matters arising

Calibration of the radiocarbon time scale

SIR,—The recently published paper by Clark and Renfrew[1] on calibration of radiocarbon dates is the latest in a series on this topic[2–5] by archaeologists who are rightly concerned by the uncertainties now involved in interpretation of data. Central to those papers has been the attempt to 'smooth' the bristlecone calibration curve of Suess[6] to negate 'kinks' and thereby ease interconversion of radiocarbon and calendar ages. Here I sound a cautionary note on such practices and question the validity of the smoothing methods. There is no dispute here over the detailed statistical techniques invoked by the various authors. The issue in question is the overworking of experimental data. There is little doubt that the methods employed are justified neither by the quality of the ^{14}C results nor by the present understanding of ^{14}C geochemistry.

The key issue is centred on the vital difference between the absolute accuracy and analytical precision off the ^{14}C measurements which comprise the bristlecone pine calibration curve. It is important to consider the inequality of these parameters. The error terms reported with ^{14}C data are derived essentially from the statistical ^{14}C counting error alone. To assess the real accuracy of the measurements, however, requires an answer to each of the following questions:

(1) Is the ^{14}C level of wood grown at an altitude around 8000 feet indicative of concentrations at sea level and at all other latitudes?

(2) Is the ^{14}C content of wood fractions other than the cellulose component necessarily a precise measure of atmospheric ^{14}C levels during wood growth?

(3) Can experimental unknowns, such as counter behaviour, contamination effects, human error, standardisation and half life uncertainty, be totally neglected? Furthermore, are systematic differences between ^{14}C laboratories possible?

To each of these questions there can, as yet, be no ideal answer. Comment can, however, be made:

(1) At the extreme altitudes where the Bristlecone Pine grows, the ambient cosmic ray neutron flux is approximately one order of magnitude higher than at sea level. Since these neutrons are the source of ^{14}C through the reaction $n + {}^{14}N \rightarrow {}^{14}C + p$, it is feasible that bristlecone pine wood could be non-representative of normal organic material. Whether through *in situ* ^{14}C production or variable atmospheric mixing, bristlecone pine ^{14}C levels could experience localised effects. Furthermore, there is already preliminary evidence that atmospheric ^{14}C levels may be latitudinally dependent. Thus Jansen[7] and Lerman *et al.*[8] have observed depletions of 0.5% to 2% in ^{14}C concentrations of southern relative to northern hemisphere wood.

(2) It has been shown with fair certainty that some chemical components of wood can be transported between tree rings[9]. Cellulose is chemically the most inert constituent of wood and, to minimise cross contamination, should be selected for precise ^{14}C analyses. Perhaps due to the limited size of samples, the major American laboratories engaged in time scale calibration do not take this precaution.

(3) It would be unrealistic to imagine that either systematic differences between laboratories or occasional freak results within one laboratory do not occur. There are many potential causes of such deviations.

The factors discussed here cannot be quantitatively assessed at present because of incomplete evidence. Only future research can clarify the situation and, for this reason, independent calibrations of the radiocarbon time scale, such as now being developed at Queen's University, Belfast, are of major significance. In the meantime a realistic approach to the available ^{14}C data is essential. In other words, besides the analytical error reported for each bristlecone pine ^{14}C analysis, there exists a further major error term to be considered. At present we cannot quantify it. Nevertheless, in view of the geochemical aspects of the factors mentioned, it would be unwise to attribute a degree of absolute accuracy less than $\pm$ 2% (2σ) to the bristlecone calibration curve (unless the archaeological specimen in question is a pinewood sample from an American mountain top and is pretreated and analysed by Suess). A 1% error in ^{14}C content corresponds to a radiocarbon age error of 80 yr so that, including reported analytical errors, it seems at present unjustified to attribute an accuracy of less than $\pm$ 200 yr to the calibration curve. In essence then the curve should be imagined not as a line but as a probability band of considerable spread (400 yr). Through this approach a realistic interpretation can be performed. Admittedly, the value of the calibration curve is severely reduced but this is the real situation which no mathematical manoeuvring should obscure.

Finally, I note that the simple approach of Suess, in adjoining ^{14}C data by hand, is in many respects preferable to smoothing operations by computer. Our need at present is for awareness of the limits of available data and for an increased availability of such results. Smoothing operations, in their role of rendering the experimental data remote, are contrary to this requirement. In addition, given the major error terms inherent in the curve, there is little reason for sophisticated mathematics. Kinks may well exist. The real existence of one such anomaly is beyond dispute[10]. It is questionable therefore whether at this time it is objective to smooth them out.

So I urge patience and restraint. Calibration, if performed at all, cannot yet be as quantitative as would be desired. There can be no justification for the delusion that major uncertainties do not exist. Over interpretation of the calibration curve for archaeological purposes is, for the time being, unwarranted.

Yours faithfully,

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