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Summary

A tree-ring dating programme was commissioned as part of a programme of repairs to the roofs of Hovingham Hall, Hovingham, by English Heritage in AD 2001. The building was designed by Thomas Worsley for himself between *c* AD 1751 and AD 1778 when he died. Thomas Worsley was George III's Surveyor General from AD 1760 and the programme of construction at Hovingham appears to have been influenced by his work in London from that date. The precise sequence of construction has been the subject of discussion and it was hoped that tree-ring dating would help clarify this. The tree-ring results indicate that seven areas of the roofs incorporate timbers felled, or probably felled, in the AD 1750s and early AD 1760s, but that at least three of these areas also include timbers felled in the AD 1770s. One apparently clear-cut result is in the Riding School roof, which appears to use trees exclusively felled in AD 1764. The correct interpretation of the results from other areas is obscure; the main alternatives are the use in these areas of some timber stockpiled before Thomas Worsley took up his London post or that there was a remodelling of these areas either following his period in London, or much later using recycled timbers. A group of oaks felled in AD 1992 from the estate woodlands are being used for the present repairs and samples from these and some thinned and wind thrown trees from AD 2000 provide a useful addition to the modern reference chronologies for North Yorkshire.

Keywords

Dendrochronology
Standing Building

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Introduction

This document is a technical archive report on the tree-ring analysis of oak timbers from several areas of the roofs of Hovingham Hall, Hovingham, North Yorkshire (NGR SE 6664 7565). It is beyond the dendrochronological brief to describe the building in detail or to undertake the production of detailed drawings. Elements of this report may be combined with detailed descriptions, drawings, and other technical reports at some point in the future to form either a comprehensive publication or an archive deposition on the building.

Hovingham Hall lies in the centre of the village of Hovingham, with the home farm and estate woodlands to the west of the hall, stables, and gardens. It stands *c* 25 kms north of York, and *c* 7 kms north-west of Castle Howard, fairly central in the current county of North Yorkshire (Figs 1 and 2). The hall as it stands is mostly the creation of Thomas Worsley (died 1778) but a combination of pressure of work, constantly changing plans, and tragic loss of his young family resulted in the building never being completed. The hall is currently the home of Sir Marcus and Lady Worsley, the estate is managed by William Worsley, whilst the most recent summaries of its development include two articles by Giles Worsley (Worsley 1994a; Worsley 1994b). The house is often referred to as 'eccentric' an impression perhaps exaggerated by the incompleteness of its plan. The entrance is unique, instead of the usual gates, lodges, and carriage drive, a gated archway on the village green takes the visitor directly into the vast Riding School, at the far end of which is the entrance to the house proper. Originally the stables and state apartments were intimately mixed, although they were eventually separated. Thomas Worsley began building in AD 1751 or AD 1752, and worked continued through the mid AD 1770s at least. There was something of a hiatus whilst he served George III as Surveyor General of the Office of Works between AD 1760, and his return to Hovingham in AD 1764. When he returned he was both richer and had access to better craftsmen, the quality of the surviving interior fittings at Hovingham are a testament to that change. He does however still seem to have followed his own unique blend of architectural ideas.

In AD 2001 an extensive series of English Heritage grant-aided repairs to the roofs were undertaken. The dendrochronological analyses reported here are part of the 'Informed Conservation' programme for the repairs (see Clark 2001). A tree-ring sampling programme of eight different areas of the roof covered by the repair programme was requested by Giles Proctor, the local English Heritage Architect, in order to help elucidate the dates and sequence of modifications of this complex structure. Changes to the scope of the repair programme meant that three other roofs were subsequently added to the initial request. The desire to construct a strong reference chronology of relatively rare eighteenth-century tree-ring data was an important component of the English Heritage funded tree-ring analysis.

In addition, during the initial assessment of the dendrochronological potential of the structures, I became aware of the use of estate oak timber on the repair programme and made the suggestion that we should additionally sample and analyse these and other estate trees as part of the updating and extension of the modern dendrochronological reference data. This suggestion was approved by English Heritage who were

particularly keen to attempt to construct a single chronology from the present day back to the period of the surviving roofs. Permission to sample this material was kindly granted by Sir Marcus Worsley.

Methodology

The general methodology and working practises used at the Sheffield Dendrochronology Laboratory are described in English Heritage (1998). The methodology used for this building was as follows.

