

THE CREATION WARS

Rodger Dalman

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CHAPTER 4: EVALUATING DATING TECHNIQUES

Given the radically different claims made about the geological evidence, it may be of value to attempt an honest and careful exploration of the dating methods at use in the field. An attempt will be made here to assess what can and can not be claimed with any degree of confidence from the dating methods used to evaluate geological and archaeological evidence

A. THE LIMITATIONS OF RADIOCARBON DATING

In recent years, a surprising number of new dating methods have been proposed and tested. While some proposed dating methods may in time prove to have rather limited reliability, several dating methods remain in common use.¹ The most important of these methods is radiocarbon dating. Radiocarbon dating is based on the fact that carbon dioxide in the atmosphere contains three different kinds of carbon: C¹², C¹³, and C¹⁴. The last of these is a radioactive element that decays with a half life of 5,730 ± 40 years. As C¹⁴ decays, its atoms release a beta-particle and become nitrogen¹⁴. The N¹⁴ atoms are stable, and they do not decay into anything else. Proposed C¹⁴ dates for artifacts fall into the range of 200 to 60,000 years ago, although few authors attempt to use C¹⁴ dating for events before 30,000 BC.² The difference between 28,650 C¹⁴ years ago and 33,980 C¹⁴ years ago is the difference between 1/32 of the original C¹⁴, and 1/64 of the original C¹⁴. These differences can certainly be recognized by Accelerator Mass Spectrometry. However, at this level, the differences between samples from the same archaeological context are likely to exceed differences produced by chronology. AMS has made it possible to date much smaller samples than were once used. The University of Toronto has used AMS to date the carbon within molded iron and small wood fragments on the surface of copper artifacts.³

C¹⁴ dating is possible for three reasons. First, it is possible because the amount of C¹⁴ in the atmosphere remains relatively constant through the years. Second, it is possible because the rate at which C¹⁴ decays is not affected by changes in temperature, pressure, water, acidity, or the decay of other radioactive material around it. Third, it is possible because living plant material absorbs C¹⁴ from the atmosphere through photosynthesis along with C¹² and C¹³. This absorption ends when the plant dies. The date at which plants and animals die can be approximated by checking the percentage of C¹⁴ that remains with a mass spectrometer. This process can then be used to give an approximate date for any artifact that contains carbon.

Under ideal conditions, C¹⁴ dating can provide useful evidence. Tony Wilkinson noted an example of this. Wilkinson described an archaeological dig that he conducted in Mesopotamia's

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Another key dating technique is thermoluminescence dating of pottery produced after roughly 7000 BC. For discussion of this dating method, see: P. A. Clark and R. H. Timpler, "Thermoluminescence Dating of Materials which Exhibit Anomalous Fading," *Archaeometry* 30 (1988): 19-36. M. J. Aitken, "Luminescence Dating: A Guide for Non-Specialists," *Archaeometry* 31 (1989): 147-59. Christopher Rollston noted in an ANE listing from June 2003 that thermoluminescence dating involves many variables. Objects with no known provenance can only have a plus or minus factor between 30% and 40%. So such dates can only be very broad approximations.

² Robin Dennell, "Accelerator Dating: the First Years Reviewed," *Antiquity* 61 (1987): 138

³ Radiocarbon," *Current Archaeology* 129 (1992): 390.

Balikh River valley. Wilkinson found the remains of an old canal that had once been connected with the Balikh River. He thought that the canal dated to the Old Babylonian period, but pottery in the canal only dated to the Greek era. When material from the bottom of the canal was C¹⁴ dated, it confirmed the Greek era date for the canal. So Wilkinson noted that a C¹⁴ date corrected his own misunderstanding of the site.⁴

Donald Collier summarized the evidence that was used to confirm the validity of C¹⁴ dating. He noted that when C¹⁴ dating was first proposed, it was tested against objects with known dates. Wood was C¹⁴ dated from Egypt, Syria and California, and the C¹⁴ dates agreed with the historical evidence within the margin of error of the method. C¹⁴ dating was next tested by dating objects in successive layers of a "tell." Each layer in the tell was C¹⁴ dated at an earlier date than the layer above it. This is exactly what would be expected from the nature of a "tell." Finally, a piece of cloth from Qumran was tested. It C¹⁴ dated to 33 AD plus or minus 200 years, which is the correct historical era for Qumran.⁵

Hershel Shanks discussed a more extensive C¹⁴ study of the Qumran scrolls. He noted that a C¹⁴ study was done with 18 scrolls and 2 pieces of cloth from Qumran. He noted that most of the C¹⁴ dates were quite close to each other. The texts of three documents contained dates, and the C¹⁴ dates agreed with the printed dates in the documents. All C¹⁴ dates for the scrolls fell within the time period known for the scrolls. One scroll fragment did C¹⁴ date at 100 BC when a date between 119 and 245 BC was expected from the kind of letters used on the scroll. However, a second piece of the same scroll dated correctly. Only one C¹⁴ date was completely unexpected. One linen fragment dated to the 13th or 14th centuries BC instead of the Qumran era. This piece of cloth was purchased from a Bedouin who claimed that it had been found at Qumran. Shanks noted that the Bedouin might have found it instead at Wadi Murabbat where similar cloth has been found.⁶ The radiocarbon date for this cloth would be correct if it came from Wadi Murabbat.

H. T. Waterbolk noted that some kinds of materials are more likely to be C¹⁴ dated correctly than other materials. He noted that C¹⁴ dating can be reliable when dating wood objects. However, the radiocarbon date refers to the time that the wood grew, not the time that it was placed in its archaeological context. Early wood beams may have been reused in later buildings. Antique wood objects might have been preserved for many years before being placed in an archaeological context.

It should also be remembered that the center of a large tree grew a century or more earlier than the outside layers of the tree. Wood samples will give different ages depending on the part of the original tree that produced the wood sample. C¹⁴ dates for charcoal are problematic for several reasons. The radiocarbon date for charcoal will be an average date produced by mixing wood carbon, and much of the wood may have grown long before it was turned into charcoal. Waterbolk noted that it is also important to evaluate the relationship between charcoal and its archaeological context. For example, charcoal in a rubbish heap may have an uncertain relationship to the objects around it. Finally, dating of "dark earth" can be no more than a

⁴ Tony Wilkinson, "A Balikh Prospect," *The Oriental Institute News and Notes* 147 (1995).

⁵ Donald Collier, "New Radiocarbon Method for Dating the Past," 330-336 in G. Ernest Wright and David Noel Freedman, eds. *The Biblical Archaeologist Reader*, (Garden City: Doubleday, 1961).

⁶ Hershel Shanks, "New Carbon 14 Results Leave Room for Debate," *Biblical Archaeology Review* 21 (1995).

reasonable possibility. "Dark earth" is a combination of charcoal and dirt, so it has substantial potential for contamination.⁷

Waterbolk mentioned another problem as well. He noted that some C¹⁴ dates are very surprising. They are quite different from what should be expected from the historical setting,⁸ and the difference can not be explained by statistical error or the probability of contamination.⁹ Michael Schiffer discussed the impact of this problem in the study of the Hohokam Indian chronology in the Southwestern United States. Schiffer noted that radiocarbon dates for the Hohokam culture present a very confusing picture. Many C¹⁴ dates are anomalies, and it is very difficult to determine which C¹⁴ dates should be accepted. Schiffer noted that the traditional way to deal with conflicting C¹⁴ dates is to accept the dates that agree with prior assumptions about the site and to reject the C¹⁴ dates that differ from the popular understanding of the site. Schiffer noted that chronological debates occur when one person's anomalies become another person's critical dates. Schiffer noted that archaeologists have recently tried to "cope with the vagaries of radiocarbon dates" by using statistical techniques. However, Schiffer argued that statistical studies of central tendencies become subjective and arbitrary. Such studies can not detect biases in groups of dates, and they treat all dates as being equally valid when some dates are more likely than others.¹⁰

