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Rapid Communication

Dating prehistoric bog-fires in northern England to calendar years by long-distance cross-matching of pine chronologies

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ABSTRACT: The ages of prehistoric fires can be approximated by radiocarbon dating of charcoal or associated material, but such dating is often inaccurate and at best imprecise. Pine trunks preserved in British and Irish peats occasionally show firescars, which might be dated through dendrochronology to yield calendar-year dates. However, unlike oak, there is no master pine chronology to provide absolute dates, so dating is dependent on interspecies cross-matching; for sites in the British Isles with no dated oaks, calendar-year dating of prehistoric pines has hitherto proved impossible. We present a first success in dating, accurately and precisely, prehistoric fire events recorded in subfossil bog-pine trunks, using long-distance cross-matching of pine chronologies between White Moss, Cheshire, and the Humberhead Levels, England. Results demonstrate a bog-fire in Cheshire in spring 2800 BC, and again in 2710 BC, between spring and summer. Further successful long-distance cross-matching of pine would permit international climatological comparisons. © 1997 by John Wiley & Sons, Ltd.

KEYWORDS: fire; prehistory; Scots pine; dendrochronology; absolute dating.

Introduction

Charcoal is often found in Holocene sediments (Tolonen, 1986; Patterson *et al.*, 1987), and testifies to past natural or human-induced fires in prehistory and more recent times. The most commonly applied method of dating prehistoric fires is radiocarbon dating, but this is often inaccurate and is at best imprecise (Baillie, 1990; Pilcher, 1991). Individual, conventional radiocarbon dates may be no better than the half millennium in which they fall (Pilcher, 1993). Improved methods, such as AMS dating of charred cereal grain, may still be inaccurate by more than a century; and the 'wiggle-matching' (van Geel and Mook, 1989) of contiguous peat layers containing a band of charcoal, cannot pinpoint its age to better than a half-century. Furthermore, use of such methods is potentially erroneous: radiocarbon dating of charcoal does not date the fire itself, but merely the age of growth-years that yielded the charcoal. For charcoal derived from the heartwood of a 400-year-old tree, or from reused timber, its radiocarbon age may pre-date the fire by hundreds of years (Baillie, 1995).

Dating prehistoric fires to calendar years

More tightly constrained dating is conceivable if twig charcoal were contained within annual laminations, such as lake

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varves. However, charcoal in varves is allochthonous; it could have washed in from the locus of a catchment fire that took place decades previously, or it could have been redeposited within the lake (Bradbury, 1996). So, although historical records at particular sites may attest to a historical fire in a calendar year, and in particular circumstances this might be matched with charcoal records in adjacent sediments, dating a prehistoric fire to a calendar year is very difficult.

Better dating might be achieved for the firescars on subfossil pine-wood entombed in peat bogs. However, surface charring may represent fire that scorched the tree-trunk, long after its death; to date a fire event accurately, the firescar must be encapsulated in the trunk. Encapsulated firescars can be seen in the cross-sections of felled modern pine trees (Lehtonen and Huttunen, 1997); by counting back the rings from present day, a fire event can be dated to the calendar year, perhaps even to its season. Major encapsulated firescars are encountered occasionally in subfossil bog-pine timbers, such as those preserved in British and Irish peats, and in theory these timbers might be dated through dendrochronology (Schweingruber, 1988) to provide calendar-year ages for the fires (Baillie, 1995).

For such dating to work, the tree-ring sequence incorporating the firescar must be matched with an absolutely dated tree-ring chronology. Unfortunately, unlike for oak (Pilcher *et al.*, 1984), there is no master pine chronology for the British Isles. Here, absolute dating of Scots pine (*Pinus sylvestris* L.) is dependent on interspecies cross-matching with oak (*Quercus*). A successful cross-match for pine was made in Northern Ireland at Garry Bog (Brown, 1991; Brown and Baillie, 1992), where prehistoric populations of pine and oak coexisted, but absolute dating of pines at sites where there are no contemporaneous and dated oak timbers nearby has hitherto proved impossible.

Current research

Research on bog-pines in northern England, conducted independently in former raised mires either side of the Pennines (Fig. 1), has focused on subfossil bog-pines preserved at White Moss, Cheshire (research by JGAL) and at Thorne and Hatfield Moors in the Humberhead Levels (research by GB). Research on bog-pines at White Moss commenced in 1988, based initially from Keele University; whereas work on the buried forest at Thorne and Hatfield Moors was initiated from Sheffield University in 1993 as part of an archaeological and environmental survey of the moors. Current work, guided by the Sheffield Dendrochronology Laboratory, has matched a 477-year pine chronology (PISY) from the Humberhead Levels with prehistoric oak chronologies from England, and with the Garry Bog pine chronology. This provides the first absolutely dated pine chronology from England, and the first long-distance cross-match between pine chronologies from England and Northern Ireland. Now we can also report that subfossil pines from Cheshire, west of the Pennines, match with PISY, providing the first ever link between pines from different raised mire sites in England. The cross-match between pine chronologies PISY (from Thorne Moors, Humberhead Levels) and WM4 (from White Moss, Cheshire) gives $t = 10.01$ — a very significant match. The Cheshire pine chronology includes trees scarred by fire. Absolute dating of this chronology has enabled the fire events to be dated to calendar years.

