	Model 2
no genealogy gaps, LXX Flood	Model 3	Model 4
genealogy gaps Flood 8K to 15K BP	Model 5	Model 6

Giem offered three pertinent testable predictions (among many possible) to make these models falsifiable. One is to test the C-14 age of inner rings and outer rings of wood that should have been living during the exponential rise in C-14. Another is to further test the various calibration curves of C-14 dates using historical material in the range of 450 BC to 770 BC where there is significant discordance among archeological items, BCP, Irish oak and German oak. If the calibration curve(s) can be invalidated for those years, then it would be invalidated for unknown prehistorical dates. Finally, because Giem argued that only variable radioactive decay rate can account for complete absence of C-14 in prediluvial wood, evidence for C-14 activity in fossil material from strata conventionally dated as preexisting C-14 limits would falsify the variable decay models. (Later, C-14 activity in fossil material was documented by Giem [2001] and Baumgardner et al. [2003].)

To augment Giem's suggestions, I consider that the following issues are critical in clarifying and/or verifying assumptions as the basis of developing date conversion models:

1. Biblical studies critically analyzing the genealogy and historical texts.
2. Verification of the time increments represented by growth rings.
3. Development of accurate models of global and local C-14 flux during the post-Flood recovery period.
4. Geologic placement of the Flood/post-Flood boundary and the associated geologic and climatic context for the whole period.
5. Complete understanding of C-14 contamination in long-lived species.
6. Biogeographic history of the tree species used for dendrochronology calibration curves.

1. Biblical studies critically analyzing the genealogy and historical texts

Hebrew scholars are needed to review the literature interpreting the Old Testament texts that are pertinent to developing a biblical chronology. Then a thorough analysis of the texts, rooted in the authority of Scripture, is needed to evaluate the previously published interpretations and present a novel chronology, if required. Until the issue is resolved of whether gaps in the genealogies (and Israelite administrations) is exegetically correct, there can be no meaningful advances made in developing dating conversions.

2. Verification of the time increments represented by growth rings

It is not clear that anyone, noncreationist or creationist, has actually verified whether old trees of long-lived species produce only annual rings or have ever produced multiple rings. In alluding to a companion paper (Woodmorappe 2003a), Woodmorappe states,

> It was concluded that the crossmatches appear to be substantially sound, albeit with some 'play' in the data. It was also suggested that multiple rings per year, while occurring in young trees and remaining a possibility for older ones, are not consistent with the *known* growth

habits of the BCP (Woodmorappe 2003b, p.120).

Whereas the assumption that a species' genetics should largely control the physiology of its growth rings is probably valid, apparently the necessary research to verify this for BCP has not been done. Woodmorappe in his ICC paper (2003a) was able to locate only a single physiological study, which was by the University of Arizona (Woodmorappe's reference 13), that appeared to support lack of multiple rings in BCP. However, Woodmorappe did not detail the techniques used in that study. Therefore it appears that Woodmorappe's confidence in strictly annual rings appears to be based primarily on the high statistical probability of accurate cross-matches, as well as an unusually brief growing season of the tree-line BCP. Literature research is needed to determine what experimental studies have been done by either tree physiologists/geneticists or by those involved in the dendrochronology labs.

I am intrigued by the fact that the BCP trees downslope from the tree-line trees always have fewer, thicker rings, can have multiple rings, and never live "as long" as the stripbark trees at tree line, especially in light of Matthews' (2006) adaptation-to-aridity hypothesis. Downes' (2010) work on high resolution correlation of tree growth and environmental conditions begs to be repeated in species used for dendrochronology. Clearly this type of work needs to be done to compare the stripbark and downslope trees of BCP. It is also possible for creationists potentially to do incremental borer analyses in which stripbark growing trees (in nonprotected populations) and downslope normal trees are tagged, rebored every year or few years and the adjacent borings from the same tree compared to verify the number of rings added in the elapsed amount of time. If it can be shown that the trees actually are adding multiple rings, then the calibration curve must be reinterpreted in novel ways. Of course, one of the main drawbacks to original research in this area is the lack of training in dendrochronology and/or tree physiology. A student is needed to enter this area to obtain an advanced degree and develop expertise that can be used to truly evaluate master tree-ring chronologies.

3. Development of accurate models of C-14 flux during the post-Flood recovery period

The excellent experimental work of Aardsma is a model for future creationist research on radiocarbon dating. However, it needs to be repeated using a wide range of assumptions, including multiple versions of variation in the C-14 flux, including local variation, such as those hypothesized by Woodmorappe (2001, 2003a). Indeed, if multiple rings are common, then the analysis of the widths of deviation peaks will need to be re-evaluated as variations in C-14 flux may co-vary with the ring numbers in unexpected ways. Suggestions such as effects of local variation or post-Flood prevalence of diluted C-14 due to geologic emission of "infinitely old" carbon dioxide, sunspot activity, erratic cosmic ray flux, magnetic fluctuations and pole reversals all must be incorporated into a model of the post-Flood world. The C-14 flux brought about by these factors is clearly going to be very difficult to model. When dendrochronologies are made to correspond precisely with real years, the tree-ring data in correspondence with the complex C-14 flux model may produce date conversions that are divergent from and more accurate than previous ones.

