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On the Need for Further Isotopic Measurements from Tree Rings [and Discussion]

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On the need for further isotopic measurements from tree rings

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Archaeological pressure for better chronology has provided the scientific community with long tree-ring chronologies and high-precision radiocarbon calibration curves. Physicists are now using the calibration curves as the only available proxy measure of past solar variation. The underlying tree-ring chronologies can, in theory, offer three lines of research potential: (1) the analysis of other isotopes on a scale of years, (2) the possibility of climatic data on a time resolution compatible with the calibration and (3) possible refinement of the ice-core timescales, by linking related (volcanic) events in both records.

The bringing together of solar physicists and archaeologists to discuss possible relations between past solar activity and the Earth's climate produced some interesting undertones. Not least among these was the implied request from the physicists 'that the archaeologists should provide dated information on environmental change' for comparison with the precisely dated solar variations implicit in the radiocarbon calibration curves.

Now here indeed was a somewhat ironic set of circumstances. Physicists, with 'their' record of past variations in atmospheric radiocarbon, asking archaeologists 'What happened at this date and that date where we see rapid depletions or enrichments in the radiocarbon record?'. It seems not to have occurred to the physicists that 'their' proxy solar record had in fact been provided for them by the archaeological community. In the U.K. archaeological money had funded the construction of the Irish oak tree-ring chronology (Pilcher *et al.* 1984) against which Pearson, also funded from archaeological sources, had performed the first, long, continuous high-precision calibration of the radiocarbon timescale (Pearson *et al.* 1986). Pearson's calibration, combined with that of Stuiver, provides the internationally accepted standard now being used as a proxy solar record.

In a nutshell, archaeologists, in providing the stimulus for the radiocarbon measurements, have provided some of the only chronologically sound data available from the past. As soon as one strays into archaeology proper, time control decreases dramatically in quality. Few archaeological sites are dateable by dendrochronology, which is essentially the only method that would allow exact comparison with the isotopic variations seen in the tree rings. Apart from the problems of archaeological dating, which the calibration was originally intended to address, it is extremely difficult to infer climatic alterations from most archaeological evidence. Even those palaeoenvironmental methods associated with archaeological research, such as pollen or insect studies, suffer badly from the inferior dating control offered by radiocarbon.

In theory it may prove impossible to ever provide environmental information that is well-enough dated to compare with the variations in past radiocarbon concentration! In this vein, we have to remember that the wiggles in the calibration curve, of interest to solar physicists, are precisely dated against the tree-ring standard. All archaeological and palaeoenvironmental dating uses the calibration curve in an attempt to relate raw radiocarbon dates to the dendrochronological timescale! By definition the use of the calibration curve tends to widen the age band. For example, if we take one of the best-dated events in the Neolithic of Britain and Ireland – the elm decline – we can assign to it, on the basis of some 20 relevant radiocarbon determinations, an average radiocarbon date of almost exactly 5000 before present (BP) (Edwards 1985). Let us imagine that there was an error of only ± 20 years associated with this date. When we come to calibrate 5000 ± 20 BP at 95% confidence we find that the elm decline – if it was a unique event – took place somewhere between broadly 3940 B.C. and 3700 B.C. This is to all intents and purposes the best-dated 'archaeological' event in British and Irish prehistory. It becomes essentially impossible to relate this event to any particular 'solar variation' within the calibration curve. Such considerations make it extremely unlikely that the original physicists' question – 'What happened environmentally at the times of this or that radiocarbon depletion or enrichment?' – can be answered sufficiently accurately to be meaningful.

Again, by a stroke of irony, some of the only environmental events in prehistory that can be precisely dated by tree rings; the possible volcanic-dust-veil events specified by frost rings in the bristlecone pine (LaMarche & Hirschboeck 1984) and by 'narrowest-ring events' in the Irish bog oaks (Baillie & Munro 1988) are events unlikely in themselves to be related to solar activity variations. In the case of the Irish bog oaks, these postulated volcanic events at 4375 B.C., 3195 B.C., 1628 B.C., 1159 B.C., 207 B.C. and A.D. 540 represent the worst general conditions experienced in the tree-ring record. Examination of the calibration curve at these points in time shows no particular pattern between volcanic-induced climatic downturns and radiocarbon variations.

Although in the future further precisely dated environmental events may be forthcoming from the tree-ring record itself, one immediate use of the dates of the apparent volcanic-dust-veil events may lie in applying corrections to the ice-core record. If the dates listed above genuinely relate to Hammer's Greenland acidity peaks at 4400 ± 100 B.C, 3250 ± 80 B.C., 1645 ± 20 B.C., 1100 ± 50 B.C., 210 ± 30 B.C. and A.D. 540 ± 10 (Hammer *et al.* 1980, 1987), then the errors in the ice core dating can be reassessed.

The difficulties and limitations in attempting to relate radiocarbon-inferred solar activity to climate are clearly shown in a recent paper by Wigley (1988). Holocene mean-temperature fluctuations deduced from chronologies of glacial advance or retreat are based on a radiocarbon timescale. To compare the temperature fluctuations with the tree-ring derived solar variations Wigley had to calibrate the radiocarbon-dated temperature curve. Wigley admits that in spite of the general consistency of the temperature record, 'it is doubtful that the dates of the major temperature minima are better than ± 100 years (2σ limits)'. So this generally good temperature record is seen to have severe chronological deficiencies when attempts are made to find out exactly when environmental changes took place.

We can add to this the fact that the temperature record, as deduced from glacial advances and retreats, is 'not a perfect palaeoclimatic record' and the additional fact that there may be 'lags effected by the damping effect of the ocean's chemical or thermal inertia'. With all these provisos it is plain that any ability to infer causal relations is going to be severely impaired.

The net result of these chronological problems is that some other precisely dated variables need to be measured. Most obvious targets are the concentrations of isotopes of hydrogen, carbon and oxygen, directly measurable in tree-ring cellulose. At least some of these isotopic concentrations should be directly related to environmental factors. A concerted effort is required by the scientific community to exploit the long tree-ring records available in Europe and America.

In particular there are replicated data-sets represented by several continuous chronologies, each of the order of 7000 years minimum length, from Ireland and Germany (Pilcher *et al.* 1984; Leuschner & Delorme 1984), England (Baillie & Brown 1988) and California (Ferguson 1969). In the case of these projected isotopic studies the stimulus will no longer come directly from archaeologists but must involve the wider scientific community.

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Discussion

G. H. Schleser (*Biophysical Chemistry Group, Nuclear Research Centre, Jülich, F.R.G.*). My comment concerns the 206-year cycle that has been mentioned frequently in this Symposium. I have measured stable isotopes with depth in a north German peat bog. From the variations observed, two cycles can be calculated by spectral analysis, leading to 187 and 1014 years, the first value being interestingly close to the 206-year cycle.

M. G. L. Baillie. The similarity may have some basis if one considers that the growth of peat bogs may be led by variations in solar output.

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