When studying the reliability of C¹⁴ dating, it is important to realize that there is a basic problem lurking in the background. The lurking problem centers on the origin of C¹⁴ in the atmosphere. When radiocarbon dating was first proposed, it was assumed that all of the C¹⁴ in the atmosphere was made by cosmic rays from outside of our solar system striking nitrogen atoms in the atmosphere turning them into an isotope of carbon. The assumption was that a cosmic ray with a strength of at least 4 million electron volts would strike the nucleus of a nitrogen atom in the atmosphere. It was thought that the cosmic ray would convert the nitrogen atom into a C¹⁴ atom. The C¹⁴ atom would then remain in the atmosphere for approximately 25 years until it was either absorbed into plant material or dissolved into water.¹¹

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H. T. Waterbolk, "Working with Radiocarbon Dates," *Proceedings of the Prehistoric Society* 37, part II, (1971): 16. Michael Schiffer argued that even wood has often been C¹⁴ dated incorrectly because fungal rot has brought new carbon into the wood. Michael B. Schiffer, *Formation Processes of the Archaeological Record*, (Albuquerque: University of New Mexico Press, 1987), 310-11.

Recently this problem has caused debate in Egyptological studies. Radiocarbon dates at Avaris have been used to argue that the 18th dynasty began around 1700 BC. This is roughly 200 years earlier than the textual record supports. Radiocarbon dates from mortar in the pyramids have been used to argue for Old Kingdom dates that are 400 years earlier than the textual record makes possible. These dates point to a significant problem with radiocarbon dating. For the Old Kingdom radiocarbon dates, see K. A. Kitchen, "The Chronology of Ancient Egypt," *World Archaeology* 23.2 (1991): 206. For the problems with dating mortar, see Ingrid U. Olsson, "Carbon-14 Dating and Interpretation of the Validity of some Dates from the Bronze Age in the Aegean," 4-38 in Paul Åström, ed. *High, Middle or Low? Acts of an International Colloquium on Absolute Chronology Held at the University of Gothenburg 20th-22nd August 1987 Part 2*, (Gothenburgh: Paul Åströms, 1987), 11-2.

⁹ Waterbolk, "Working with Radiocarbon Dates," 15.

¹⁰ Schiffer, *Formation Processes of the Archaeological Record*, 308-11.

¹¹ Philip Kogan, *The Cosmic Power: Foundations of Nuclear Physics*, (London: Sampon, Law, Marston & Co., 1966).

This explanation for radiocarbon dating was discussed by W. M. Gibson in his book *The Physics of Nuclear Reactions*. Gibson noted that minor fluctuations have been found in the amount of C^{14} in the atmosphere. Gibson suggested that these fluctuations may have been caused by variability in the magnetic fields of the earth and the sun. While the number of cosmic rays in outer space has not changed very much in the last 50,000 years, the magnetic fields in the solar system do change. Such changes have a direct impact on the number of cosmic rays striking the earth. During some periods, the cosmic rays are deflected by the earth's magnetic fields and by the gravitational flux in solar flares.¹² If C^{14} in the atmosphere is produced by cosmic rays striking nitrogen atoms in the atmosphere, then changes in the atmosphere's C^{14} content should correlate with changes in the magnetic fields in the solar system. M. Stuiver studied how magnetic fields changed over time and how these changes may have affected the amount of C^{14} in the atmosphere. He noted that bricks and pottery found in archaeological contexts do give at least general evidence for changes in the earth's magnetic fields.

Stuiver argued that between 4000 BC and 500 BC, there was about 10% more C^{14} in the atmosphere than there was before World War II. Stuiver noted that the amount of C^{14} in the atmosphere was also affected by the rate that atmospheric carbon was seized or released by the great carbon reservoirs like the oceans and the arctic tundra. The amount of carbon stored in these carbon reservoirs was in turn greatly affected by global temperature changes.¹³ R. S. Keir studied the rate at which the oceans seized or released carbon. He argued that changes in ocean temperature have a strong impact on how ocean water circulates vertically in the water column. This in turn affects how much organic material is picked up and carried by the ocean currents. He argued that a 50% decrease in ocean circulation caused by melting glacial water could produce the 10% increase in the C^{14} content of the atmosphere seen by several researchers.¹⁴

Gibson noted another source for C^{14} in the atmosphere. The last couple of centuries have seen a huge increase in the burning of fossil fuels like coal, natural gas, and petroleum. These fuels are very ancient reservoirs of carbon. Since they were formed so long ago, they have no C^{14} remaining in them. So when fossil fuels add carbon dioxide and carbon monoxide to the atmosphere, the proportion of C^{14} in the atmosphere is reduced. This in turn gives recently produced plant material an older apparent age.¹⁵

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Samuel Glasstone, *Sourcebook on Atomic Energy*, (Princeton: D. Van Nostrand, 1967), 714. H. S. Ahluwalia, "Solar Polar Field Reversals and Secular Variation of Cosmic Ray Intensity," 79-86 in M. Dryer, ed. *Solar and Interplanetary Dynamics*, (Dordrecht: D. Reidel, 1980), 79. Krishna M. V. Apparao, *Composition of Cosmic Radiation*, (London: Gordon and Breach, 1975), 35-47.

W. M. Gibson, *The Physics of Nuclear Reactions*, (Oxford: Pergamon Press, 1980). M. Stuiver, "Origin and Extent of Atmospheric C^{14} Variations During the Past 10,000 Years," 27-40 in *Radioactive Dating and Methods of Low-Level Counting*, (Vienna: International Atomic Energy Agency, 1967), 28.

R. S. Keir, "Reduction of Thermohaline Circulation during Deglaciation: The Effect on Atmospheric Radiocarbon and CO_2 ," *Earth & Planetary Science Letters* 64, (1983): 445-56.

Gibson, *The Physics of Nuclear Reactions*. Damon noted that the use of nuclear weapons have added C^{14} to the atmosphere. So in the future, objects formed in this century may be very difficult to date with carbon dating. Paul E. Damon, "Solar Induced Variations of Energetic Particles at One AU," 429-48 in Oran R. White, ed. *The Solar Output and its Variation*, (Boulder: Colorado

There is also an unseen problem lurking in the background behind traditional explanations of atmospheric C^{14} . That problem was suggested by the lunar landings of the 1960's and 1970's. When dirt from the moon was analyzed, it was found to contain high levels of C^{14} . Since the moon has no atmosphere, this C^{14} could not have been formed by cosmic ray bombardment of atmospheric nitrogen. Since C^{14} has a half life of only 5730 years, there should be no C^{14} in dirt from the moon. Initially, the presence of C^{14} in moon dust was used by the young earth community to argue for a young moon. Every other dating method used to analyze the moon rocks pointed to the fact that the moon rocks were very old indeed. So another source for the moon's C^{14} was sought, and that source was found in the solar wind. Both the United States and China sent satellites into orbit that were designed specifically to determine the make up of the gas streaming out from the sun in the solar wind. Similar experiments were conducted aboard the European Spacelab I. These studies found that solar flares often include: iron, oxygen, fluorine, lithium, magnesium, silicon, and other elements including both C^{12} and C^{14} .¹⁶

Paul Damon discussed the heavy atoms found in the solar wind. He suggested that the C^{14} in the solar wind may be produced by a "hip" reaction in nitrogen atoms in the sun. This C^{14} was then sent out from the sun in the solar wind and solar flares. There seems to be little doubt that C^{14} atoms do travel out from the sun and strike the earth's atmosphere. If so, the amount of C^{14} in the atmosphere may be closely related to the rate at which C^{14} is emitted by the sun. The sun, in turn, does not seem to emit C^{14} at a constant rate. Damon noted that the sun is a variable star that fluctuates within certain limits. Since the time of Christ, the sun has fluctuated both on an 11 year solar flare cycle, and on a 180 year cycle. This cycle seems not to have functioned between 4000 BC and the 1st century AD.¹⁷ The instability of the sun can be seen in evidence from the Maunder Minimum. This name refers to the period from 1645 AD to 1715 AD. This period was one of the colder parts of the "little ice age," which lasted from 1430 AD to 1850 AD. During the Maunder Minimum, sun spots, solar flares, and auroras in the night sky almost disappeared.¹⁸ During the "little ice age," the arctic ice pack expanded, and glaciers advanced in Alaska, Scandinavia, and the Alps. Villages in northern Europe began to suffer from the cold after 1310 AD. Between 1400 AD and 1480 AD, many villages in northern Europe were completely abandoned. Between 1433 AD and 1438 AD, great crop failures were seen in Europe.¹⁹

Associated University Press, 1977.)

