AP Content :: Scripturally Speaking

Dating in Archaeology: Radiocarbon & Tree-Ring Dating

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[EDITOR'S NOTE: This is the first of a two-part series on "Dating in Archaeology." Part II is titled "Dating in Archaeology: Challenges to Biblical Credibility."]

Over the last few decades, archaeology has come into its own as a scientific endeavor. Gone are the romantic images of gentlemen in pith helmets carting off treasures to the museums and estates of Europe. Gone, too, is the idea that archaeologists are always on the side of the Bible believer. Modern interpretations frequently challenge biblical accounts. Further, dates generated by new techniques are often at odds with the timing of events given by Scripture.

The purpose of this first article is to discuss problems with radiocarbon and tree-ring dating (or dendrochronology), which are the two most common direct dating techniques in archaeology. Problems with relative dating by interpretation of material culture—arrowheads, pottery, tools—will be the subject of the next article.

RADIOCARBON DATING

In the 1940s, researchers began to study the effect of cosmic radiation on the upper atmosphere. They found that it could transform common nitrogen-14 (14N) into a radioactive isotope of carbon called carbon-14 (14C), or radiocarbon. Both radioactive and nonradioactive (12C,13C) forms of carbon can react with oxygen to form carbon dioxide, which becomes part of the atmosphere. From here it can enter plants by respiration, animals by feeding, and the oceans by exchange with the atmosphere (Figure 1).

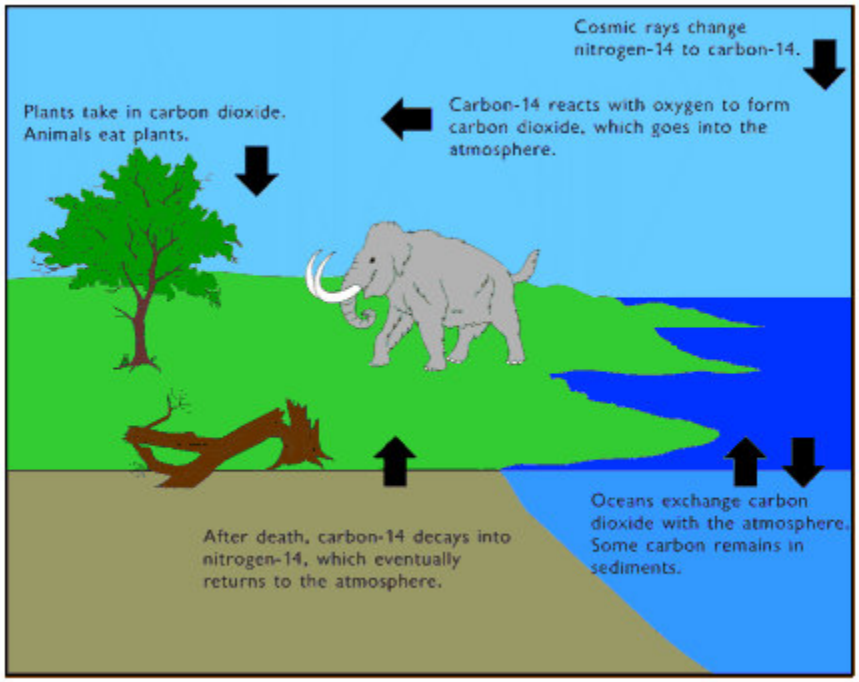

Figure 1. The part of radiocarbon in the carbon cycle

Early in these studies, Willard F. Libby and his coworkers realized that they could use this process as a tool for dating objects containing carbon. Take, for instance, a piece of charcoal from an ancient campsite. While the wood

was alive and growing, it was taking in carbon dioxide. Its ratio of common carbon-12 to radioactive carbon-14 closely matched the ratio in the surrounding air. But after that ancient camper cut it for firewood, it no longer took in carbon dioxide. The carbon-14 slowly decayed, while the amount of carbon-12 stayed the same. Theoretically, if we know the ratio of these two isotopes, and the decay rate, we can calculate the radiocarbon age of the charcoal. The decay rate for carbon-14, expressed as a half-life, is 5730 years (e.g., if our sample contains 1 gram of carbon-14 now, 5730 years ago it contained 2 grams).

