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BOSCOBEL HOUSE, NEAR BREWOOD, SHROPSHIRE DENDROCHRONOLOGICAL ANALYSIS OF OAK TIMBERS

SCIENTIFIC DATING REPORT

Ian Tyers

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SUMMARY

A tree-ring dating programme was commissioned on timbers from Boscobel House. The results identified that timbers in two areas of the complex were datable by tree-ring dating techniques, with these areas using timbers felled during the late-sixteenth through to the mid-eighteenth centuries. A dating programme was commissioned on this Scheduled Monument to inform a new interpretation and presentation of the site. This report archives the dendrochronological results.

CONTRIBUTORS

Ian Tyers

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The sampling and analysis of timbers at Boscobel House was funded by English Heritage (EH). Practical help and valuable discussions were provided by Nicola Stacey, Senior Properties Historian (EH), and Richard Lea, Properties Presentation Dept (EH). Ella Harrison, Custodian (EH) kindly facilitated access.

ARCHIVE LOCATION

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INTRODUCTION

This document is a technical archive report on the tree-ring analysis of oak timbers from Boscobel House, Shropshire. 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.

Boscobel House stands in countryside *c* 12km north-west of Wolverhampton, and *c* 15km east of Telford (NGR SJ 8376 0824) within the county of Shropshire (Fig 1). The Shropshire/Staffordshire border runs along the eastern boundary of the site. Boscobel House is a timber-framed building made famous as the location of an oak tree that sheltered the future Charles II from Parliamentarian searchers after the Civil War battle of Worcester in 1651; he subsequently spent a night in Boscobel House, supposedly pacing in the attic when not hiding in a 'priest hole'. The building was a hunting lodge reputably built *c* 1632, and was subsequently a working farm. A descendant of the original 'Royal Oak' still stands, looking rather forlorn, in an adjacent field. It became a visitor attraction fairly soon after the Restoration. The house had significant alternations and additions to make it more 'authentic' by the Evans family, which owned it from 1812. It is now in the care of English Heritage, and a Scheduled Monument.

METHODOLOGY

Tree-ring dating employs the patterns of tree-growth to determine the calendar dates for the period during which the sampled trees were alive. The amount of wood laid down in any one year by most trees is determined by the climate and other environmental factors. Trees over relatively wide geographical areas can exhibit similar patterns of growth, and this enables dendrochronologists to assign dates to some samples by matching the growth pattern with other ring-sequences that have already been linked together to form reference chronologies.

The building was visited in February 2009, and again in August 2009. An assessment of the dendrochronological potential of timbers in several areas of the structure had been requested by Nicola Stacey. This assessment aimed to identify whether oak timbers with sufficient numbers of rings for analysis existed in key areas of the building. This assessment concluded that limited numbers of timbers in both the North Range and in the Hunting Lodge contained suitable material, whilst both the two priest holes were considered unsuitable for sampling and analysis. English Heritage requested sampling to proceed and Scheduled Monument Class 6 consent was granted for up to 23 samples.

The sampling took place during October 2009. The selected 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 ring sequences in the cores were revealed by sanding.

This preparation revealed the width of each successive annual tree ring. Each prepared sample could then be accurately assessed for the number of rings it contained, and at this stage it was also possible to determine whether the sequence of ring widths within it could be reliably resolved. Dendrochronological samples need to be free of aberrant anatomical features, such as those caused by physical damage to the tree, which may prevent or significantly reduce the chances of successful dating.

Standard dendrochronological analysis methods (see eg English Heritage 1998) were applied to each suitable sample. The complete sequence of the annual growth rings in the suitable samples was measured to an accuracy of 0.01mm using a micro-computer based travelling stage. The sequences of ring widths were then plotted onto semi-log graph paper to enable visual comparisons to be made between sequences. In addition, cross-correlation algorithms (eg Baillie and Pilcher 1973) were employed to search for positions where the ring sequences were highly correlated. Highly correlated positions were checked using the graphs and, if any of these were satisfactory, new composite sequences were constructed from the synchronised sequences. Any *t*-values reported below were 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 need to have been obtained from a range of independent sequences, and that these positions were supported by satisfactory visual matching.