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W. Heinrich, "Cosmic Rays and Interactions with the Geomagnetic Field and Shielding Material," *Radiation Physics and Chemistry* 43 (1994): 19-34. Einar Tandberg-Hanssen and A. Gordon Emslie, *The Physics of Solar Flares*, (Cambridge: University Press, 1988.) Clayton and Thiemens discussed the chemical make up of the solar wind and its variability over time. Robert N. Clayton and Mark H. Thiemens, "Lunar Nitrogen: Evidence for Secular Change in the Solar Wind," in R. O. Pepin, et al, eds., *The Ancient Sun*, (New York: Pergamon Press, 1980).

¹⁷ Damon, "Solar Induced Variations of Energetic Particles at One AU," 429-48.

¹⁸ John A. Eddy, "The Maunder Minimum," *Science* 18 (1976): 1189-202.

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The cause of the cold years between 1645 AD and 1715 AD has been debated. It has also been suggested that the cold famine was caused by volcanic ash in the atmosphere. If understood this way, perhaps the ash may have prevented sun spots from being seen. Volcanic activity was clearly involved in at least the coldest years between 1645 -1715 AD, although it is unclear whether volcanic activity alone could produce a "little ice age" this long. Barry Weiss argued that the "little ice age" was a period of low solar flare activity. He contrasted it to the period of high solar flare

The lack of solar flare activity during the "little ice age" has led a few authors to suggest that solar flare activity and solar energy emissions may have been decreased during the great glacial eras as well.²⁰ Since C¹⁴ dating relies on a relatively stable C¹⁴ content of the atmosphere, and since atmospheric C¹⁴ seems to come at least partly from the sun, solar variability may call into question the reliability of C¹⁴ determinations for any date before the end of the last glacial period. If the linkage between solar energy output and global climate should hold up, it may be difficult to evaluate the accuracy of C¹⁴ dates before roughly 10,000 BC. The problem of C¹⁴ in the solar wind is an issue with which few in the academic community are willing to deal. Even raising the question can result in contempt and disdain from "serious" scholars in the field.²¹ At some point, the academic community will be forced to study the question in more detail.

Several other factors also limit how effectively C¹⁴ dating can be used. One limitation of radiocarbon dating was pointed out by Craig Gerlach and Owen Mason. Gerlach and Mason pointed out that C¹⁴ dates are only statistical statements of probability. They noted that it is important to understand the nature of radiocarbon dating. If a half dozen pieces of wood are taken from the same log, no two pieces of wood will give the same C¹⁴ date. Instead, all six pieces will give dates that fall along a bell shaped curve, and the center of the curve will be very close to the date that the wood died. The bell curve results from the random nature of radioactive decay.²² Radiocarbon dates from the same log may differ by hundreds of years or more. So it is necessary to C¹⁴ date a variety of samples from an archaeological context in order to create a bell curve, and to estimate the center of the curve.²³ Gerlach and Mason noted that radiocarbon dates are very expensive. Often only one or two samples from a site are dated. It becomes difficult to determine where along the bell shaped curve those specific samples should fall and where the center of the curve may be.²⁴ If Gerlach and Mason are right, it is important to remember that C¹⁴

activity in the 12th century AD which was a very warm period. Similarly, a period of very low solar flare activity lasted from 1420 to 1260 BC. This was a time of great drought and population movement in the ancient Near East. Barry Weiss, "The Decline of Late Bronze Age Civilization as a Possible Response to Climatic Change," *Climatic Change* 4 (1982): 196.

²⁰ Stuiver, "Origin and Extent of Atmospheric C¹⁴ Variations During the Past 10,000 Years," 38

²¹ The author raised this problem on the ANE list during the fall of 2005 and was attacked for doing so.

²² Robert J. Braidwood, "Further Remarks on Radioactive Carbon Age Determination and the Chronology of the Late Prehistoric and Protohistoric Near East," 57-67 in Kurt Bittel, et al, eds. *Vorderasiatische Archäologie*, (Berlin: Gebr. Mann, 1964), 58. Braidwood noted that one date in three will fall more than one sigma deviation of the center of the bell curve. 1 date in 22 will fall more than two sigma deviations from the center.

²³ The uncertainty produced by calibration curves was an important part in a debate at Oxford's Yarnton Manor in 2005. Supporters of Finkelstein and Mazar debated the relative merits of a "high" or "low" chronology for Israel's United Monarchy based on their excavations at Megiddo and Rehov. Both sides argued from radiocarbon evidence, but neither side was able to convince the other of the strength of its case. For a summary of the conference, see Hershel Shanks, "Radiocarbon Dating: How to Find Your True Love," *Biblical Archaeology Review* 31 (2005): 50-3.

²⁴ Craig Gerlach and Owen Mason, "Calibrated Radiocarbon Dates and Cultural Interaction in the Western Arctic," *Arctic Anthropology* 29 (1992): 54-80. Michael J. Shott, "Radiocarbon Dating as a Probabilistic Technique: The Childers Site and Late Woodland Occupation in the Ohio Valley,"

dates are at best only rough ball park figures. It is easy to overlook that fact because radiocarbon dates are sometimes printed as chronological dates and are described as absolute dates.²⁵

Another limitation of C¹⁴ dating grows from the fact that the amount of C¹⁴ in the atmosphere changes slightly from year to year. C¹⁴ dates then differ from chronological dates, and it is necessary to change C¹⁴ dates into chronological dates. Gibson noted that the minor fluctuations in the atmosphere's C¹⁴ content can be identified with tree ring studies. Some trees grow for many centuries. Counting the rings in these trees gives a chronological ladder into the past. Tree rings grow at different thickness each year depending on climatological conditions in that year. All of the trees in a region tend to have tree rings of comparable thickness in a given year. The pattern of thick and thin tree rings can then be studied across a wide collection of logs found in archaeological contexts. A tree ring ladder into the past can then be constructed by studying where each log's tree ring pattern fits with other logs. Today, dendrochronologists have developed a rather convincing tree ring ladder all the way back to around 9000 BC. The bristle cone pine chronology from the Southwestern United States covers a time period of 7,484 years. The European oak chronology also dates back to around 9000 BC, although it is somewhat more problematic.²⁶ This tree ring ladder can then be used to study changes in the atmosphere's C¹⁴ content. C¹⁴ determinations are made of several tree rings that can be dated chronologically by simply counting the tree rings. The two sets of dates are then compared with each other.

