PITFALLS IN THE CALIBRATION OF RADIOCARBON AGES

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ABSTRACT

The further back the calibration of the radiocarbon time-scale extends, the more it will be used. Calibration is not simple, however, and it may even lead to erroneous conclusions unless certain precautions are taken. Confusion may be caused by the use of different symbols for citing dating results, ages based on different half-lives, and incorrect comparison of ages obtained by different methods. This article looks briefly at the pitfalls that may be encountered in the calibration of radiocarbon ages.

Introduction

Calibration of the radiocarbon time-scale has made tremendous progress recently. The officially recommended calibration curves cover the period from the present to 2500 BC. Other accurate calibration curves reach back to about 8100 yrs BP and a floating, very tentative, calibration extends all the way back to 13,300 yrs BP (Stuiver and Kra 1986). The longest continuous wood chronology (German oak), which goes back to 7938 BC might have another 300 dendro years added to it through additional cross-matching of the oldest Holocene oak trunks, dating from between 9300 and 9000 yrs BP (Becker et al. 1991). A 1604-year floating Early Holocene and Late Glacial chronology of pine has also been established (Becker et al. 1991). A new Calibration Issue will be published in *Radiocarbon* (Stuiver 1993). Comparison of the ^{14}C and $^{230}Th/^{234}U$ ages of Barbados corals provides information about long-term trends in atmospheric ^{14}C over the past 30,000 years (Bard et al. 1990, Stuiver 1990).

The further back the calibration reaches, the more it will be used - and also misused. The purpose of this article, therefore, is to point out the pitfalls and sources of confusion that archaeologists should be aware of when calibrating radiocarbon ages and seek to avoid.

To calibrate or not?

Most radiocarbon ages of geological interest should not be calibrated, because the Holocene chronostratigraphic classification is based on conventional radiocarbon years BP. For instance, the beginning of the Holocene has been defined as 10,000 ^{14}C yrs BP (see Mangerud et al. 1974, 1982).

The age of events connected with the Late Weichselian and Holocene shore displacement in the Nordic countries is expressed as conventional radiocarbon years BP. Stone Age dwelling sites were usually located close to the shore. When related to shore displacement chronology, radiocarbon ages on archaeological material, e.g., hearth charcoal, from Stone Age sites should not be calibrated - or both should be calibrated.

The results obtained by other physical dating methods, e.g., thermoluminescence (TL) or optically stimulated luminescence (OSL), refer to sidereal years. As a rule, ^{14}C dating results must always be calibrated in comparison with dates obtained by other independent methods or with historical dates.

Prerequisites for a successful calibration

Calibration is not simple owing to irregularities in the calibration curve and to the statistical uncertainty of radiocarbon ages. For the calibration to succeed one needs good-quality samples, precise and accurate dating results, an appropriate calibration procedure, and correct interpretation of the calibration results. Thus, the basic prerequisite is knowledge about the sample and about the theory of calibration.

When fine calendrical resolution is the goal, the sample must have a short life span (10 - 20 yrs). The calibration curve used must be applicable to the time-width of the sample. For material representing many years the detailed calibration curve has to be smoothed to an extent commensurate with the sample age span. If the sample represents one year of growth, the 10-yr curve should be used; use of a smooth curve would lead to oversimplification of the true age. However, if the analysis is imprecise, it does not make much difference what curve is used. (Mook 1983, Jope 1986, Pearson 1986, Mook et al. 1987.)

The dating result indicates the weighted average age of the sample only. There are several problems in defining the temporal relationship between the dates on wood and charcoal and the events being studied (see Taavitsainen 1990:26-47). The main difficulties are due to: 1) the difference in time between the calibrated date of a sample and the death of the tree it represents, and 2) the possibility of having dated stand-dried wood or timber from old houses transported to and rebuilt in a new dwelling site. These problems can be overcome if the dating project includes many dates on different materials and several types of objects, and the dating results are compared with observations made during the excavations (Carpelan & Kankainen 1990). Whenever possible, the archaeologist should try to choose a sample with 10 - 20 outer annual rings, to obtain a date close to the time when the tree died or was felled.

Several complications are encountered in the radiocarbon dating of water-lain organic sediments, and the date obtained is often too old (e.g. Olsson 1991a and references therein). Lake sediments from periods with agricultural activity conducted in the vicinity of the sampling site may yield anomalous old ages, useless in determining the date of the event of interest observed in the sediment (Tolonen 1980 and references therein). AMS ^{14}C dating of pure pollen is a potentially valuable approach for assigning high-confidence dates to botanical changes observed in pollen analysis of lake sediments (Long & Davis 1992).