Libby's initial results seemed very successful, and in 1960 he received the Nobel Prize in chemistry for his development of this important new technique.

Measurement Limits

Until the last few years, laboratories measured carbon-14 content indirectly by extracting all the carbon from a sample and then counting its radioactive emissions. Unfortunately, many of these systems required relatively large samples to obtain accurate results. Archaeologists faced the dilemma of either preserving or dating their precious finds. The application of accelerator mass spectrometry (AMS) to carbon isotope analysis has changed this picture dramatically. An AMS system has the advantage of counting individual carbon-14 atoms.

Laboratories using the decay-measuring method claim they can analyze several grams of carbon with a typical accuracy of ±40-150 years, and a maximum range of 30-40,000 years. AMS labs claim they can measure several **milli**grams of carbon with a typical accuracy of ±80-400 years, and a maximum range of 40,000 years (Taylor, 1987, Table 4.1; see also Aitken, 1990, Table 4.1). However, being able to measure tiny amounts of carbon-14 is **not** the same as proving that objects are thousands-of-years old.

Radiocarbon Assumptions and Problems

Like other radiometric methods, radiocarbon dating faces technical problems and operates under some questionable assumptions.

1. Perhaps the most critical assumption of radiocarbon dating is that the rates of carbon-14 production and decay are in a state of balance or equilibrium, and have been so for millions of years. If this were true, the carbon-12/carbon-14 ratio in living organisms will be the same as the ratio in an organism that lived thousands of years ago. However, we have reason to think that this is not true, as we will see in a later section.

2. Radiocarbon dating assumes a constant decay rate for the breakdown of carbon-14. At present, we have no firm evidence for any systematic change in this rate.

3. Contamination by groundwater, soil, or foreign matter is always a potential problem. However, people working with radiocarbon dating feel confident that good sample collection can overcome this problem.

4. Some organisms may exclude the heavier carbon-14 isotopes preferentially, making them look too old (e.g., living shellfish that have a radiocarbon "age" of several hundred years). Comparison of carbon-12 and carbon-14 with the stable isotope carbon-13 is supposed to correct this problem (see Aitken, 1990, pp. 62-64). Environmental factors, such as forest fires and volcanic eruptions, which increase the local concentrations of carbon dioxide, may also have an effect on the carbon-14/carbon-12 ratio.

5. Looming over all these assumptions is the idea that cross-checking with other archaeological information will confirm whether the radiocarbon date is "reasonable." This introduces the specter of subjectivity.

TREE-RING DATING

The radiocarbon method has a less convenient, but senior partner in the form of tree-ring dating. This venerable science began in the early part of the twentieth century when A.E. Douglass was looking for a way to investigate

the historical relationship between solar activity and climate. He noticed variations in the width of annual growth rings in yellow pine trees growing around Flagstaff, Arizona. The year-to-year variations were the result of changes in rainfall, while the larger patterns were perhaps the result of some longer-term trend. Douglass used a cross-identification system to match patterns in trees of the same age. He later extended his work to the giant redwoods of California. Eventually he had a chronology going back more than three thousand years.

In the mid-1920s, Douglass began to apply tree rings to dating in archaeology. His idea was to match ring patterns in the timbers of Native American structures, with the ring patterns in yellow pines. This is a relatively simple matter if the ruins are only a few hundred years old. But if they predate the living trees, then it is necessary to use indirect methods. Douglass bridged the gap by overlapping patterns of successively older timbers. This classic technique is called **cross dating**.

Researchers have since applied Douglass' pioneering techniques to other species, including living and dead specimens of the bristlecone pine. From this longest-living of all trees, they have constructed a chronology going back almost ten thousand years.

