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DENDROCHRONOLOGY AT BELFAST AS A BACKGROUND TO HIGH-PRECISION CALIBRATION

M G L BAILLIE, J R PILCHER, AND G W PEARSON

Palaeoecology Centre, Queen's University, Belfast

Northern Ireland

INTRODUCTION

The tree-ring program at Belfast originally aimed at the construction of a 6000-year oak chronology. The stimulus for this work came from the large numbers of sub-fossil oaks uncovered in Northern Ireland during land drainage and motorway construction in the late 1960's (Pilcher et al 1977). It became clear that any attempt to build such a long chronology would break naturally into two distinct units. One unit related to the construction of a pre-historic (BC era) chronology dependent on the sampling of large numbers of essentially random sub-fossil timbers. For this unit to be successful, timbers would have to survive relatively uniformly through time. The second chronology building unit was related principally to the AD era, with a natural extension into the first millennium BC at least. This unit was envisaged as the link between the present day and the necessarily floating sub-fossil chronologies. This AD chronology was based on modern, historic, and archaeologic timbers.

Work on these two units of chronology has been proceeding in parallel since the early 1970's. The two units will be complete when the chronology is consolidated for the first millennium BC. Currently, the absolute Belfast chronology extends from the present to 13 BC (Baillie 1980; 1982).

In this issue high-precision calibration results are presented for most of the last six millennia (Pearson and Baillie, 1983; Pearson, Pilcher, and Baillie, 1983). Oak timber was used for all the calibrations. We aim to establish the credibility of these chronologies and to indicate the limitations and difficulties of constructing a long oak chronology. Compared with the very long-lived bristlecone pines used to construct a 7104-year chronology (Ferguson, 1969), and also used, to check the most recent five millennia (LaMarche and Harlan, 1973) the problems associated with the construction of a similarly long chronology using a species such as oak are quite different. The short age span of individual trees means that many more overlapping patterns are needed and problems associated with short overlaps become critical. On the other hand oak does not normally show missing or double rings.

METHODOLOGY

Our approach has been to process groups of individual ring patterns into more robust, replicated, site units which represent the chronology building blocks. We do this because by selecting groups of timbers that occur together, there is a greater probability of finding cross-dating between the individuals. Also, mean chronologies tend to improve the common signal by cancelling some of the random noise associated with individual ring patterns.

All cross-dating between ring patterns has been visual and statistical. The Belfast CROS program (Baillie and Pilcher, 1973) was used as standard, and only matches that were visually acceptable and produced 't' values well in excess of 3.0 were accepted. More important from the point of view of overall chronology integrity is insistence on replication. In dendrochronology, replication comes at three levels: 1) Cross-dating of individuals, 2) cross-dating of chronologies, 3) Tertiary replication, which is available in Europe in the parallel oak chronologies produced by independent workers in Ireland and Germany (Becker and Schmidt, 1982; Schmidt and Schwabedissen, 1982). Constant replication yields chronologies that stand up well to independent verification.

It is necessary at this stage to examine one particular problem facing a dendrochronologist seeking to build or extend a chronology involving many short lived timbers. Let us assume that there are two chronologies placed approximately end to end on the basis of non-tree-ring evidence and the dendrochronologist can find only a low correlation associated with a short overlap. The true situation could be either a) a real gap exists between the chronologies, b) the chronologies lie exactly end to end, or c) a short overlap exists (a short overlap is likely to be just as difficult to identify as a non-overlap).

The dendrochronologist faces the dilemma of not being able to separate c) where the match is genuine from a) where in fact no significant overlap exists and any possible 'match' is simply the highest random correlation resulting from comparison of the two chronologies. In order to avoid errors in such situations secondary and tertiary levels of replication are required.

VALIDATION OF THE BELFAST CHRONOLOGIES

It is now desirable to justify the chronologies that were used for calibration. The three principal sections of chronology at Belfast are the absolute chronology from the present to 13 BC (Baillie, 1980, 1982), the Garry Bog 2 chronology spanning from the 2nd to the 10th centuries BC, and the recently extended Belfast 'Long' chronology (Pilcher and Baillie, 1978) now spanning the 10th to the 53rd century BC.

THE AD CHRONOLOGY. The Belfast chronology back to 13 BC is made up of multiple site chronologies and cannot be separated from other chronologies of Scotland, Ireland, and England with which it cross-matches and by which it is replicated. Thus an overall British Isles chronology complex exists which is independent and precisely correct. As a final check, various English chronologies, within the British Isles complex have been dated to precisely the same year against the independent German chronologies. Examples of these stepwise correlations are shown in Fig 1, which illustrate the tertiary level of replication.