Since C¹⁴ dates and absolute chronological dates are not exactly the same, it is necessary to have a way to convert C¹⁴ dates into chronological dates. This is done with the use of "calibration curves." These "calibration curves" indicate what the C¹⁴ date would be for a specific chronological date. The construction and use of these calibration curves is a complicated and somewhat controversial process. The "calibration curves" undulate rather than following a consistent path. Occasionally, a calibration curve even reverses slope. Because of this, a specific C¹⁴ date can in some cases be equated with more than one chronological period. When the "calibration curve" flattens out, a specific C¹⁴ date can actually indicate a wide time span of chronological ages.²⁷ Recently it has become common to write chronological dates as years "BC" while uncalibrated radiocarbon dates are written as years "bc." However, this distinction is not

American Antiquity 57 (1992): 213-26. M. J. Aitken, *Science-Based Dating in Archaeology*, (London: Longman, 1990), 79-82.

The meaning of the word "absolute" in this context has been hotly debated. Some authors use the word absolute to describe a specific date. Others use the word absolute to refer to an approximate date found by a scientific method. Still others use the word absolute simply in distinction to a relative date. A relative date simply suggests that one event was either before or after another event with no indication of chronology. An absolute date is then seen as an attempt to suggest a date of some kind. The diversity of use given to the word absolute provides confusion when reading the literature.

²⁶ Aitken, *Science-Based Dating in Archaeology*, 44-5. Damon, "Solar Induced Variations of Energetic Particles at One AU," 429-48.

²⁷ Staso Forenbaher, "Radiocarbon Dates and Absolute Chronology of the Central European Early Bronze Age," *Antiquity* 67 (1993): 237. Gordon W. Pearson, "How to Cope with Calibration," *Antiquity* 61 (1987): 96-103. Tom Aitchison, et al, "Summarizing a Group of ¹⁴C Dates on the Historical Time Scale: With a Worked Example from the Late Neolithic of Bavaria," *Antiquity* 65 (1991): 108-16.

always followed. Gibson noted that tree ring dates and C^{14} dates differ by 175 years between 1600 BC and 1625 BC. Egyptian objects manufactured around 3000 BC radiocarbon date around 2700 BC.²⁸ By 9000 BC, tree ring and C^{14} dates differ by over 700 years.²⁹ The calibration curve distinguishing radiocarbon from chronological dates looks very much like the difference between "BC" and "bc" dates was gradually increasing. Before 9000 BC, it may be impossible to evaluate how far apart radiocarbon and chronological dates may become. This adds at least a degree of uncertainty to C^{14} dates for carbon deposited before the tree ring horizon.

Another problem with C^{14} dating is that it is very easy for a dated sample to be corrupted by either older or newer organic material.³⁰ Waterbolk noted that C^{14} dates can be altered by both contamination and admixture of materials. Contamination includes root penetration into the sample, infiltration of humic acids, the secondary deposition of lime from the environment, and the exchange of carbonates with the environment. Admixture includes the actions of animals at the site, mixture of material from older occupation levels, and unrecognized strata in the city tell or archaeological site.³¹ Waterbolk noted that laboratories often pretreat samples to remove contaminants. However, the method of pretreatment depends on the kind of contamination expected. This adds an element of uncertainty to the dating process.³² So the accuracy of a C^{14} date depends on how accurately the contamination of a sample is predicted by the laboratory. Waterbolk also noted that the problem of contamination becomes more serious with samples of greater age. A small amount of recent carbon only distorts the date of a recent sample a slight amount. However, the same amount of recent carbon introduced into a very old sample will have a very great impact on the C^{14} date obtained.³³

Another unrecognized form of contamination can be seen in the presence of trace amounts of C^{14} in coal seams. Coal is so ancient that there should be no C^{14} left in it. Trace amounts of C^{14}

²⁸ Gibson, *The Physics of Nuclear Reactions*.

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Not all calibration curves agree with each other. Fairhall and Yang noted that chronological dates for the varved sediment from Saanich Inlet in British Columbia differ sharply from radiocarbon dates for those sediment layers. Radiocarbon dates were consistently lower than chronological dates between the time of Christ and 7000 BC. Between roughly 2000 BC and 4000 BC, radiocarbon dates were 1000 years earlier than chronological dates. A. W. Fairhall and I. C. Yang, "Carbon-14 Variations in Terrestrial and Marine Reservoirs during the Last 11 Millennia," in R. O. Pepin, et al, eds., *The Ancient Sun*, (New York: Pergamon Press, 1980), 179. This evidence would suggest a different calibration curve, and it adds another note of uncertainty in the evidence.

³⁰ Shott, "Radiocarbon Dating as a Probabilistic Technique: The Childers Site and Late Woodland Occupation in the Ohio Valley," 202. J. Bischoff, et al, "Abrupt Mousterian/Aurignacian Boundary at c. 40 Ka Bp: Accelerator ^{14}C dates from L'Arbreda Cave (Catalunya, Spain)," *Journal of Archaeological Science* 16 (1989): 571-72.

³¹ A "tel" or "tell" is the site of an ancient settlement. Towns grew up near springs, fords, or trade route intersections. Since these locations were important, towns were usually rebuilt after they were destroyed in a war. This constant rebuilding process created archaeological sites that resembled layer cakes. Each destruction layer was earlier than the layer above it.

³² Labs differ in their methods for removing contaminants, and labs may give dates for the same sample that differ by a thousand years.

³³ Waterbolk, "Working with Radiocarbon Dates," 17-20.

may result from decay of uranium in the coal. Russell Rotta argued that there is too much C¹⁴ in coal deposits to be explained this way. He argued that the amount of C¹⁴ in coal deposits demonstrates that the earth is a young planet.³⁴ Not everyone would agree with his evaluation of the evidence.

J. Gordon Ogden discussed another example of contamination. He noted that lake bottom sediments can be especially difficult to date with radiocarbon dating for two reasons. First, the lake water may include dissolved limestone. Since limestone is calcium carbonate, dissolved limestone brings to the water very old carbon that contains no C¹⁴. Ogden noted that living plants growing in limestone rich water may contain as little as 50% of the C¹⁴ normally found in living plants. The classic example of this problem is Montezuma Well in Arizona. Living plants from this site radiocarbon date between 17,300 and 24,750 years old. Ogden noted a less serious example of this problem at Silver Lake in Ohio. This is a hard water lake, and the water in the lake contains limestone dissolved from the lake bed. Living plants taken from Silver Lake date as 980 years old. Ogden noted that even this date was in a sense too young. C¹⁴ was added to the lake water by fallout from nuclear weapons tests in the 1950's. If the effect of this added C¹⁴ is discounted, the plants would appear older yet. Ogden noted that this can be a problem even in soft water ponds. He gave as an example Seth's pond in Massachusetts. Sediment layers in this pond contain the pollen of European plants that were introduced to the pond after Martha's Vineyard was settled in 1750. Yet these sediment layers radiocarbon date as 1070 plus or minus 156 years old.³⁵ Gerlach and Mason noted a similar problem with wood from sunken ships and animal remains that are underwater. They studied wood above and below the water level at Cape Krusenstern and at Gambell cemetery on St. Lawrence Island. They found that about 400 years had to be added to radiocarbon dates of underwater materials to compensate for old carbon dissolved in the water.³⁶

The problem of old carbon contamination can even appear in deep ocean sediment core samples. Ruddiman and McIntyre noted that radiocarbon dates for cores taken from the Atlantic floor have proven to be unreliable for levels from the late glacial and early deglacial periods. Ice rafted continental detritus brought a significant amount of old carbonates and organic compounds into the deep ocean during these periods. This old carbon was eventually deposited in ocean floor sediments. The old carbon has produced dating errors of over a thousand years in radiocarbon samples. Bioturbation and bottom currents have also mixed carbon rich sediments from different time periods.³⁷

Some of the more difficult objects to date with radiocarbon dating are cave paintings and wall paintings. Wall paintings have been found world wide, although many are of comparatively recent date. The problems with cave paintings can be seen in three ancient French caves found at

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Russell B. Rotta, "Evolutionary Explanations for Anomalous Radiocarbon in Coal?" *Creation Research Society Quarterly* 41 (2004): 104-12.

