Scientific Dating of History

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This article presents a summary and evaluation of the scientific methods that are used to set date for ancient history. Historians date the beginning of history toward the end of the 4th millenniumBC when writing systems appeared in Mesopotamia and Egypt. They date the beginning of civilizations living in organized agricultural communities to between 10,000-8000 BC. Various method of scientific dating are used to set these dates.

Carbon 14

When cosmic radiation enters the upper atmosphere of the earth, it strikes nitrogen atoms, and thermal neutrons are produced. These react with nitrogen in the atmosphere to produce a radioactive form of carbon known as carbon 14. ($N^{14} + n = C^{14} + H$). As this carbon 14 is mixed into the world's carbon reservoir, it also becomes a component in the atmosphere's carbon dioxide. Through photosynthesis this C^{14} is taken in by plants. When the plant dies, this intake process ceases. The carbon 14 atoms in the organism are radioactive, that is, they disintegrate spontaneously at a rate which is peculiar to C^{14} atoms. Carbon 14 atoms have varying lives. They may last hours or hundreds or thousands of years. The factor that determines the life span of individual C^{14} atoms is unknown, so we cannot predict whether an individual C^{14} atom will last a second or thousands of years. However, when scientists deal with a large number of these atoms in a statistical way, it becomes clear that half of these atoms will decay in about 5600 years. In another 5600 years half of those remaining will disintegrate. This period of about 5600 years is called the half-life of C^{14}. As the C^{14} atoms are disintegrating, they are reverting to their original status as nitrogen atoms and at the same time giving off electrons. The emission of these electrons can be measured with the proper instruments. The measurement of the rate of emission of these electrons forms the basis of radiocarbon dating. A new piece of wood should emit radiation at a rate of about 14.5 disintegrations a minute for each gram of natural carbon. A piece of wood 5600 years old should show only half as much activity. Wood 11,200 years old should be only one quarter as active as the recent wood, and so on. This, of course, is true only if the world's carbon reservoir in the past was basically the same as that of today.[1]

At first glance it seems that radiocarbon dating gives a good objective means of dating objects from the past, as long as adequate, uncontaminated samples of material are available. However recent research has raised serious questions about the validity of the assumptions which are the basis of radiocarbon dating, particularly the assumption that the carbon exchange reservoir has been constant through time. This question is of particular importance, because if there was a time in the past when the percentage of C^{14} in the carbon store was significantly less than at the present, all samples from that period will give a false impression of antiquity proportionate to this difference. The opposite, of course, is also true.

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[1] Stuart Fleming, *Dating in Archeology*, pp. 56-58.

There are some known factors which have created changes in the percentage of C^{14} in the carbon store in recent times. The heavy burning of fossil fuels since the Industrial Revolution has increased the *amount* of inactive C^{12} in the atmosphere and decreased the *percentage* of C^{14} in the carbon store. Wood growing in the 1950's contains about 2% less C^{14} than expected and has a false antiquity of up to 160 years. On the other hand it is estimated that atmospheric nuclear tests have increased the radioactive fraction of the world's carbon inventory by nearly 3%. The point is that the standards and points of reference for radiocarbon dating have been set up in a time when anomalies are present in the production and dispersion of C^{14}. More recently there has been yet another change with the reduction of atmospheric nuclear testing. The C^{14} standard is a stock of oxalic acid at the National Bureau of Standards. Since this acid is a recent preparation, it may contain some excess radioactivity from the weapons testing effect. Attempts have been made to correct for this by comparison with wood from 1895, but the question still remains whether it is possible in the present erratic conditions to establish a standard which is sufficiently accurate to apply to past millennia when conditions may have been drastically different.[2]

Besides these factors there are other variables which apparently affect the C^{14} store. There is evidence that changes in geomagnetic field intensity, changes in solar activity, changes in the distribution of radiocarbon throughout various components of the exchange reservoir, and climatic changes would effect C^{14} concentrations.[3]

The various forms of carbon, C^{12}, C^{13}, and C^{14} have different efficiencies of movement in transfer from one component in the reservoir to another. This is called isotopic fractionation. In practice this means that two different species of trees growing in the same climate may have different fractionation factors. Plants growing in different climates and even plants growing a different distance above the ground in the same climate or a different distance from the sea will also vary in isotopic composition. We must expect that there are similar levels of variability in archeological organic remains and attempt to account for them in assessing the accuracy of radiocarbon dating.[4]

Accurate radiocarbon dating also requires that C^{14} have a uniform, known rate of decay. Early calculations of the half-life of C^{14} ranged from 7200 years to 4200 years.[5] Libby settled on a half-life of 5,568 years. More recent determinations suggest 5,730 years as correct. It seems fair to say that the half-life of C^{14} is not certain.

Even if we accept the claim that we can accurately determine the present rate of decay of C^{14}, we must assume that this rate has always remained constant and that the isotopic composition of our sample is not altered by any other cause except C^{14} decay. While I know of no evidence that either of these assumptions is wrong, it should be noted that they are assumptions, not proven or verifiable facts.