Symbols for citing ^{14}C dating results

From 1959 to 1962 *Radiocarbon* published only conventional radiocarbon ages on the BP scale. But, to meet the needs of archaeologists, in 1963 it also began publishing AD/BC dates, which were obtained by subtracting 1950 years from the BP ages. At that time it was not known that there is a difference between a radiocarbon age and a calendar date. In 1977 *Radiocarbon* stopped the designation of AD/BC. Nevertheless, this confusing way of referring to conventional radiocarbon ages as if they were calibrated is still seen today in publications.

The first dendrochronological calibration curves and conversion tables were published in the late sixties and early seventies. They were not very accurate but extended back to more than 7000 years from the present. Trouble arose because there was no agreement on how to indicate calibrated radiocarbon dates. The symbols AD and BC were extensively used for both conventional and calibrated ages. Some laboratories reported the calibrated ages with an explanation, e.g., "MASCA corrected date" (which refers to Museum Applied Science Center for Archaeology correction factors, Michael & Ralph 1972), or placed an asterisk (*) before an AD/BC date to indicate that the age had been calibrated. The radiocarbon community merely stressed the importance of specifying the calibration curve used.

In 1972, contributors to *Antiquity* were instructed to give conventional-versus-calibrated dates: bp/BP, ad/AD, bc/BC - the lower case letters standing for conventional radiocarbon ages, the upper case letters for calibrated ones (Daniel 1972:265). This convention, which is used fairly widely, should be avoided, however, because in it BP has a different meaning from the original one. BP stands only for ^{14}C years before present, which is the year 1950.

Since 1985 it has become common practice to report conventional radiocarbon ages in years BP, and dendrochronologically calibrated ages as cal BP, cal AD or cal BC. Historical - non ^{14}C - ages are generally given in AD or BC. This practice was recommended by the Twelfth International Radiocarbon Conference (Mook 1986).

The Radiocarbon Conference convention meets the needs of the radiocarbon community, but not all archaeologists seem to be happy with it. Ages are being described in a variety of ways, and the potential for misunderstanding is growing (Chippindale 1990). The information acquired by calibrating precise ^{14}C determinations is lost if one symbol for citing ^{14}C determinations is used with two different meanings. This allows calibrated dates to be taken as uncalibrated and vice versa. Whenever conventional ^{14}C ages are calibrated for interpretation purposes, this should be clearly stated.

Libby half-life vs. real half-life

In the early sixties it was proved that the Libby half-life of ^{14}C, 5568 $\pm$ 30 yrs, is shorter than the real half-life of ^{14}C, 5730 $\pm$ 40 yrs. Great care should therefore be taken when using radiocarbon ages published in the sixties and seventies, because during those years some researchers "calibrated" radiocarbon ages by multiplying them by 1.03. This procedure was often erroneously referred to as **calibration** even though it was really no more than a **conversion** of radiocarbon ages from one half-life basis to another.

Comparison of ages obtained with different methods

Comparison of radiocarbon dates with, e.g., thermoluminescence dates provides an additional source of confusion. TL dates, like radiocarbon dates, are often given in years BP. But the thermoluminescence method has no known systematic error comparable to that of radiocarbon dating (i.e. the variations in atmospheric radiocarbon), so TL and radiocarbon dates of, say, 5000 yrs BP mean two quite different things.

Discussion

Radiocarbon dating is an interdisciplinary research method. The archaeologist, however, is seldom aware of the potential and limitations of radiocarbon analyses, or of hazards such as sample contamination. Successful calibration requires high-precision radiocarbon determinations and high-precision samples. To be sure they get good quality samples, archaeologists should select their sample materials together with a dating expert, and should continue to work in close cooperation with this expert until the results have been published (see Switsur 1990).

Too often the results of radiocarbon analyses are published as plain numbers, perhaps only with a remark on whether the ages agree with the results of pollen analyses or archaeological evidence. Information pertinent to the radiocarbon ages should include:
- pretreatment, and the fraction used for dating
-$\delta^{13}C$, if measured, and whether the dating result was corrected for isotopic fractionation
- a discussion of the representativity of the sample (possible contaminants in the sample)
- time-width and "own age" of the sample
- calibration: how and why the selected curve was used (was the curve "softened" to suit the time-width of the sample?).

The radiocarbon community is working hard to extend the calibration of radiocarbon ages further back and also to maintain and improve the quality of radiocarbon analyses (Olsson 1991b and references therein). It is now up to archaeologists to see that this important development is fully and correctly utilized in archaeological research.

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