³⁵ J. Gordon Ogden III, "Radiocarbon and Pollen Evidence for a Sudden Change in Climate in the Great Lakes Region Approximately 10,000 Years Ago," 117-27 in E. J. Cushing and H. E. Wright Jr. eds. *Quaternary Paleoecology*, (New Haven: Yale University Press, 1967), 119-21

³⁶ Gerlach and Mason, "Calibrated Radiocarbon Dates and Cultural Interaction in the Western Arctic," 54-80.

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William F. Ruddiman and Andrew McIntyre, "The North Atlantic Ocean during the Last Deglaciation," *Palaeogeography, Palaeoclimatology, Palaeoecology* 35 (1981): 159.

Lascaux, Chauvet, and Cosquer. These caves contained a surprising number of cave paintings. They are painted in red, yellow, brown, and black paint as well as charcoal. The Lascaux cave alone contains over 1500 paintings. Animals depicted in these caves include horse, deer, bison, penguin, ibex, bulls, rhinoceros, panther, owl, lion, and mammoth. The C¹⁴ dates proposed for these caves are very different. The Chauvet cave paintings have been C¹⁴ dated around 31,000 BC. The Lascaux cave paintings have been dated around 17,000 BC. The earliest images in the Cosquer cave have been dated around 27,000 BC. It is fair to ask how reliable these dates are. It is striking that the proposed radiocarbon date for the Chauvet cave paintings is chronologically about as far removed from the Lascaux cave paintings as the world today is removed from the height of the last glacial period. It is also striking that the Neolithic Age in western France only began well after 6000 BC.³⁸ Dates offered for earlier hunter/gatherer cultures are at best somewhat problematic. There is also a very striking contrast between the early cave paintings and the earliest pottery and statuary. The cave paintings were produced with exceptional technical ability. They demonstrated realism, a use of perspective, and the use of multiple painting pigments and tools. In contrast, the earliest clay forms and statuary looked like globs of clay stuck together with only limited shaping. Yet the clay shapes are dated after 9000 BC which is much more recent than cave paintings. This is at least troubling.

Perhaps the strongest evidence for dating any French cave comes from the cave at Cosquer. This cave was found on the Mediterranean Sea shore near Marseilles France. The entrance to this cave was roughly 125 feet below sea level. The first 575 feet of the cave was filled with sea water. Paintings in the Cosquer cave were almost certainly painted at a time when the cave mouth was open to the air.³⁹ So it is important to determine when the cave mouth would have been open to the air. Two factors must be born in mind. The first is that the European crustal plate rose and fell as glacial ice formed on it and melted. Crustal material is relatively light and it floats on the magna beneath it. During the glacial periods, the glacial ice sheets were heavy enough to push part of the crust down into the earth's magma.⁴⁰ Uncovered areas like southern France rose as the ice covered regions sank. It is difficult to estimate how far southern France rose during the Ice Age. As the ice pack melted, the crust rebounded causing substantial movement along the fault lines. There is no way to estimate how rapidly the region fell to its current elevation. This process can be seen by noting the difference in the heights of fossil shorelines in southern France and North Africa.⁴¹

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Chris Scarre, "The Early Neolithic of Western France and Megalithic Origins in Atlantic Europe," *Oxford Journal of Archaeology* 11 (1992): 121-54.

Jean Clottes and Jean Courtin, *The Cave Beneath the Sea: Paleolithic Images at Cosquer*, (Harry N. Abrams, 1996).

At the height of the last glacial, between 84,000 and 98,000 cubic kilometers of ice covered about 10% of the earth's surface. Roger G. Barry, "The Significance of Global Snow and Ice Cover for Global Change Studies," *GeoJournal* 27 (1992): 293-97.

Reginald A. Daly, *The Changing World of the Ice Age*, (New Haven: Yale University Press, 1934), 112-46. Tjeerd H. Van Andel, "Late Quaternary Sea-Level Changes and Archaeology," *Antiquity* 63 (1989): 734. Douglas L. Inman, "Application of Coastal Dynamics to the Reconstruction of Paleocoastlines in the Vicinity of La Jolla, California," 2-49 in P. M. Masters and N. C. Flemming, eds. *Quaternary Coastlines and Marine Archaeology*, (London: Academic Press, 1983), 6-10.

The second factor that must be born in mind is that the ocean surface rose and fell rapidly as glacial ice formed and melted. At the height of the last glacial period, the sea surface was somewhere between 65 and 150 meters below its current level. The exact distance that the sea level fell has been debated endlessly, although the general consensus is that it fell somewhere around 300 feet, with a rather large plus or minus factor. The sea levels fell because such a huge amount of water was trapped as ice on the land. As the glacial ice melted, the sea level rose rapidly. Within the academic literature, there is a fair diversity of opinion about the rate at which the sea returned to its current level. However, many authors suggest rates of rise that would place the mouth of the Cosquer Cave at sea level either at the end of the Younger Dryas or around 8000 BC.⁴²

The great antiquity of the French cave paintings can be seen by a detailed study of the paintings. Jean Clottes noted evidence for the antiquity of the cave paintings at Chauvet. The paint lines at Chauvet could be seen under a magnifying glass to be full of small gaps that were caused by erosion. The spaces in the sketches were filled with micro-crystals and concretions.⁴³ These developed over a great many years. So the condition of the cave paintings demonstrated that they are very ancient paintings. However, they also illustrated why the cave paintings have been almost impossible to date reliably with C¹⁴ dating. The erosional cracks in the painting occurred as moisture moved over the surface of the cave wall. At one point in the Chauvet cave a torch mark was superimposed over a calcite layer that had formed on top of an earlier drawing. This calcite contained very ancient carbon, and it was obviously imported onto the cave painting by moisture in the cave. The moisture that covered cave paintings contained dissolved limestone. This lime bearing moisture created the crystals found within the paintings. The same lime bearing moisture flowed over the charcoal dust and charcoal fragments that made up many of the paintings. As cave water soaked into charcoal dust, very old carbon was carried into the charcoal. It is unclear whether a sample of charcoal could have been purified of it sufficiently to give an accurate radiocarbon date. When this charcoal was dated with C¹⁴ dating, it was impossible to separate out completely the old carbon contamination from the original charcoal painting.⁴⁴ A similar problem affected charcoal buried in the cave floor since water containing old carbon flowed down the cave walls and sank into the dirt on the cave floor. So radiocarbon dating of charcoal from cave paintings may produce dates far older than the actual chronological

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H. H. Lamb, *Climate, History and the Modern World*, (New York: Methuen, 1982), 107. Van Andel, "Late Quaternary Sea-Level Changes and Archaeology," 734.

⁴³ Florence Raynal, "The Chauvet Prehistoric Cave," http://www.france.diplomatic.fr/label_france/ENGLISH/SCIENCES.CHAUVET/cha.html

⁴⁴ Watchman noted a problem with silica deposits on painting in Australia and the United States. Alan Watchman, "Perspectives and Potentials for Absolute Dating Prehistoric Rock Paintings," *Antiquity* 67 (1993): 58-65.

date of the cave paintings.⁴⁵ Despite the confidence expressed in many publications, there is no way to radiocarbon date the French cave paintings with any accuracy at this time.