Supposedly, tree rings produce "real" dates. For example, say we wanted to date a piece of German oak furniture. We could try to match a pattern of rings on the furniture, with a pattern of rings in living oaks from a forest near to where it was made. Using our tree-ring chronology for German oaks, we might get a date of A.D. 1651. This represents the year when the tree was cut and, presumably, gives a good estimate of the furniture's age. In contrast, if we applied radiocarbon dating, all we could say is that the piece dates to sometime in the seventeenth century.

Problems with Tree-Ring Dating

The most questionable assumption in dendrochronology is the rate of ring formation. General principles of biology and climate suggest that trees add only one ring each year. Individual bristlecone pines, which grow very slowly in arid, high altitude areas of western North America, will sometimes skip a year of growth. This might make a tree appear younger than it really is, but dendrochronologists fill in the missing information by comparing rings from other trees.

However, trees would appear too old if they grew more than one ring per year. Most dendrochronologists, drawing on an influential study by LaMarche and Harlan (1973), believe that bristlecone pines do indeed add only one ring per year. Yet not all scientists accept this study. According to Harold Gladwin (1978), the growth patterns of the bristlecone trees are too erratic for dating. Lammerts (1983) found extra rings after studying the development of bristlecone saplings. He suggested that the existing chronology should be compressed from 7,100 to 5,600 years.

Other problems relate to the analysis of growth-ring patterns. Baillie warns:

> As with conventional jig-saws, some people are better at pattern recognition than others and, if the analogy is not too brutal, there are those who recognise the problems, and those who might try to force the pieces together. It has to be remembered that there is only one correct pattern: each tree has grown only once and ultimately its ring pattern can only fit at one place in time. Simply because two pieces look alike does not necessarily mean that they fit together (1982, p. 23).

Computers can provide an important tool for some of this analysis. But researchers must still judge the statistical significance of an apparent match. Also, they must consider variables like local climate and aging, which affect the width of the rings.

THE ASSUMPTION OF EQUILIBRIUM

The stories of these two dating methods converged when researchers realized that they did not always give the same answer. Despite Libby's hopes, radiocarbon dating never could provide an independent measure of age because it contains a critical flaw.

To calculate the radiocarbon age of a specimen, we need to compare the carbon-12/carbon-14 ratio **now**, with the carbon-12/carbon-14 ratio **at the time of death**. However, we do not know the ratio at the time of death, which means we have to make an assumption. Modern radiocarbon dating **assumes** that the carbon-14/carbon-12 ratio in living organisms is the same now as it was in ancient organisms before they died. In other words, the system of carbon-14 production and decay is said to be in a state of balance or equilibrium. Yet this assumption is questionable, even for an old Earth.

The problem is akin to a burning candle (cf. Chittick, 1970, p. 66). Without stretching the analogy too far, let us imagine that the wax represents carbon-14. We could take a ruler and measure the length of the remaining candle. We could even measure the rate at which the candle is burning down. But how can we know when the candle was lit? We simply cannot answer this question without knowing the original length of candle. Perhaps we could make a guess from a nearby unlit candle, but it would only ever be a guess.

In the old-Earth model, the process of making carbon-14 began billions of years ago. The evolving atmosphere filled rapidly with carbon-14, but this rate slowed as carbon-14 found its way into the oceans and the biosphere. Eventually, the carbon-14 would break down into nitrogen-14, thus completing the cycle. Geologists freely admit that this process has not always been in equilibrium, but they maintain that this will not affect the radiocarbon method in any practical way.

The first signs of trouble with this assumption surfaced in Libby's early work. He settled on a specific decay rate (SDR) of 15.3 atoms per minute per gram of total carbon in the specimen, and a specific production rate (SPR) of 18.8 atoms per minute per gram of carbon in the Earth's active carbon inventory. Libby never seriously questioned the discrepancy between these two numbers. He felt that his method was accurate, and that the numbers were close enough. But during the 1950s, researchers started to notice a regular disagreement between radiocarbon and "well-established" archaeological dates. As Aitken comments: "In retrospect it seems to have been unduly optimistic to assume that the modern values were the true starting values for all time past" (1990, p. 66).