An initial assessment was undertaken shortly after receiving the request documentation in company with Paul Hewett, of Martin Stancliffe Architects, to ensure that there were suitable timbers present in most of the areas of the building. This assessment aimed to identify those oak timbers with the most suitable ring sequences for analysis. Although at assessment we usually concentrate on ensuring there are timbers with more than 50 annual rings present, at Hovingham it was much more important to identify whether there was extensive survival of the original sapwood and bark-edge. This was because the short period of building at the site (27 years maximum) meant that only by obtaining precise felling dates for these timbers were we likely to clarify the building programme. This assessment identified that all accessible areas except one contained some suitable material, although since some areas were quite small there was less choice than was considered ideal. Several areas were inaccessible at the time of assessment but would become available as the repair programme continued.

Subsequent arrangements were made to sample the building timbers over a four day period. The repair programme had advanced by this stage to allow access to areas previously inaccessible, but had also unfortunately involved the defrassing of some timbers previously earmarked for sampling. This had removed some areas of bark-edge survival, although some areas survived. Further discussion with English Heritage at this stage gave agreement to continue despite the increased difficulty of obtained bark-edge dates from some areas. Samples were obtained from ten of the eleven selected areas of roof, the exception being area 1Da which is an apparently later roof using unsuitably young oak timbers. Three of the areas contained almost no suitable material and yielded only a single sample each. Such a situation would normally lead to rejection of an area for sampling, but at Hovingham because of the expectation of broadly contemporary construction of these areas, and their potential value to the final chronology, such limited potential did not automatically lead to rejection of the area concerned. The dendrochronological sampling programme attempted to cover the suitable phases by obtaining samples from as broad a range of timbers, in terms of structural element types, scantling sizes, carpentry features, and surface condition as was possible within the terms of the request.

The most promising timbers were sampled using a 15mm diameter corer attached to an electric drill. The cores were taken as closely as possible along the radius of the timbers so that the maximum number of rings could be obtained for subsequent analysis. The core holes were left open to aid ventilation. The ring sequences in the cores were revealed by sanding.

The recently felled material was obtained by examination of the estate wood yard in company with David Brown, the head forester. This was followed by a trip around the estate to examine the areas where the material came from. Discs and offcuts from two groups of trees felled the previous winter were collected, and then David cut by chainsaw short sections from fourteen trees felled '8-10 years earlier' in anticipation of this repair programme. These trees had been seasoned in the log and then cut into slabs and were being used piecemeal for replacing rotten sections of timbers in the hall roofs. The samples were cut from the central slab thus including the centre and the outside of the trunk, and usually from a point *c* 3m up the trunk thus avoiding complications caused by the roots. These samples were removed to Sheffield, left to dry and then further trimmed by band saw.

The complete sequences of growth rings in the cores and slices that were selected for dating purposes were measured to an accuracy of 0.01mm using a micro-computer based travelling stage (Tyers 1999). The ring sequences were plotted onto semi-log graph paper to enable visual comparisons to be made between sequences. In addition a cross-correlation algorithm (Baillie and Pilcher 1973) was employed to search for positions where the ring sequences were highly correlated. These positions were checked visually using the graphs and, where these were satisfactory, new mean sequences were constructed from the synchronised sequences. The *t*-values reported below are derived from the original CROS algorithm (Baillie and Pilcher 1973). A *t*-value of 3.5 or over is usually indicative of a good match, although this is with the proviso that high *t*-values at the same relative or absolute position must be obtained from a range of independent sequences, and that these positions are supported by satisfactory visual matching.

All the measured sequences from this assemblage were compared with each other and any found to cross-match were combined to form a site master curve. These, and any remaining unmatched ring sequences, were tested against a range of reference chronologies, using the same matching criteria: high *t*-values, replicated values against a range of chronologies at the same position, and satisfactory visual matching. Where such positions are found these provide calendar dates for the ring-sequence.