There is much that is not understood about the French caves. It has been suggested that the caves were not occupied because the floor of the caves lack significant evidence of human occupation when the cave paintings were being made. It has also been suggested that the animals depicted on the cave walls were not the kind of animals normally hunted for food by the culture that created the cave paintings.⁴⁶ Penguin and lion bones certainly have not been found in this archaeological context, even though these animals are included in the cave paintings. There has been a huge debate about the purpose of the cave paintings. Perhaps more of a debate should also revolve around the dating of the paintings. The claim is frequently made that these caves were sanctuaries of some kind, although there is no way to know if that was true.⁴⁷

The problems with C¹⁴ dating have led to increasing skepticism about the validity of the dating process. This rising skepticism can be seen in Staso Forenbaher's article "Radiocarbon Dates and Absolute Chronology of the Central European Early Bronze Age." Forenbaher noted that several authors have discussed the difficulties and contradictions introduced by C¹⁴ dating in the Bronze Age of Europe. He noted that radiocarbon dates and the historical evidence have often contradicted each other, and radiocarbon dates of the same archaeological context are sometimes rather wildly contradictory.⁴⁸ Forenbaher noted that some C¹⁴ dates are never even published because they are embarrassingly wrong. He noted that radiocarbon dates are also falling out of favor because they are so expensive. He noted that an entire archaeological team can be funded for a week in Eastern Europe more cheaply than requesting a single C¹⁴ determination. Forenbaher argued that C¹⁴ dating can be useful for dating early history as long as its limitations are always remembered.⁴⁹ Recently, radiocarbon dates from Tell el- Dab'a in Egypt have generated considerable academic discussion because they are often two centuries earlier than would be expected from the textual evidence.⁵⁰ Such problems lead to increased uncertainty about the reliability of the method.

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For a somewhat more skeptical discussion of the "hard water problem" in dating, see G. Jalut, et al, "Palaeoenvironment of the Valley of Ossau (Western French Pyrénées) during the Last 27,000 Years," *Pollen et Spores* 30 (1988): 362-66. Jalut noted that the hard water problem sometimes occurs and sometimes does not. He argued that there may be no clear explanation for why it occasionally happens, and that the affect caused by hard water is sometimes within the limits of the margin of error of radiocarbon dating anyway.

⁴⁶ Raynal, "The Chauvet Prehistoric Cave."

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W. J. Sollas, "The Mysteries of Rock Art," 118-22 in Brian M. Fagan, ed. *The Seventy Great Mysteries of the Ancient World*, (London: Themes & Hudson, 2001), 119.

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Roger Matthews noted two examples of this problem from the Near East. He noted that radiocarbon dates from Asiab and Jarmo have been confusing. Matthews, *The Early Prehistory of Mesopotamia 500,000 to 4,500 BC*, 40, 45.

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Forenbaher, "Radiocarbon Dates and Absolute Chronology of the Central European Early Bronze Age," 218-19. A. F. Harding, *The Mycenaeans and Europe*, (London: Academic Press, 1984), 278.

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Radiocarbon dates from Tell el-Dab'a are highly erratic. The dates are placed in a grid determined by the tell layers to impose some kind of order on the evidence.

B. THE DIFFICULTIES IN DATING BONES

Shortly after radiometric dating was discovered, it became obvious that bones could not be dated very reliably. Bones have only a limited amount of carbon, and that carbon easily dissolves in water. L. Vance Haynes pointed to another problem with dating ancient bones. He noted that old bones often absorb humic acids as water percolates through the sediments in which the bones are deposited. Humic acids are created in the soil as buried vegetation decays. Buried bones absorb humic acid easily because bone is very porous, and it also has a high specific surface area. Collagen in buried bone is slowly replaced by humic acids until the collagen is completely replaced by them. The humic acids import carbon into buried bones which may or may not have any relationship to the age of the buried bones. Ground water carries humic acids into buried bones. So the extent that buried bones are contaminated with unrelated carbon will depend on how often ground water touches the bones. Haynes argued that only collagen in bone can be C^{14} dated, and then only if it was purified of humic acids.⁵¹ The reliability of the purification process can be questioned. Waterbolk discussed this problem. He noted that laboratories try to remove humic acids by pretreating the sample in an alkali solution and washing out the alkali with hydrochloric acid. Waterbolk noted that humic acids often can not be removed at all. He argued that earlier C^{14} dates have often been significantly wrong because the possibility of humic acid contamination was greatly underestimated.⁵²

A good example of the problems associated with dating ancient bones can be seen in a study written by Jane Kelly and Marsha Hanen. They summarized the debate that has swirled around the Old Crow site in the Yukon. This site was first identified in 1966 by C. R. Harrington. He found caribou bones at the site that he claimed were early bone tools. The caribou bones were C^{14} dated between 25,000 BC and 30,000 BC. If this date is accepted, the bones were deposited during the last glacial period. This would not be impossible during an Ice Age because the Old Crow site is in a part of the Yukon that was not covered with ice during the last glacial period. However, Harrington's conclusions have been widely debated. Initially, many questioned whether Harrington's caribou bones were actually early tools at all. It is quite possible that his caribou bones were not tools, and that humans had nothing to do with the site. Recently, Harrington's C^{14} dates have also been called into question. This should not be surprising given the great difficulties involved in dating ancient bones. A quite wide variety of dates has been proposed for Harrington's caribou bones. Some authors believe that they are not ancient at all. Other authors suggest dates for the site of 60,000 BC, 80,000 BC, 100,000 BC, or even earlier. It is rather obvious the C^{14} dating can not settle the debates over how the history of this site should be understood.

Another method often used to attempt to date bones is called "amino acid racemization." This dating method is popular partly because it is much cheaper than radiocarbon dating. Bada and Finkel discussed this dating method in some detail. They noted that there are 20 different kinds of amino acids in all living organisms. They exist in all living things because amino acids are the building blocks or proteins. Each of these amino acids can have two different molecular structures. They can be either "right handed" or "left handed" molecules. Only L- amino acids

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. L. Vance Haynes, "Bone Organic Matter and Radiocarbon Dating," 163-68 in *Radioactive Dating and Methods of Low-Level Counting*, (Vienna: International Atomic Energy Agency, 1967).

⁵² Waterbolk, "Working with Radiocarbon Dates," 17. Aitken, *Science-Based Dating in Archaeology*, 86.

exist in most living things. However, L- oriented molecules are unstable, and the "left handed" orientation must be continually preserved by life functions. After death, L- amino acid molecules convert to R- molecules by a process called "racemization." This process continues until each amino acid arrives at equilibrium with an equal number of L- and R- molecules. Racemization occurs at a different rate for each amino acid. For example, Aspartic Acid arrives at equilibrium in approximately 3500 years. On the other hand, Isoleucine Acid only reaches equilibrium in 50,000 years. These two amino acids are the acids most commonly used in dating organic material.⁵³ B. J. Johnson and G. H. Miller noted that amino acid racemization has been used to argue for an arrival of human beings in North America between 40,000 and 60,000 years ago.⁵⁴ Johnson and Miller noted that dating bone material with amino-acid racemization requires that the bone material be preserved in a stable environment. They noted that bones from the 4th century Roman catacombs can not be dated correctly with amino-acid dating because of the high humidity levels in the catacombs. The high moisture levels led to racemization of aspartic acid at a very high rate. On the other hand, bones from Egyptian tombs often do give accurate amino acid dates because of the arid conditions in the tombs. Amino acid dating has been treated with skepticism by the archaeological community. However, Johnson and Miller argue that improvements in the procedure make the dating process much more reliable than it once was.⁵⁵ The greatest problem with amino acid racemization has been that the rate of racemization depends on the temperature, moisture level, and acidity of the site. For amino acid dating to be valid, there must be some reason to believe that temperature, moisture, and acidity levels at the site have not changed since the bone was deposited in the site. This is generally true in Egyptian tombs, but is not true in most archaeological contexts.