4. Geologic placement of the Flood/post-Flood boundary and the associated geologic and climatic context for the whole period

There are two goals that this meets. First, the boundary needs fixing in order to estimate the amount of geologic activity that has occurred since the Flood. That is, if the Flood ended at the K/Pg boundary, then a great deal of tectonic and sedimentary action occurred between the Flood and the time the first long-lived trees began growing where they do now. If the C-14 in Flood fossils gives a radiocarbon age of 40,000 to 50,000 BP, then obviously wood with a radiocarbon age of 11,000 BP did not begin growing immediately after the Flood as most creationist authors have assumed. Second, the factors affecting the C-14 flux need to be determined. For the post-Flood recovery, this is best accomplished through an understanding of geology (including the Earth's radiation input) and climate (as interpreted from geologic and other independent data rather than from tree rings). Thus, this study is closely related to that of developing the C-14 flux model. I would suggest that a team of geophysicists, geologists, paleontologists, astrophysicists, and radiometric dating specialists work together to hammer out a consensus model.

5. Complete understanding of C-14 contamination in long-lived species

A review of the literature is needed to establish whether carbon assimilation is only from the air or can be from conversion of carbonate in the sap. Likewise, does contamination from C-14 in newly generated carbohydrates transfer laterally or conversion of cellular N to C-14 occur in high elevation plants? These will help verify or falsify claims of contamination with new C-14 or "infinitely old" carbon in living trees, especially of the wood formed in earlier years.

6. Biogeographic history of the tree species used for dendrochronology calibration curves

Too often in creationist writings, the dendrochronological ages of living trees are accepted at face value and, based on the biblical chronology followed, the writer assumes that the particular tree must have been growing within a few years after the Flood. Without the geologic and climatic context of the post-Flood recovery, this assumption is completely unwarranted.

For example, Bailey (1970) and Meyer (2012) cited BCP fossils suggesting that the immediate ancestor of the three modern species of BCP existed in the Cretaceous or Paleocene in Alaska. High elevation fossils from the lowermost Oligocene of New Mexico and Upper Oligocene in Utah and Colorado suggest that high elevation slopes and subalpine forest had developed in what is now the Rocky Mountains and Great Basin at that time. The BCP in the White Mountains is the Great Basin BCP, *Pinus longaeva*, and is thought to have differentiated on arid mountaintops in the Pliocene/Pleistocene following the formation of the Cascade rainshadow and then spread throughout the Great Basin during the Pleistocene glaciation when vegetation zones were forced to lower elevations. From a creationist perspective (K/Pg Flood boundary), this indicates that the lineage that would differentiate into three species of BCP probably existed before the Flood (perhaps as a monobaramin within a larger pine holobaramin) and the Great Basin BCP could have differentiated as early as the Oligocene or Miocene, but more likely in the Pliocene.

When considering dendrochronology, especially that of the BCP, from a creationist perspective, one must recognize that neither the trees themselves nor the conditions suitable for the growth of these trees existed at the particular locality for many years after the Flood, certainly for decades, if not several centuries. Therefore to develop calibration curves and dating conversions, one must know the geological and biological constraints on when the tree-ring chronology could even begin at the sampling locality. Detailed

surveys of the literature on fossil material and ecology in geologic and biogeographic contexts of all the species used for calibration of C-14 dates are needed.

CONCLUSION

Creation scientists have rightly given attention to understanding and questioning dating of long-lived trees by growth rings, especially as dendrochronology relates to attempts to calibrate dates obtained from radiocarbon dating. This is especially true given the personal rivalry in which the field of dendrochronology developed as documented first hand by Gladwin (1978, which was originally published in the conventional literature). The most significant creationist publications in this regard are those of Aardsma, Brown, Downes, Giem, Lammerts, Matthews, and Woodmorappe. Giem's overview of work on radiocarbon conversion places the remaining studies in context and provides direction to those thinking about the problem. Brown follows the no gaps-LXX-constant decay model; Aardsma, the gaps-ancient Flood-constant decay model; whereas Lammerts, Matthews, and Woodmorappe follow the no gaps-MT-constant decay model. All of these workers have made important contributions to the creationist understanding of dendrochronology and radiocarbon dating. Downes' research clearly shows that the verdict on multiple vs. few false rings in BCP, as well as other species, is not out yet; much higher resolution physiology work is needed in these species. I recommend testing of Matthews' hypothesis that multiple false rings are an adaptation to aridity, rather than just a sporadic response to rainfall irregularities. Woodmorappe's model of time-staggered disturbance and C-14 anomalies deserves further investigation and should be rigorously refined and tested as a possible contributing factor to age inflation; it may hold the key to unlocking the resolution to this whole conundrum. Certainly the research of Aardsma sets a high bar for other creationists to attain in developing algorithms and analyzing data. However, each of these workers seem to have been limited by the underlying assumptions of their work. In a question and answer session, Aardsma (1990, p. 15) stated that he tried various assumptions and experimental conditions. However, he did not publish the results of those permutations, so those remain unknown. In this paper, I call for the thorough review of a number of issues that affect the beginning assumptions that researchers might use. We need studies that incorporate and examine the full range of assumptions, thus exposing how these assumptions affect experimental design and interpretation. Until this happens, developing biblically compatible master tree-ring chronologies and C-14 dating conversions will likely remain at an impasse. This is especially critical, because the apparent robustness of dendrochronology has convinced many conservative Christians that young-age creationist models are faulty. Also dependent on resolving the chronology issue and more nuanced interpretation of tree rings is the future development of creationists' models of the pre- and post-Flood environments, which currently is in its infancy.

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