The tree-ring dates produced by this process initially only date the rings present in the timber. The interpretation of these dates relies upon the nature of the final rings in the sequence. If the sample ends in the heartwood of the original tree, a *terminus post quem (tpq)* for the felling of the tree is indicated by the date of the last ring plus the addition of the minimum expected number of sapwood rings which are missing. This *tpq* may be many decades prior to the real felling date. Where some of the outer sapwood or the heartwood/sapwood boundary survives on the sample, a felling date range can be calculated using the maximum and minimum number of sapwood rings likely to have been present. The sapwood estimates applied throughout this report are a minimum of 10 and maximum of 46 annual rings, where these figures indicate the 95% confidence limits of the range (Tyers 1998a). These figures are applicable to oaks from England and Wales. Alternatively, if bark-edge survives, then a felling date can be directly utilised from the date of the last surviving ring. The dates obtained by the technique do not by themselves necessarily indicate the date of the structure from which they are derived. It is necessary to incorporate other specialist evidence concerning the re-use of timbers, seasoning, and the repairs of structures before the

dendrochronological dates given here can be reliably interpreted as reflecting the construction date of phases within the structure.

Results

Plans of the roofs produced by Martin Stancliffe Architects were supplied with the original request documentation, subsequently digital copies of these and other drawings were supplied. These labelled different parts of the roof by area (Areas 1A - 2B), and where necessary sub-roof (eg 1Da - 1Dd), and provided truss and purlin numbering schemes (eg T1 - T7, P1 - P6). Where appropriate these are followed throughout this report, and cross-referenced with drawing numbers (the original supplied drawings date from February AD 2000, the digital copies are of various dates). Where no drawings were supplied arbitrary truss numbering schemes of the same style were applied. Sample locations throughout were recorded by a combination of the truss number, purlin number if appropriate, and the structural element description (Table 1; Figs 3 - 9).

A total of 49 timbers was selected as most suitable for sampling (Table 1). These samples were numbered **1-49** inclusive. Samples **11-16** are from area 1A, the roof over the Ballroom, samples **17-22** and **31-36** are from the two quite different roofs of area 1B, over the Ionic room, samples **23-30** are from area 1C, the roof over the Dining room, samples **39-49** are from three of the four roofs of area 1D, over the Hunting Hall. Sample **38** is from Area 1E, the roof of the northern lean-to on the Riding School. Samples **1-10** are from area 2B, the Riding School roof, whilst sample **37** is from area 2B, stabling forming the southern lean-to on the Riding School.

Eight of the core samples (numbers **1**, **12**, **30**, **36**, **37**, **38**, **46**, and **48**) when examined in the laboratory were rejected because they had too few rings for reliable analysis or because they had fragmented too badly. The remaining 41 samples were measured (Appendix 1) and the resultant series were then compared with each other. Thirty one sequences were found to match together to form an internally consistent group (Table 2; Fig 10). A 131-year site mean chronology was calculated, named HOVHALL. The site mean, and the ten unmatched samples were then compared with dated reference chronologies from throughout the British Isles and northern Europe. A single well correlated position was identified for the HOVHALL sequence. Table 3 shows example correlations of the HOVHALL mean sequence at the dating position identified, AD 1643 – AD 1773 inclusive, against independent reference chronologies. The remaining ten measured samples did not match either the rest of the material from Hovingham or reference chronologies and are thus undated by this analysis.

A map and catalogue of the estates woodlands were provided by David Brown, the head forester, and the supplied material was from specified woodland compartments. The material was provided with arbitrary numbers (**101-119**) at the time of analysis (Table 4; Figure 2). Samples **101a-101c** were three sections of a single wind-thrown tree from compartment 4a, Sheriffs wood (SE 644 757) within Hovingham High Wood which was brought down in high winds in winter AD 2000/1. The three sections were from the base, *c* 5m up the trunk, and from a side branch. Samples **102-115** comprised fourteen trees felled 8-10 years

previously from compartment 19, Calf Close (SE 653 757) from Hovingham High Wood, for use in the repair programme. Samples **116-119** comprised a selection of four samples from trees thinned in compartment 25b of Bankwood (SE 656 745) the previous winter, one of these appears to have already been dead (sample **119**).

All these samples were measured (Appendix 2) and the resultant series were then compared with each other. All were found to match together to form an internally consistent group (Table 5; Fig 11). The three sections of sample **101** were initially combined into a composite sequence and then a 197-year site mean chronology was calculated using this and the other 18 series, this was named HOVWOOD. This site mean was then compared with dated reference chronologies from throughout the British Isles and northern Europe. A single well correlated position was identified for the HOVWOOD sequence. Table 6 shows example correlations of the HOVWOOD mean sequence at the dating position identified, AD 1804 – AD 2000 inclusive, against independent reference chronologies.