These problems encouraged a systematic study in which researchers used the radiocarbon method to date tree rings. Two levels of error emerged. One was a small-scale, short-term variation that can make a given radiocarbon date appear up to four hundred years older or younger than expected (Taylor, 1987, Figure 2.11). Much of this error may be the result of sunspot activity, which in turn affects solar radiation and the production of carbon-14.

A second error comes from an S-shaped, long-term trend (Figure 2). One bend of the curve peaks in the middle of the first millennium A.D. Radiocarbon ages during this period **over**estimate dendrochronological ages by up to a hundred years. The curve switches direction around 500 B.C., when radiocarbon ages begin to **under**estimate supposed dendrochronological ages. The discrepancy grows as we go back in time, so that by the fifth millennium B.C., radiocarbon dates are too recent by 800 years.

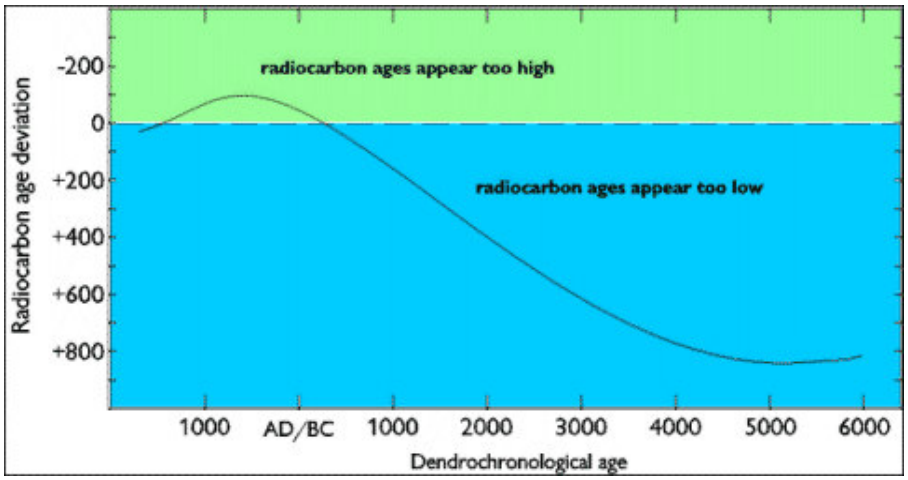

Figure 2. Major trend in the plot of dendrochronology vs. radiocarbon dates. Dates above dashed zero line overestimate tree-ring ages; dates below underestimate tree-ring ages (after Taylor, 1987, Figure 2.8).

No one can explain this major trend adequately on the assumptions of an old Earth or an equilibrium system. Common suggestions include changes in the Earth's magnetic field, or climatic changes following the last ice age, or a combination of both (Aitken, 1990, p. 67). Despite the unknowns, researchers continue to "calibrate" their radiocarbon dates by dendrochronology.

NONEQUILIBRIUM RADIOCARBON DATING

Several creationists believe that the radiocarbon method may still be of some use, but only if we recognize that the Bible and nature record an instantaneous Creation and a cataclysmic Flood. Not only are these the most significant events to have ever affected the physical world, but they occurred over a relatively short time span of only a few thousand years.

In a world with such a history we would expect **non**equilibrium conditions. Production of carbon-14 began only 6,000 years ago—the approximate time of Creation. Roughly 1,500 years later, the Flood upset the entire carbon cycle. As the discrepancy between SPR and SDR shows, the Earth is still in the process of attaining equilibrium. Further, we know from the radiocarbon dating of tree rings that as we go back in time, we find less and less carbon-14. If there was less carbon-14 in the past, then there has been less decay in our samples than the equilibrium model assumes. And if there has been less decay, then the samples are not as old as they may seem.