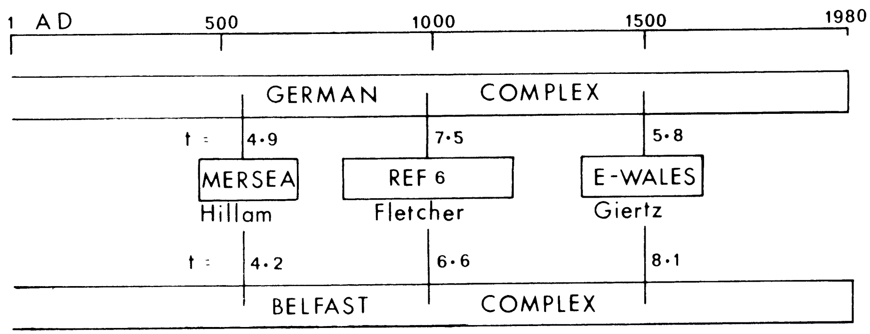

Fig 1. Tertiary replication of the German and Irish chronology complexes via England. For details see Baillie (1982).

THE BC ERA: THE LONG CHRONOLOGY - GB2 LINK. Substantial sections of sub-fossil chronology were completed by the late 1970's including the chronology of 2990 years placed approximately between 1000 and 4000 BC, (now extended to 5300 BC) and the Garry Bog 2 chronology of 719 years, dated to the first millennium BC. No cross-dating could be found between the ends of the chronologies. Recently, two new strands of evidence were obtained, the first of these relates to the high-precision ^{14}C analysis of samples from GB2. Both the long chronology and GB2 were "wiggle" matched against the bristlecone-pine results derived by Suess (1978). The exercise suggests that the long chronology spans 5300 to 940 BC ($\pm$ 20) while GB2 spans 940 to 220 BC ($\pm$ 20). The second innovation involves the chance discovery of a new group of sub-fossil oaks from Swan Carr near Durham (northern England). An initial collection of 20 samples from the site yielded a 750-year chronology, falling broadly within the first millennium BC. Comparison of this Swan Carr chronology with GB2 yielded an excellent agreement (t = 6.0). The oldest portion of the chronology extended the GB2 chronology back 208 years and suggested that a significant overlap, potentially of the order of two centuries should exist with the long chronology. Unfortunately, any match must be between timbers from northern Ireland and north eastern England. Is matching to be expected? Since Swan Carr and GB2 show good agreement over more than 500 years of overlap it is not unreasonable to expect at least some agreement between Swan Carr and the end of the long chronology. In practice a significant match is found with the final year of the long chronology equivalent to year 207 of the Swan Carr chronology (t = 4.8) (Fig 2). (If this is correct the long chronology and GB2 were separated in real time by a single year). To seek some replication for this match, the long chronology was divided into its constituent site units, ie, GB1 and Ballymacombs More. A consistent match is found with the Swan Carr chronology at this position t = 4.7 (cf GB1) and t = 3.6 (cf BMcC). No other consistent match exists. It is interesting that this match occurs within the likely time period specified by the high-precision "wiggle" matching (Pearson, Pilcher and Baillie, 1983). If this tentative match can be further replicated it will ensure that the Belfast calibration for the BC period is made on a continuous chronology. Recently further confirmation of this link has been obtained by comparison with chronologies for N Germany.

THE BC ERA: INTEGRITY OF THE LONG CHRONOLOGY. At this critical juncture in both the dendrochronologic and the high-precision debate, the existing long chronology (Pilcher, *et al* 1977) should be re-examined. Since that time, replication has become more formalized; normally, secondary and, preferably, tertiary replication is now sought for all sections of chronology. The site units of which the Belfast Long chronology is composed (Fig 3) show two points where secondary replication is not available. These occur ca 1900 BC where only the Garry Bog site chronology is represented and at ca 2550 BC. If problems of

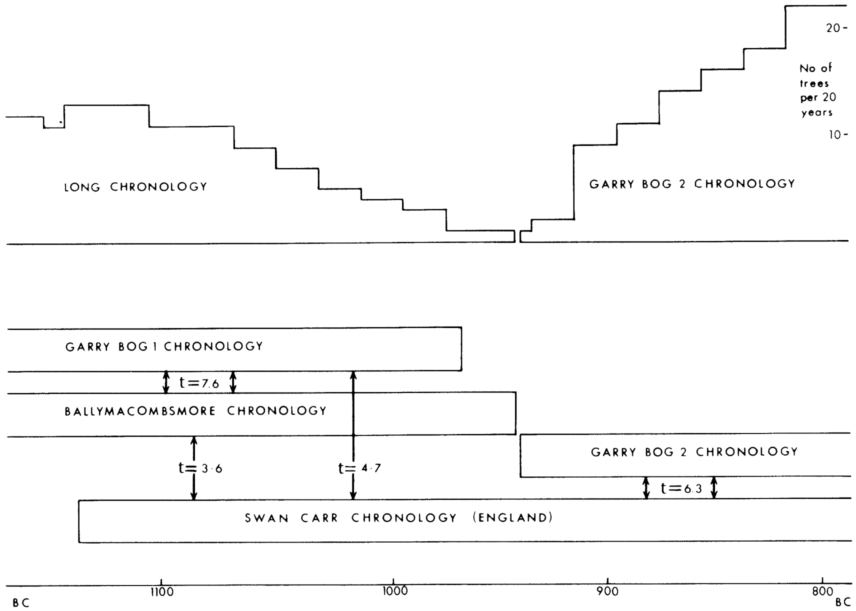

Fig 2. Possible matching position between the Belfast Long chronology and the Swan Carr/Garry Bog 2 chronology. This tentative link requires further replication but is consistent with the ^{14}C information.