Discussion

Hovingham Hall roofs

The 131-year chronology HOVHALL, constructed from original roof timbers, is dated AD 1663 – AD 1773 inclusive. It was created from thirty-one timbers from seven different parts of the structure. Twelve of the dated samples were complete to the original bark surface, ten other dated samples includes some sapwood, and eight of the remaining nine dated samples are complete to the heartwood/sapwood boundary (Table 1). The results need to be reviewed by the structural origin of the samples. The terminology of the structural elements of post-medieval roofs is not as clearly defined as those for medieval roofs (see eg Alcock *et al* 1996). Figures for each roof discussed below are included where available, the terminology employed in the figures, descriptions, and tables where possible follows the recent proposals of Campbell (2000). It should be noted that the Hovingham roofs often exhibit an unusual combination of king- and queen-post features and defy normal descriptive terminologies. Unless otherwise noted the Hovingham Hall roofs discussed below are constructed of oak (*Quercus* spp.), at least in the visible area above the floorboards and excepting some probably later softwood common rafters. They are characterised by the presence of clear sawing marks on the inner and outer faces. There are oak pegs throughout, and there is a strong tendency to use only halved and quartered beams. The trusses in each area have a complex collection of assembly marks using Roman numerals and tags, made using chisels. These are typical of later medieval and post-medieval roofs, but an unusual feature (which I did not have time to pursue in detail) is that each truss seems to be distinguished by the use a different length of chisel, ranging from *c* 5/8in to *c* 1½in (*c* 16 – 38mm).

Area 1A, roof over the Ballroom. This roof and that of the Riding School are of similar truss design with some differences in the details and the relative proportions between the two roofs. It would appear to be best described as an open queen-post type with double sloping joggled queen posts to produce cross-bracing to a triple joggled subsidiary post, or punchion (Fig 4a). There are iron stirrups top and bottom of the queen posts, although these are possibly replacements. Above the strainer beam is a splayed king

post/strut with a housed ridge plate. There are raking braces from the strainer beam to the principal rafters, and some wind bracing from the purlins to the trusses. Three pairs of common purlins are halved over the principals. Five of the six samples (Table 1; Fig 4b) from this roof were dated. One is complete to the original bark surface, whilst the other four are complete to either the original heartwood/sapwood boundary, or include some sapwood. The sample complete to bark ends with an apparently complete ring for AD 1758 indicating this timber was felled in the winter of AD 1758/9. The date for the four samples complete to the heartwood/sapwood boundary or with some sapwood are compatible with this interpretation, although some variation in precise felling dates cannot be excluded on the basis of the results obtained from other areas. These dated samples are from two of the three trusses in this roof and include posts and purlins. The documentary evidence suggests building work in this area was completed by AD 1766. The single felling date obtained may indicate either seasoned timber was used in this area, or that building work began before Thomas Worsley's period in London and there was a hiatus, perhaps in the fitting out phase, until after his return. The first suggestion is unlikely because of the clear presence on the timbers of distortion on the sawn faces that occurred after their sawing. This can only occur if they were squared before being seasoned, and they should only have been squared once the construction of the trusses had begun. It therefore seems likely that the roof was completed *c* AD 1759.

Area 1B east and west, roofs over the Ionic room. This area has two distinct roofs, both aligned north-south and positioned next to each other so that there is a central gutter between the two (Fig 5). Twelve samples are from this area, six from the two trusses forming the eastern roof, and six from the two trusses forming the western roof (Table 1). Eleven of these were usable samples and nine of these were successfully dated. All six samples from the eastern half are dated whilst three from the western half are dated. Both areas produce results which may indicate two phases of activity are present. Alternatively the two roofs may be of different dates, or there may be the extensive presence of re-used or stored timber. The eastern roof is of mansard type, with short splay-headed king struts above a collar/tiebeam. There is a collar/tiebeam at the break of roof slope, and presumably a tiebeam below the floor. There seems to be little structural bracing. There are three eastward facing dormer windows. Only two timbers retained sapwood, both these being the collar/tiebeams at the mansard height. One of these retained bark edge and was felled in the winter of AD 1773/4. The other collar/tiebeam is likely to be of the same date. In contrast the other four dated samples, three of which are complete to the heartwood/sapwood boundary, appear to be earlier (the heartwood/sapwood boundary dates are AD 1729, AD 1732, and AD 1733). If all these are assumed to part of the same felling episode the combined interpretation for them indicates felling in the period AD 1743-75, so they could be part of the AD 1773 phase. However, the English oak sapwood distribution is skewed toward the lower numbers and it seems more likely that they were felled in the AD 1750s or AD 1760s. The purlins and principal rafters were discoloured and had a different texture when compared to both the timbers in the other roofs, and the collar/tiebeams, hence they might be re-used from an earlier structure. It is thought that this area was extensively remodelled in the AD 1830s (Giles Worsley pers comm). Perhaps this mixture of material of differing dates was all recycled from the modified structures below or from elsewhere in the Hall. The western roof is not of mansard type, but is another of the splay-headed king-post roofs seen elsewhere at Hovingham. The details are obscured by the supporting