The nonequlibrium approach attempts to apply this information to radiocarbon dating. But like the equilibrium method, it must still rely on certain assumptions. Robert Whitelaw's (1970) version, for example, assumes that cosmic radiation and atomic decay have remained constant since the Creation. He proposes that the SDR has risen steadily since the Creation, and that the burial of almost all plants and animals in the Flood brought an initially high SPR down to current levels. Whitelaw also sets the Creation at roughly 7,000 years ago, and the Flood at roughly 5,000 years ago. Table 1 shows the effect of his corrections on equilibrium ages.

Problems with Nonequilibrium Dating

According to equilibrium radiocarbon dating, the Egyptian "Old Kingdom" period began approximately 4,100 years ago (Finegan, 1979, p. 404). Whitelaw's scheme lowers this age by 600 years (to c. 1550 B.C.), which puts Moses and the Exodus at the time of the great pyramid builders such as Djoser and Cheops. Clearly, this upsets the established Egyptian chronology. It means, for instance, that Thutmose III cannot be the pharaoh of the Exodus. However, we need more than a few corrected radiocarbon dates to embark on an overdue reorganization of early Egyptian dynasties. Our most reliable account of the oppression and departure of the Israelites is the Bible, and it mentions neither pyramids, nor the names of Egyptian kings.

The difficulties do not end here. Occasionally we find a radiocarbon date that confirms biblical history. For example, Bryant G. Wood cites a radiocarbon date of 1410 B.C. ±40 years to support a biblically consistent account of Jericho's fall (1990, 16[2]:53; see also Jackson, 1990). Using Whitelaw's method, this date adjusts to sometime in the late eighth to early ninth century B.C. This leaves us with an unsavory choice: either we can accept the date, but debate its archaeological context; or we can reject the date outright, suggesting the sample was contaminated or the measurement flawed.

Finally, Whitelaw's model puts any published age greater than 6,000 years into the pre-Flood era (Table 1). However, this may not work in every case. For instance, a baby mammoth named Dima was recovered from the frozen tundra of Siberia, and seems to belong to the post-Flood era. Conventional radiocarbon dating gives it an age of 27,000 years, which by Whitelaw's model adjusts to the first few hundred years after the Creation. Yet it is hard to imagine how a baby mammoth from the time of Adam could find its way into the post-Flood world.

Whitelaw's Nonequilibrium Age	Published Equilibrium Age
1,000	1,115
1,500	1,730
2,000	2,310
2,500	2,900
3,000	3,500
3,500	4,110
4,000	4,725
4,500	5,350
(Flood) 5,000	5,990
5,500	8,860
6,000	12,530
6,500	19,100
7,000	Infinite

Table 1: Relationships between corrected and published ages of specimens in years since death (Whitelaw, 1970, p. 65)

SUMMARY

Radiocarbon dating assumes that the carbon-12/carbon-14 ratio has stayed the same for at least the last hundred thousand years or so. However, the difference between production and decay rates, and the systematic discrepancy between radiocarbon and tree-ring dates, refute this assumption. Instead, the evidence for change is entirely consistent with a recent Creation and catastrophic Flood.

Some creationists have used this information to model a biblically consistent version of the radiocarbon method. While commending them for their effort, we should not be surprised at their lack of success, for this reason: they must still presume to know the starting conditions. This is the critical assumption on which all "absolute" dating methods must fail, whether they are used by evolutionists or creationists.

Similarly, we should not accept the claims for dendrochronology at face value. Bristlecones may add more than one growth ring per year, and the "art" of cross dating living and dead trees may be a considerable source of error.

Both radiocarbon dating and dendrochronology face technical problems, and are loaded with uniformitarian and old Earth ideas. They assume that nature works today the same as it has worked for millions of years, yet the facts do not support this contention. Neither method should give us cause to abandon the facts of biblical history.

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