Methods and results

Pine samples from each site were air-dried and sanded before being measured. Ring-width sequences were produced for each tree, and samples with over 50 rings were compared using cross-matching programs (Baillie and Pilcher, 1973; Munro, 1984) and verified by visual comparison of graphs. Samples that cross-matched with each other were combined to form site chronologies. At White Moss, mean tree ring-width measurements were produced for each of 136 samples. These initially yielded five chronologies ranging from 71 to 261 years (Lageard, 1992). Further sampling and analysis has created a 323-year chronology (WM4). One tree (D2.9) showed a major firescar between chronology years 82 and 83 (Fig. 2).

Established methods (Arno and Sneck, 1977; Sheppard *et al.*, 1988) were used to analyse the firescar rigorously for

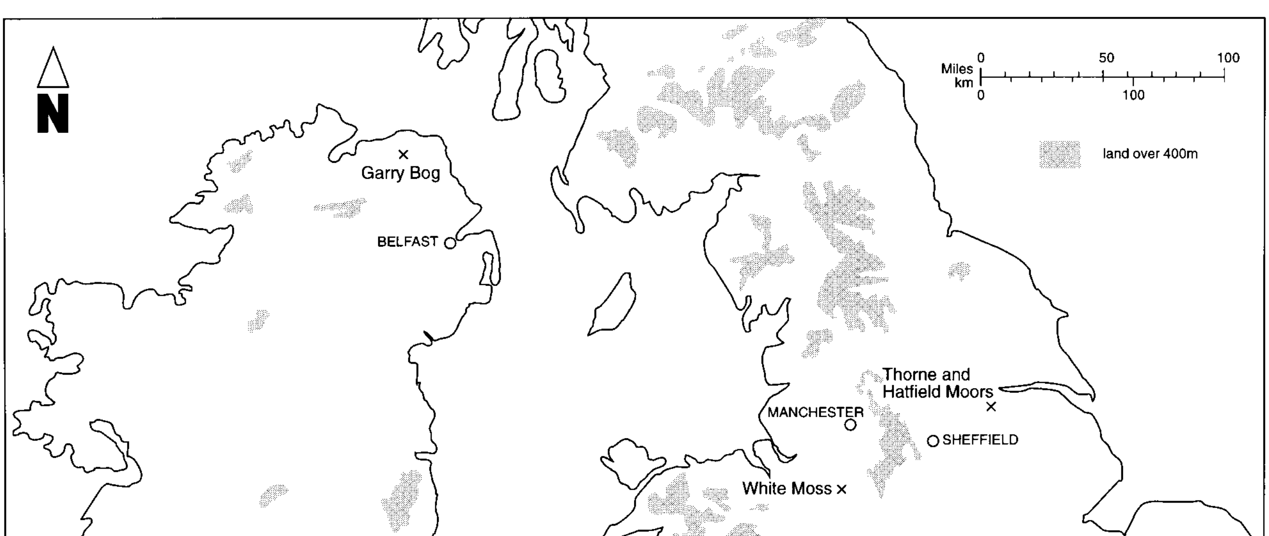

Figure 1 Map showing location of White Moss, Cheshire; Thorne and Hatfield Moors (Humberhead Levels), South Yorkshire and Humberside. Map also shows location of Garry Bog, Northern Ireland.

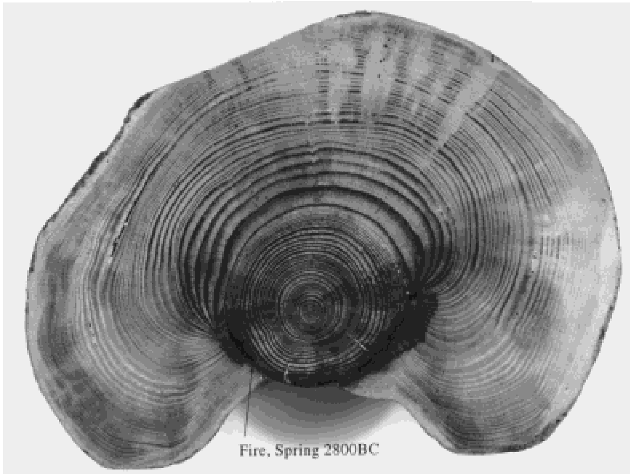

Figure 2 Scots pine (*Pinus sylvestris* L.) wood-disc sample D2.9, from White Moss, with major firescar, absolutely dated to the spring of 2800 BC. Note the disruption (caused by the fire) to the previously concentric growth pattern, and the subsequent growth release, in the tree ring immediately afterwards. Photograph: Gerald Burgess.