structure of the deeply coved ceilings which rise up from below to more than half way up the king posts. There are raking braces to the principal rafters and two lines of purlins on either slope. The restoration work was completed in this area by the time sampling was begun and heat insulation and other fittings prevented access to much of the structure. This, combined with the intrusion of the ceiling into the roof space, meant that it was particularly awkward to access and the sampling locations were somewhat limited. Nevertheless the three datable samples obtained suggest some differences of dating may also be present in this roof. Here, two samples retain bark-edge, but these are two years apart; winter AD 1754/5 and winter AD 1756/7. No notes were initially made that identify the presence of distortion on these timbers, which would have indicated whether they were used green. Unlike most of the other roofs they were not re-examined subsequently due to the disruption it would have caused. The other dated timber does not retain bark-edge but did retain a small amount of sapwood. This timber was felled in the period AD 1753-89. Thus it could be broadly contemporary with the other two timbers, or it may be somewhat later. The coved ceiling under the western section is thought to be a nineteenth-century amendment. Clearly the dated timbers do not relate to that change, unless recycled materials were used here also.

Area 1C, roof over the Dining Room. This area contains three extraordinary asymmetric trusses (Fig 6a). The northern half looks like one half of the trusses seen in area 1A and area 2A, except that there are only raking braces and not cross-bracing. The queen post (if it should be called that!) is sloping-joggled and iron stirruped, features seen elsewhere at Hovingham. However the bracing does not reach the punchion post which is plain and unjoggled. The strainer beam is flared and curves into the curiously doubled principals, creating an effect almost like a cruck blade on its side. Above this is a peculiar trestle-like pair of braces rising to the ridge. The south side is completely different, the strainer beam junctions with the doubled principal at the point near where the double thickness stops. There is no southern equivalent timber to the north-side queen post. Instead a smaller single joggled punchion post stands further south. This has a single raking brace to the principal, whilst a further plain punchion is positioned symmetrically to the one on the north side. There are two rows of purlins on the northern slope and three on the southern. The westernmost truss has none of the southern structure to make way for a domed light well for the staircase beneath. Seven of the eight samples taken from this part of the structure contained enough rings to warrant analysis (Table 1; Fig 6b), and four of these were found to date. Here the evidence for two phases of activity, or the stockpiling of timber, is more clear cut than it is for Area 1B. Two timbers retain bark, one for the winter of AD 1754/5 and one for spring AD 1755. Both these are the north-side queen posts. Such a difference could reflect a real difference in felling season, but it more likely reflects a phase of felling over a period of a few weeks at the onset of spring growth in AD 1755. The other two samples must be later although neither have retained bark edge. They include sapwood out to AD 1764 and AD 1765 respectively and are interpreted as being felled between AD 1765 and AD 1785. All four of these timbers show clear evidence for being converted whilst green, the distortions on the sawn faces being quite evident. We therefore have a roof where a timber felled in AD 1754/5 is jointed to a timber felled after AD 1765, both of which appear to have been initially used green. There are however some important differences (Fig 12): the queen post is chamfered and has a little chamfer stop at both top and bottom, the curving strainer beam does not have a chamfer. Also the queen post is slightly thicker than the strainer beam, and the joint is not particularly

tightly made, unlike those in other parts of Hovingham. The solution appears to lie in a diagram used in the current guidebook (Worsley nd, 7) which shows Thomas Worsley's design for this block incorporating a roof of identical design to those in areas 1A and 2A, and quite unlike the roof now there. Perhaps the queen posts on the northern side are from that original roof, whilst the purlins and strainer beams relate to its subsequent remodelling. Documentary evidence suggests this area was completed by AD 1772. Giles Worsley has suggested that this is the area of Thomas Worsley's AD 1750s temporary *manege*.