Uranium²³⁸ series dating is often attempted when dating rocks limestone layers, very old bones, teeth, seashells, and travertines (or spring deposits). Sediment layers containing fossils are also often dated indirectly with uranium²³⁸ series dating when the fossils themselves can not be dated. When rock layers above and below a fossil layer are dated, an approximate date for the fossil layer can be assumed. Uranium²³⁸ decays with a half-life of 4.47×10^9 years, which is a very long time. As uranium²³⁸ decays, helium accumulates through the emission of beta particles, and the decay series eventually produces lead. Ideally, the age of a sample can be dated by measuring the products of radioactive decay remaining in a sample.

Chen Tiemei and Yuan Sixun discussed the limitations of uranium series dating for dating bones and teeth. Tiemei and Sixun argued that uranium series dating has been attempted for bones and teeth produced between 50,000 BC and 350,000 BC. They noted that uranium is geochemically quite active and that it interacts with carbonate sediments, fossils, and coral formations. Tiemei and Sixun noted that the mechanism by which uranium is absorbed into bone is poorly understood. Tiemei and Sixun noted that many bones and teeth continue to absorb

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Jeffrey L. Bada and Robert Finkel, "The Upper Pleistocene Peopling of the New World: Evidence Derived from Radiocarbon, Amino Acid Racemization and Uranium Series Dating," 463-79 in P. M. Masters and N. C. Fleming, eds., *Quaternary Coastlines and Marine Archaeology*, (London: Academic Press, 1983).

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The earliest human settlement of North America has been a point of archaeological debate and several authors would not agree with a date this old.

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B. J. Johnson and G. H. Miller, "Archaeological Applications of Amino Acid Racemization," *Archaeometry* 39 (1997): 276.

uranium from their environment long after they have been fossilized.⁵⁶ This often leads to a deviation between the apparent uranium series date and the true chronological date. Tiemei and Sixun also noted that the size and shape of a bone has a very marked impact on the amount of uranium that the bone absorbs from its environment. Taking these problems into account, they suggested a method for obtaining uranium series dates that they believe to be valid.⁵⁷ Several authors have noted the limitations of uranium series dating. Bada and Finkel argued that uranium series dating can be an effective tool for dating coral but that it is a poor tool for dating bone. They noted that uranium dating was used to prove that the Piltdown Man was a hoax. Various bones in the Piltdown Man's skeleton had different amounts of uranium. This demonstrated that the bones came from different sources.⁵⁸ Samuel Glasstone also discussed difficulties associated with uranium series dating. He noted that measuring the amount of helium in a sample has only very limited reliability because part of the helium might have escaped.⁵⁹ He also noted that lead present in a sample might have come from some other source than the decay of uranium. Glasstone noted that these problems can be limited somewhat by looking for the presence of lead isotopes in samples that do not result from the decay of uranium.⁶⁰

Other radioactive elements have also been used to date fossils and sediments. Several of these were described by Felix Sulman in his book *Short- and Long-Term Changes in Climate*. Sulman discussed first protactinium/ionium dating. Protactinium²³¹ decays into an isotope of thorium called ionium. So protactinium series dating is often called thorium dating. It is used especially for sediments produced around 200,000 years ago. Sulman also discussed potassium/argon dating. This dating method uses an isotope of potassium. All rocks and minerals that contain potassium (K³⁹) also contain trace amounts of an unstable isotope of potassium (K⁴⁰). The K⁴⁰ isotope decays to produce argon and calcium with a half life of 1.3 billion years. So potassium/argon dating is used to date very old rocks.⁶¹ The limitations of potassium/argon dating can be seen in the dating of basalt lava rock from Hualalai in Hawaii. Lava rock that erupted in 1800/1801 AD has given potassium/argon dates ranging from 160 million years old to 3.3 billion years old. This suggests a significant problem with the reliability of the dating system.⁶² Tiemei and Sixun noted that potassium/argon dating was used to date the bones found

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A. G. Latham noted that buried bones often absorb between ten and one hundred times the uranium that originally existed in the bone. A. G. Latham, "Uranium-Series Dating of Bone by Gamma-Ray Spectrometry: Comment," *Archaeometry* 39 (1997): 218.

Chen Tiemei and Yuan Sixun, "Uranium-Series Dating of Bones and Teeth from Chinese Palaeolithic Sites," *Archaeometry* 30 (1988): 59-61.

⁵⁸ Bada and Finkel, "The Upper Pleistocene Peopling of the New World," 463-79.

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Shortly before an earthquake, microscopic fractures form in rock that can release trapped gas. So a history of earthquakes at a site can call into question any date based on the amount of helium found at the site.

⁶⁰ Glasstone, *Sourcebook on Atomic Energy*, 711-12.

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Felix G. Sulman, *Short- and Long-Term Changes in Climate*, (Boca Raton: CRC Press, 1982). Sulman also discussed rubidium/strontium dating. This is very similar to potassium/argon dating, but has an even longer half life.

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J. G. Funkhouser and J. J. Naughton, "Radiogenic Helium and Argon in Ultramafic Inclusions from Hawaii," *Journal of Geophysical Research* 73 (1968): 4601-607, as discussed in *Creation* 27

at Olduvai Gorge, Omo Valley, and Koobi Fora. They noted that the Olduvai Gorge site was unique because it was made up of several successive layers of volcanic "tuff," with sediment layers in between the volcanic layers. The sediment layers contain hominid bones. Tiemei and Sixun noted that the successive volcanic layers at the Olduvai Gorge gave the site a distinct chronological structure since the volcanic layers could be dated with potassium/argon dating.⁶³ If the successive volcanic layers can not be dated reliably this way, the importance of the evidence from Olduvai Gorge becomes more difficult to evaluate.

To put this problem in a broader context, it is fair to ask how radiometric dating methods like uranium series dating could be very reliable. If the world was formed by God's direct creative activity, there is no way to determine the original relationship between uranium and lead, or protactinium and thorium, or potassium and argon. On the other hand, if the world began in gravitational collapse, a similar problem results. Radioactive elements and isotopes that were floating freely in space would have been decaying long before gravitational collapse formed the world. The products of radioactive decay would have been present as gravitational collapse formed the earth. Beyond that, the earth itself functions as a nuclear reactor.⁶⁴ There is some evidence that on two occasions, enough nuclear material gathered close to the earth's surface to start a sustained nuclear reaction.⁶⁵ There is no reliable way to evaluate how nuclear reactions deep inside the earth affect the elements and isotopes that appear in magma intrusions and perhaps even sediment layers.⁶⁶ This is especially important when fossil bones are dated by suggesting dates for rock layers above and below the fossils. Thin and watery lava that erupts to the earth's surface will lose helium or radon gas. However, magma intrusions into limestone layers are much less likely to gas off helium or radon. The same is true for eruptions of very thick and viscous lava. The validity of radioactive series dating methods depends partly on the location, content, and condition of lava when it hardened to produce the rocks that are being dated. These factors are often difficult to reconstruct.

For radioactive series dating to be reliable, four conditions must be met. First, it must be possible to prove how much of the original radioactive element was present in the sample when it was formed. Second, it must be possible to prove that the products of radioactive decay were not present in the sample when it was formed. Third, it must be possible to prove that all of the original element and its decay products remained in the sample throughout its history. Fourth, it must be possible to prove that additional atoms of the original element and its decay products did

(2005):30.

⁶³ Tiemei and Sixun, "Uranium-Series Dating of Bones and Teeth from Chinese Palaeolithic Sites," 59.

A United States geological survey report noted that the chronology of specific spots in the geological column have been reevaluated in recent years. This has happened as the behavior of isotopes within the earth's crust has been better understood. See the discussion in <http://pubs.usgs.gov/gip/geotime/radiometric.html>. This search for understanding is still ongoing.