the season of the year in which scarring had taken place; the first half of the early wood was affected, indicating a spring fire. This tree, and 10 contemporaneous unscarred trees, exhibited significant growth release in the tree-rings immediately after the fire; two others suffered severe stress, in the form of narrow rings; and two trees appear to have died as a direct consequence of this fire. (The spatial and ecological aspects of this will be considered elsewhere (Lageard *et al.*, in preparation).) Although the tree (D2.9) survived the fire and continued to add tree rings, they never subsequently completed the trunk's circumference. A later firescar event, recorded in another sample, took place between tree-rings 172 and 173 of the WM4 chronology — this time between the late spring and early summer wood.

The best estimates for the ages of these fires had been the calibrated radiocarbon ages of subfossil pine wood from the site, which at 2-sigma gave a range from 3520 to 2462 cal. BC (Lageard, 1992). Now, a significant advance has produced actual calendar years for the fires. The cross-match of chronology WM4 against the absolutely dated PISY chronology has enabled the fire events at White Moss to be assigned to spring 2800 BC and to between the spring and summer of 2710 BC (Fig. 3).

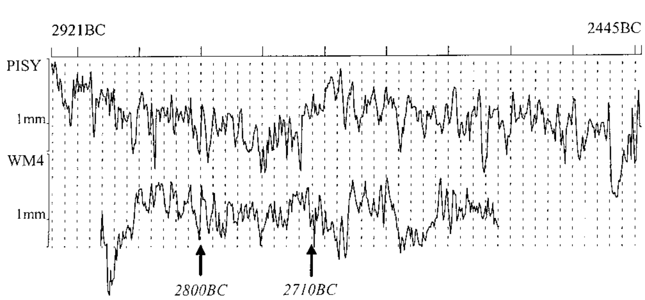

Figure 3 Tree-ring graph showing the cross-match between pine chronologies PISY (from Thorne Moors, Humberhead Levels) and WM4 (from White Moss, Cheshire), which gives $t = 10.01$ — a very significant match. The fire events at White Moss (identified from firescars) are highlighted. The Thorne Moors chronology, PISY (2921 to 2445 BC), contains 68 trees. The White Moss chronology, WM4 (2881 to 2559 BC), contains 26 trees. Vertical scale is logarithmic.

Discussion and conclusions

In the initial stages of research on the dendrochronology of bog-pines, there were doubts as to whether meaningful bog-pine chronologies could be compiled satisfactorily from sites. These doubts were assuaged by studies in Scotland (Bridge *et al.*, 1990; Gear and Huntley, 1991), which demonstrated success in local cross-matching. However, early pine studies did not achieve the same success in regional and national cross-matching as was possible for oak. Indeed, hitherto, pine growth on mires in the British Isles has been considered idiosyncratic and perhaps only capable of local (intrasite) cross-matching.

The data presented here represent the first long-distance cross-matching of bog-pine between regions in mainland Britain, and a first success in dating, accurately and precisely, prehistoric fire events recorded as firescars in subfossil bog-pine trunks, using long-distance cross-matching of pine chronologies. Results demonstrate a bog-fire in Cheshire in spring 2800 BC, and again in 2710 BC, between spring and summer.

The replication of this first long-distance match between English pines was checked by testing WM4 against the Irish pines: WM4 was found to match well against the Irish pine chronologies from both Garry Bog ($t = 4.77$) and Sharavogues ($t = 4.76$). There is now the prospect of success in future attempts at both interregional and international long-distance cross-matching of bog-pines — for example, of prehistoric pines in bogs in Scotland and Ireland. There is the prospect too that for significant periods of the Holocene, such as those highlighted by Pilcher *et al.* (1995), pine tree-rings from a range of sites in the British Isles might eventually be tied to calendar years. If calendrical dates can be applied, then both fire-frequency and year-by-year dendroclimatological comparisons might be made with pine chronologies elsewhere (Fritts, 1991), for example, in Fennoscandia, where there are long (albeit incomplete) chronologies (Briffa *et al.*, 1990; Briffa, 1994; Zetterberg *et al.*, 1996), compiled largely from lake sites. Eventually, this would allow comparison of internationally matched palaeo-datasets with modern fire-frequency data and climate dynamics (Larsen, 1996).

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