Area 1D, roofs over the Hunting Hall. Eleven samples were obtained from three of the four separate areas of roof over the Hunting Hall. Area 1Da contained a clean oak roof of circular sawn timbers retaining no sapwood and using very young trees. No sampling was possible in this area. This roof would appear to be a later replacement for the original structure. The structure is a lean-to roof with each truss having a main post and a joggled double-punchion subsidiary post, and two raking braces, one to the tiebeam and the other to the principal rafter. There are three common purlins. The structure is almost identical to that seen in area 1E, although the condition of the timbers here is significantly better. Six samples were obtained from area 1Db. This is a king-post roof with a splayed head and a housed ridge (Table 1; Fig 7). Four samples were obtained from this area before bats were discovered in residence, forcing the curtailment of the sampling in this area (English Heritage and English Nature 1999). All were suitable for analysis and three were dated. One retained some sapwood whilst the other two included the heartwood/sapwood boundary. Assuming they are a single phase of felling a date between AD 1739 and AD 1770 is indicated. The three heartwood/sapwood boundary dates are earlier than those from elsewhere in the building, perhaps showing this is a relatively early part of the roof. Four samples were obtained from area 1Dc. This is another king-post roof with straight joggled raking braces and a splayed head (Table 1). Some features make it unusual: the trusses are asymmetric, and the roof was originally, or later adapted to, a lean-to type to the west side. All the samples were suitable for analysis but none were found to cross-match either with each other, or with other material from the hall, or to be datable against reference data. Area 1Dd is the extremely odd south-western roof (Fig 7). In this area there is a single large king post, one of the few whole trees used in the roofs at Hovingham, but which demonstrates the usual original Hovingham features of a splayed head, housed ridge, stirrups, and straight joggles. This post is not square to the roofs above it and a thicket of bracing at a variety of angles support the east-, north-, and south-facing roofs that lean on this post. One sample was obtained from the bracing here, this sample dates, and again retains some but not all its sapwood. A felling date between AD 1748 and AD 1784 is indicated. Hence the results from these four roofs are inconclusive. One area is apparently a later replacement but was not sampled. One area is undatable although its eccentricity perhaps points to a Thomas Worsley design, and two have datable timbers but none that retained bark-edge. The tree-ring dates produced cover all or most of the likely period between the inception of the building and the death of Thomas Worsley and thus do not notably advance our understanding of the chronological development of the building. The heartwood/sapwood boundary dates however do suggest these two areas may be amongst the earliest of those sampled. This area is thought to be incomplete internally at the time of Thomas Worsley's death, although when the outer shell was completed seems uncertain.

Area 1E, roof of the northern lean-to of Riding School. This structure is a lean-to roof with each truss having a main post and a joggled double punchion subsidiary post. Two raking braces from this lead one to the tiebeam and the other to the principal rafter (Fig 8a). There are two common purlins. The structure is almost identical to that seen in area 1Da, although the poorer condition here prevented the identification of circular saw marks or other features. There are nine trusses in all, but the roof contains no particularly promising timbers. Only one sample was obtained from this structure, but it was not suitable for analysis (Table 1; Fig 8b).