Dendrochronology

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[2] Main source: Fleming, *op. cit.*, pp. 58-61, 65.
[3] Fleming, *op. cit.*, pp. 70-72.
[4] Fleming, *op. cit.*, pp. 61-64.
[5] W. F. Libby, *Radiocarbon Dating*, 1965, p. 35.

Because of seeming discrepancies between radiocarbon dates and dates determined by other means, attempts have been made to correct the radiocarbon scale on the basis of dendrochronology. The basic premise of this method is that trees grow a ring per year. We can then determine the age of very ancient living trees such as the bristlecone pine, which go back as far as 4,600 years. By comparing the ring patterns on the inner portions of the oldest living trees with wood from dead trees whose lifespan overlapped the living trees, but reached back much further, we can get back at least 7,000 years. By comparing the age of such wood determined by ring count with the age determined by radiocarbon dating we have a means for correcting the radiocarbon scale. The basic flaw in this method is that it cannot be demonstrated that one tree ring always equals one year's growth. In extreme cases of heavy spring frost as many as five rings have been produced in a single year's growth. At other times trees can be missing rings.[6] Such anomalies seem most likely to occur in the arid, cold, marginal conditions in which the bristlecone pine grows. Does timber grown at such high altitudes present a true picture of the behavior of other trees that grow around sea level?

There are also problems pertaining to laboratory technique. Controlling the background count of extra impulses induced by incident cosmic rays and dealing with fluctuations of background radiation during the counting period are problems which must be faced. The filling gas used for the Geiger counter also has an effect on the counting characteristics. Inter-laboratory variation is also a problem in comparing samples tested at different labs.

There are other problems which do not relate directly to the validity of the radiocarbon method, but rather to the quality of the samples provided. Does the sample actually belong to the time and level in question, or is it intrusive? Has the sample been properly taken and prepared? Is it free from contamination by other carbons? If the sample is from wooden beams, is it possible that they were re-used over a long period of time? All of these factors could affect the results, even if the method-itself were basically sound.

Another problem created at the archeological end of the work is the danger of misunderstanding, or subjective manipulation of the laboratory results. Sometimes reports fail to give adequate recognition to the fact that the radiocarbon dates reported by the lab only express a two out of three probability that the actual date of the object falls within the plus or minus range reported by the lab. Often reports fail to give an adequate accounting for date determinations that have been rejected by the writer. In an attempt to determine radiocarbon dates for the Early Bronze Age in Palestine 45% of the dates obtained by the laboratory were rejected, but this fact was not adequately explained.[7] In a summary study of Near Eastern chronology Homer Thomas remarks in the introduction, "When carbon-14 dates were obviously wrong, they were not included."[8] In a study like this we would like to ask, "How many were obviously wrong? How wrong were they?" The only explanation Thomas offers is, "In any case, radiocarbon dates will never provide a really firm, close dating for the archeologist."[9] Though perhaps made tongue-in-cheek, T. Säve-Söderbergh's introductory remarks to the Nobel Symposium are a fitting

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[6] Fleming, *op. cit.*, pp. 38, 39.
[7] Calloway and Weinstein, *BASOR* 225, p. 11.
[8] Thomas, *Studies in Mediterranean Archeology*, p. 11.
[9] Thomas, *ibid*.

reminder of an ever-present temptation. “If a C^{14} supports a theory, put it in the main text. If it doesn’t entirely contradict it, put it in a footnote. If it is completely ‘out of date’, we drop it.”[10]

Thermoluminescence

Another form of scientific dating of special interest is thermoluminescence. Its special usefulness is that it can be applied to pottery, the most abundant remnant of ancient cultures. It is based on the fact that the firing of pottery releases the energy which has been stored up in the crystal lattice in the form of electrons trapped in regions of imperfection by long term exposure to nuclear radiation. In other words, when the pottery is fired, this store of energy is knocked back to zero. If we can measure the TL energy which has built up in the pottery, we should be able to calculate how long ago the pottery was fired. Just like carbon14 dating the success of this technique depends on being able to accurately determine a uniform rate of buildup and account for disturbing factors and possible sources of contamination. I will not deal with TL at length, because I do not believe that it has yet had a thorough and adequate testing period, so that it can be fairly evaluated. However, it is fair to say that question marks and uncertainties still remain, and TL dating cannot yet claim to be a solution to the archeologist’s dating problem. At Dinkha Tepe in Iran six TL readings were taken. Four of the six TL readings fell into the range of the C^{14} readings. However, they are of very questionable usefulness because of the wide range of standard deviation: (1850 ± 190, 1550 ± 410, 2630 and 2400 ± 500).[11] Hopefully, the final report from Dinkha Tepe will prove useful for a consideration of dating problems since TL, C^{14} and tablets are all available from the site.

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[10] T. Säve-Söderbergh, *Nobel Symposium*, p. 35.
(Listed under I. Olsson, ed.).

[11] K. Prag, *Iran* 12, p. 129.