P. K. Kuroda and W. A. Myers, "Plutonium-244 in the Early Solar System," *Radiochimica Acta* 64 (1994): 155. P. K. Kuroda and W. A. Myers, "Plutonium-244 Fission in the Most Primitive Meteorites," *Radiochimica Acta* 64 (1994): 167-74.

The normal assumption is that both U and Pu were present at the formation of the solar system. However, rock first hardened enough to trap Xe as a product of decay around 4.8 billion years ago. Kuroda and Myers, "Plutonium-244 in the Early Solar System," 155.

not enter the sample from the environment. It is sometimes possible to make a good case that these four conditions have been met. When they are met, radioactive series dating may provide useful evidence for the history of an artifact, bone, rock, or sediment layer. More often than not, it is impossible to demonstrate that these conditions have been met. When these conditions are not met, all dates derived from these methods should only be accepted with a grain of salt.

C. CIRCULARITY IN THE USE OF EVIDENCE

It was noted above that C¹⁴ dates are often either accepted or ignored depending on whether they agreed with a presupposed understanding of a site's history. Along the same lines, amino acid racemization is only possible if a sample is purified of contaminants, and that is a difficult process. If a date obtained by amino acid racemization disagrees with the site's presumed history, the date will be assumed incorrect. Uranium series dating is also often difficult. Dates must often be adjusted to compensate for contamination of the sample with uranium from the environment. Dates obtained with uranium series dating are only likely to be accepted if they agree with the assumed history of a site. The circular character of the use of dating evidence is obvious. Evidence is selected on the basis of an assumed history. That selected evidence is then used to "prove" the history of the site.

There are many world views in academic literature, and each world view is partly based on circular reasoning. Among many other world views in the literature, the reader will encounter: a young earth perspective, an evangelical old earth perspective, a post-Wellhausen critical perspective, a radically skeptical historical perspective, and a wide variety of mainstream scientific perspectives. Each perspective assumes a view of history, then each allows that view of history to determine the nature of the evidence sought and the conclusions drawn from the evidence. Each perspective defines valid scholarship in terms of the assumed worldview.

Circular reasoning can be seen almost everywhere. A good example may be an article by Stephen Gould of Harvard. His article was titled: "Magnolias from Moscow: A Colorful 20-Million-Year-Old Leaf Is an Elegant Test of the Theory of Evolution."⁶⁷ Gould discussed a Miocene lakebed that was exposed on the surface of the ground near Clarkia Idaho. It has been argued that the lakebed was formed between 17 and 22 million years ago. The ancient lakebed was found by the property owners while bulldozing a skimobile race track. So the lakebed was just below the current ground surface. The lake bed shale was roughly ten feet thick. It was waterlogged, and it was so soft that it could easily be split with a butter knife. When layers of the sediment were split, fossil leaves, insects, and fish were found. The fossil leaves at this site have gained the greatest fame. The leaves were preserved so completely that microscopic leaf structures remained intact. When the soft shale was split open, the leaves still had their original shape and color. Some were green. Others were autumnal colors of red and brown. After a few minutes of exposure to the atmosphere, the leaves oxidized, turned to black dust, and blew away. The lake bottom contained leaves from trees that grew in warmer climates like bald cypress, tupelo, and magnolia. These trees grow today in the southern Appalachian Mountains. Gould noted that some tree species represented at Clarkia only grow today in eastern Asia. An example of this would be the dawn redwood that today grows only in central China.

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Stephen Jay Gould, "Magnolias from Moscow: A Colorful 20-Million-Year-Old Leaf Is an Elegant Test of the Theory of Evolution," *Natural History* 101 (1992): 10-8. The name Moscow in the title of this article referred to the town of Moscow in Utah.

Gould argued that the fossil leaves at Clarkia only survived intact for three reasons. First, many leaves were blown directly into the lake without being transported great distances. Second, the stagnant lake bottom contained no oxygen so the leaves did not decay. Instead, they were rapidly buried by fine grained sediment. Third, the shale has remained waterlogged down to the present time.

Gould noted that a number of academic papers have been published about leaves, twigs, and fruit found in the Clarkia shale. Gould noted that recently studies have been conducted with DNA derived from the chloroplasts of Magnolia and Bald Cypress leaves found at Clarkia. Gould noted that Magnolia DNA from Clarkia was compared with DNA from a closely related contemporary Magnolia species. The comparison produced 13 "silent" DNA changes that would not produce a change in the living plant. The study also produced 4 DNA changes that would result in the production of different amino acids in the living plant. A similar study was done of Bald Cypress DNA from Clarkia. When 1,320 base-pair sequences were studied, only 11 differences were noted between Clarkia Bald Cypress and contemporary plants in this species. All 11 of these changes were "silent" changes that would not have produced a visible change in the plant itself. The conclusion was drawn from this that Bald Cypress DNA has not changed significantly in the last 20-million years. When Dawn Redwood trees at Clarkia and central China were compared, 32 base-pair differences were found. Gould argued that there was a perfect correlation between the DNA differences found and the evolutionary difference between the plant species. On the basis of this evidence, Gould argued that the fossil DNA at Clarkia provided striking evidence that evolution was true. Gould noted that creationists have claimed that evolution was unproven dogma. He argued that the Clarkia DNA illustrated the kind of research that proved the truth of evolution.⁶⁸

Gould was correct in his observation that creation science authors often give an unfair critique of evolution. However, the Clarkia sediment would seem to be a poor site to use to defend evolution. Several problems immediately suggest themselves with Gould's explanation of the evidence. It is fair to ask if the very limited DNA differences in the Clarkia Magnolia leaves really prove the truth of evolution. Over 20-million years, greater changes than that might be anticipated. A certain amount of genetic diversity clearly does occur on the species level, and diversity on that level can be widely demonstrated.⁶⁹ That is something quite different from proving the evolution of species.

Beyond that, how could fossil leaves have retained enough cellular structure over 20-million years for their DNA to be still intact? Is that a reasonable belief? How could a lakebed at ground level have remained waterlogged for 20-million years as great glacial periods and interglacial periods swept slowly over the site? It is fair to ask if the Clarkia lakebed would have remained waterlogged even during the post-glacial climate optimum. Around 4000 BC, land ice was very rare anywhere in North America. Would this site have remained moist? It is also fair to ask if Magnolia and Bald Cypress may have spread to the Rocky Mountain valleys during the centuries around the post-glacial climate optimum. Gould's explanation for the site may or may not seem very likely depending on the presuppositions brought to the evidence. It would seem appropriate

⁶⁸ Gould, "Magnolias from Moscow," 16-8.

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Docile European cattle developed into Texas Longhorns in response to environmental factors. The human population has developed both pigmy and Watusi cultures. This diversity does not constitute changes on the species level.

to evaluate the evidence from this site very carefully to see if dates proposed for it can actually be demonstrated.

To sum up all of this discussion, it is reasonable to ask how reliable the dating methods currently in use may be. All dating methods seem rather problematic although the degree of uncertainty varies from method to method. Dendrochronology seems to be reasonably reliable because trees seldom produce more than one annual ring, but dendrochronology is not useful before 9000 BC. Radiocarbon dating seems to be fairly reliable when a sample can be protected from all sources of contamination. Yet in the real world, sources of contamination are very common and are far more difficult to remove than is sometimes claimed. The weight given to other dating methods will largely depend on the presuppositions brought to the research. Authors and researchers work in the context of worldviews. These worldviews shape how evidence is chosen and how it is evaluated. It is important to recognize this basic reality when reading literature in the field. It is always vital to look for the hard evidence behind any claims and to evaluate how correctly the evidence is being used. This is true whether the claims are being made by young earth authors, evangelical old earth authors, mainstream scientists, evangelical theologians, or mainstream liberal/critical Biblical scholars. The actual evidence is far more important than any claims made about the evidence or any interpretations offered to explain the evidence.