Area 2A, roof of Riding School. This roof is of similar truss design to that in area 1A with some differences in the details and the relative proportions of the spaces (Fig 9a). It would appear to be best described as an open queen-post type with double-sloping joggled queen posts to produce cross-bracing to a triple-joggled subsidiary post, or punchion. Above the strainer beam is a splayed king post/strut with a housed ridge plate. Here there are raking braces from the joggled king post/strut to the principal rafters. There are iron stirrups at top and bottom of the queen posts. The principals have an unusual jowl where it widens before entering the floor. Three pairs of common purlins are halved over the principals. There is no original wind-bracing. Trusses 2 and 4 have decorative jowls on the inner faces of the queen posts, the others are plain. Nine of the ten samples from this area were usable (Table 1; Fig 9b). All nine were dated, and six include complete sapwood and the original bark surface. These six samples end with an apparently complete ring for AD 1764 indicating all this material was felled in the winter of AD 1764/5. The other three dated samples include some sapwood and the interpretations of these are compatible with the results from the other six. These dated samples include posts, principal rafters, and purlins derived from three different trusses. The results indicate this roof uses timbers felled at a single period. There is clearly visible distortion on the sawn faces that occurred after their sawing. This can only occur if they were squared before being seasoned, and they should only have been squared once the construction of the roof trusses had begun. This feature combined with the single felling date obtained from six different timbers therefore makes it likely that this roof was completed *c* AD 1765. The construction of the Riding School is thought to have been completed by AD 1768. This clear cut result is not however the end of the story, as there are a number of structural features that indicate this is the second roof on the riding school. There are lines of eaves on the east wall of the ballroom block indicating an earlier roof existed with a different roof alignment. The restoration team also identified a number of structural features in the stonework which suggest the eastern third of the riding school is an addition. Since the tree-ring dates indicate that at least trusses 2, 4, and 5 are contemporary it follows that the entire roof was rebuilt after this addition. This is interesting for two main points; firstly if in this area AD 1765 work is already replacing earlier work the scale of remodelling at Hovingham maybe greater than hitherto imagined, secondly if an earlier roof is entirely replaced here, these timbers may appear elsewhere in the structure and may explain some of the complex results obtained from areas 1B and 1C.

Area 2B, roof of southern lean-to of Riding School. This structure is of splayed-headed king-post design, with sloping joggled raking braces to the principals. It was later converted to lean-to form by extending the line of the southern slope upwards to the wall of the Riding School. This four-truss structure contains no

particularly promising timbers. No drawings were provided of this area and only one sample was obtained from this structure, it was not suitable for analysis (Table 1).

Areas 1A, 1B, 1C, and 2A It is important to appreciate that dendrochronological dating can only date the felling of the tree, and only then if bark-edge survives on a datable core. For the results outlined above for Hovingham it is equally important to question whether the bark-edges obtained from the sampling are indications of phases of felling for almost immediate use or whether they are phases of felling in anticipation of projected future requirements. In at least one, and probably three areas (1B east, 1B west, and 1C), if the material was being used green, the results indicate there are a minimum of two phases of building activity. In these area it is a possibility that Thomas Worsley remodelled these roofs following a change in the design or intended use of these areas, or that subsequent nineteenth-century amendments by the first Sir William Worsley employed recycled timbers from within the structure. In two other areas there is tree-ring evidence to suggest the roofs were completed earlier than has been hitherto imagined (1A and 2A). Unfortunately in the only other area with any results (1D) they are too imprecise to be of any significant value in interpretation, although they do not exclude the possibility of an early date for this area. If the bark-edge dates reflect phases of felling in anticipation of future requirements (such as occurred in the present round of repairs), with stockpiling and seasoning to be expected, then the results provide *terminus post quem* dates for periods of building activity.

It should be noted that seasoning is not considered to have been normal practise for structural timberwork in the medieval period, and may not have been so in most circumstances in the post-medieval or early modern periods. There is some documentary and tree-ring evidence from the seventeenth- and eighteenth-century phases at Lincoln Cathedral that implies a seasoning period of *c* 4 years was used there at this period (the evidence at Lincoln Cathedral has recently been summarised in (Laxton *et al* 2001, 79-82)). Whether seasoning was undertaken in the eighteenth century at Hovingham is unknown. After completing the analyses reported above, the Hovingham roofs were re-examined, except that of 1B east which was no longer accessible. In all areas there is the characteristic distortion in cross-section that indicates these timbers have seasoned after being sawn. This physical evidence suggests that the Hovingham timbers were used, or at the least converted for use, whilst still green (Fig 13) These distortions would not occur if they had cut seasoned logs.

It seems reasonable to assume that the death of Thomas Worsley in AD 1778 provides a *terminus ante quem* date for all the original activity in the roofs. The dendrochronological results make it clear that at least seven areas of these roofs include timbers from his period. It is not clear of course if the surviving structures are exclusively his original roofs, or whether some are his subsequently modified roofs, it is also possible that some are later roofs using timbers from his period. The extensive archives at Hovingham may provide evidence for alternative interpretations than those outlined here.