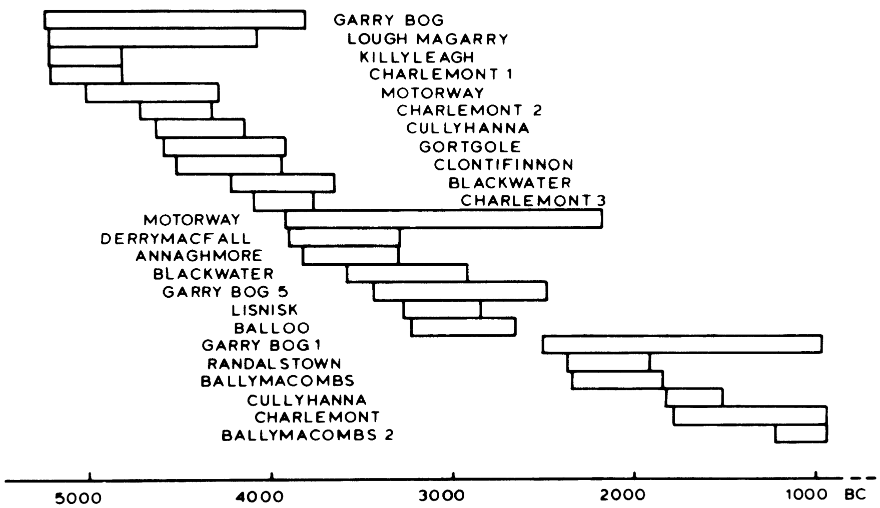

Fig 3. Site units included in the Belfast Long chronology. Only two points lack secondary replication, (ca 1900 and 2500 BC).

the type discussed above were to affect the Long chronology it is at these points that the chronology would be vulnerable. Around 1900 BC, the Garry Bog chronology, although it is only a single site chronology, is so well replicated internally with many trees of over 300 years in length that it need not be considered here. This leaves only one vulnerable point in the Long Chronology. At circa 2550 BC the Motorway chronology relies on a single ring pattern QUB 1546. This has to be the weakest point in the Belfast Chronology.

THE 1546 LINK. Figure 4 visualizes the 1546 situation. Solid replicated blocks of ring patterns are available in an essentially "end to end" mode. Had tree 1546 not been acquired a gap would undoubtedly have occurred in the Long chronology at this point. Thus, is 1546 an adequate link across this gap? The relationship between 1546 and the younger group of the ring patterns is firm, supported by individual 't' values of 6.1 and 7.3 and a value of 't' 7.2 when compared with the mean of the four trees. Thus, the weakest point in the whole Long chronology complex depends on the relationship between 1546 and the four older ring patterns. The evidence in Figure 4 is self-explanatory. Each of the individual ring patterns replicates the match with 1546 and, in this case, the mean of the four ring patterns gives 't' = 6.3. The correlation seems strong.

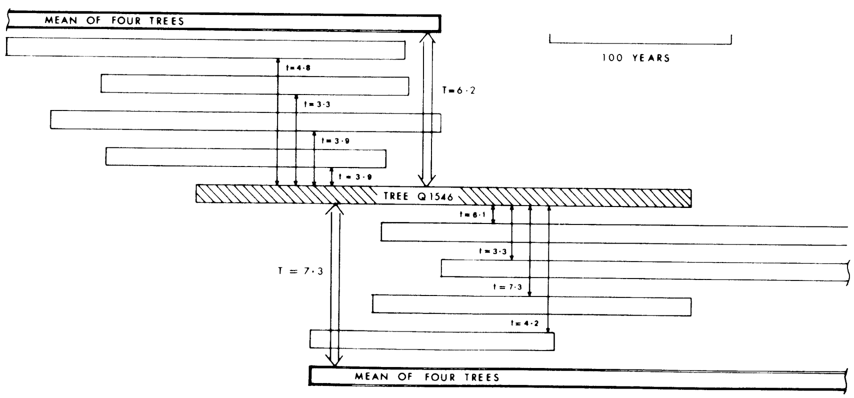

Fig 4. Weakest link in the Belfast Long chronology. Tree QUB1546 is the only link between two well-replicated blocks of chronology. The diagram shows that consistent primary replication is achieved at both sides of this link. Had this tree not been found, the chronology would still be in two parts.

CONCLUSION

Confirming evidence has been presented for the internal integrity of the two main sections of chronology so far constructed at Belfast. If the various correlations supporting the Swan Carr/Long chronology link are borne out by further replication, it would appear that a continuous chronology now exists from ca 200 BC to around 5300 BC. With recent advances in German sub-fossil and prehistoric dendrochronology, as well as Roman advances in England, it is only a matter of time before the entire chronology complex is precisely established. This consolidation will make the tree-ring axis of the high-precision calibration absolute.

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