Estate trees

The modern chronology HOVWOOD was constructed from 19 trees from three different compartments of woodland all within 1½ km of each other on the Hovingham estate. The high levels of correlation between individual trees in different compartments, along with the relatively uniform tree-ages and growth rates, indicate that there is nothing to be gained by separating the different compartments into different tree-ring chronologies. Tree-ring analysis confirms the timbers in compartment 19 were felled 9 years before the others which supports the verbal information from the head forester. The estate estimates compartments 19 and 25b were planted *c* AD 1820 and *c* AD 1800 respectively. The results from the tree-ring analysis suggest that planting dates of *c* AD 1800 and *c* AD 1840 are more likely. Compartment 4a was replanted in 1982 with some older oaks left in place as shelter belts. Sample **119** should be from compartment 25b, although there remains a possibility it has been mixed up with other material in the estate wood yard. The construction of a chronology up to AD 2000 provides a significant extension to modern data sets. The majority of modern oak chronologies in the British Isles were made in the later AD 1970s and early AD 1980s. The construction of chronologies incorporating newer data thus provides good opportunities for improved calculation of oak climatic responses because of the longer stretch of parallel tree-ring data and climate information. Most modern tree-ring data sets are usually created by sampling standing trees selected for age, straightness, or their dominance of the local woodland stand. Modern chronology sample selection is thus quite unlike the selection criteria applicable for historical or sub-fossil data, where cross-matching is the only criterion for inclusion in a data set. HOVWOOD, based on trees felled for construction, trees from woodland thinning, and wind throws, and treated as an assemblage of archaeological material, is thus a better modern analogy for historic tree-ring chronologies. Creation of a network of such material from across the country potentially offers a better baseline from which to extrapolate climate reconstructions into the historic and sub-fossil chronologies.

The study of modern trees is also useful for interpreting historic assemblages. In this case the correlations between the material gives an indication of the sort of correlation to expect from an assemblage of relatively undisturbed 120-190 year old oaks growing in a 1½km area. The values obtained (Table 5) are notably higher than those usually obtained from most historic assemblages, and are clearly higher than those obtained from the hall roof timbers (Table 3). The other interesting aspect relates to the amounts and variability of the sapwood between and within these trees. The three sections of **101** were specifically collected since they provided an opportunity to examine sapwood variability within the tree. The different amounts of sapwood in radii **101a** and **101b** reflect the common observation that there is more sapwood at the top than the bottom of an oak trunk. The branch sample **101c** unfortunately disintegrated as it dried out but it originally contained more sapwood than the trunk. The very small amounts of sapwood observed on the apparently dead tree **119** from compartment 25b again reflects a not uncommon observation that trees in distress have less sapwood. With historic material with incomplete sapwood we apply an estimated minimum and maximum number of sapwood rings that statistically covers 95% of the identified sapwood variation. In line with this prediction one of the 19 modern trees has more sapwood than the estimated maximum we currently apply to historic material.

Conclusion

The dendrochronological analysis of timbers from eleven of the Hovingham Hall roofs has identified that seven areas include datable timbers: three areas include timbers felled in the AD 1750s, the Riding School roof contains timbers felled in the winter of AD 1764/5, and at least three areas contain timbers probably felled in the later AD 1760s or early AD 1770s. Three areas, over the Dining Room and the Ionic Room, appear to include two different phases of timbers. Two areas produced no timbers with surviving bark-edge but allowing for missing sapwood they clearly date from the time of Thomas Worsley. One area was not sampled, and three areas yielded samples that could not be dated.

The use by the estate of their own woodland for repairs to the hall roofs has provided an opportunity to create a new modern data set from the estate. This sequence unfortunately does not go far enough back to overlap with the original hall roof material, perhaps indicating that Thomas Worlsey's building programme led to some denudation of the estate woodlands. The methods of selection of the samples and construction of the chronology make it somewhat different from the normal modern tree-ring chronology used by dendroclimatologists and this may have implications for future climate reconstruction work.

The relative youth of the samples from the roofs, where most are from trees less then 100 years old when felled, contrasts strongly with the current age structure of the estates woodlands, where much of the standing oak is over 150 years of age. This difference may indicate that the construction of the hall had over-stretched the resources of the estate, and may be one of the reasons why the Hovingham roof trusses include quite so many short and relatively slight structural elements.

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