Not every tree can be correlated by the statistical tools or the visual examination of the graphs. There are thought to be a number of reasons for this: genetic variations; site-specific issues (for example a tree growing in a stream bed will be less responsive to rainfall); or some traumatic experience in the tree's lifetime, such as injury by pollarding, defoliation events by caterpillars, or similar. These could each produce a sequence dominated by a non-climatic signal. Experimental work with modern trees shows that 5–20% of all oak trees cannot be reliably cross-matched, even when enough rings are obtained.

Converting the date obtained for a tree-ring sequence into a useful date requires a record of the nature of the outermost rings of the sample. If bark or bark-edge survives, a felling date precise to the year or season can be obtained. If no sapwood survives, the date obtained from the sample gives a *terminus post quem* for its use. If some sapwood survives, an estimate for the number of missing rings can be applied to the end-date of the heartwood. This estimate is quite broad and varies by region. This report uses a minimum of 10 rings and a maximum of 46 rings as a sapwood estimate (see eg English Heritage 1998, 10–11).

Where bark-edge or bark survives, the season of felling can be determined by examining the completeness or otherwise of the terminal ring lying directly under the bark. Complete material can be divided into three major categories:

- 'early spring', where only the initial cells of the new growth have begun – this is equivalent to a period in March/April, when the oaks begin leaf-bud formation;
- 'later spring/summer' where the early wood is evidently complete but the late wood is evidently incomplete, which is equivalent to May-through-September of a normal year, and
- 'winter' where the latewood is evidently complete and this is roughly equivalent to September-to-March (of the following year) since the tree is dormant throughout this period and there is no additional growth put on the trunk.

These categories can overlap as, for example, not all oaks simultaneously initiate leaf-bud formation. It should also be noted that slow growing or compressed material cannot always be safely categorised.

Timber technology studies demonstrate that many of the tool marks recorded on ancient timbers can only have been done on green timber. There is little evidence for long-term storage of timber or of widespread use of seasoned, rather than green, timber in the medieval period (see eg English Heritage 1998, 11–12).

Reused timbers can only provide tree-ring dates for the original usage date, not their reuse. Identifying reused timbers requires careful timber recording which notes the presence of features which are not functional in the structure. It is always possible that some timbers exhibit no evidence of earlier usage, and are thus 'hidden reused' timbers. The dendrochronological impact of this problem is particularly acute where only single timbers have been dated from a structure.

The analysis may highlight potential same-tree identifications if two or more tree-ring sequences are obtained that are exceptionally highly correlated. Such pairs, or sometimes more, are then used as a same-tree group and each can be given the interpreted date of the most complete of the samples. They are most useful where several timbers date but only one has any sapwood or where same-tree identifications yield linkages between different areas.

RESULTS

In October 2009 16 timbers from two separate areas of the building were cored; these cores were labelled 1–16 inclusive. Ten timbers were sampled in the North Range, and six from the Hunting Lodge. There is some uncertainty over the origins of this material, since it included several timbers that may have been part of the later modifications to the property (Figs 2–5). No other suitable and accessible timbers were located in these areas. Each sample was assessed for the wood type, the number of rings it contained, and

whether the sequence of ring widths could be reliably resolved. This assessment confirmed that all the sampled timbers were oak (*Quercus* spp.) and that 12 were suitable for dendrochronological analysis. The four exceptions were sample 7, a full-height post from the North Range, samples 13 and 14, which are a queen post and a purlin from the Hunting Lodge attic, and sample 16, a cellar beam from the Hunting Lodge. Sample 14 contained too few rings for analysis, while samples 7, 13, and 16 contained bands of unresolvable narrow rings. There was good survival of sapwood in most of the targeted areas, although the Hunting Lodge attic had been defrassed, resulting in significant loss of sapwood in this area. Bark-edge survival was good in the North Range. The details of these samples are provided in Table 1.

The samples were prepared for analysis, measured, and the resultant ring series were compared with each other. Four samples from the north-eastern end of the North Range were cross-matched (Table 2) and, although these have relatively poor intra-correlation, these four individual sequences provide plenty of support for their dating locations. In addition, five samples, three from the south-western end of the North Range and two from the Hunting Lodge, were also found to cross-match each other consistently (Table 3). Each cross-matched group was combined into a single composite data set, named NR1 and NR2+HL. These two composites, their nine component individual sequences, and the remaining three unmatched sequences were then each compared with medieval and later tree-ring data from throughout England and Wales. Both the composite sequences, and their component samples, and two of the otherwise unmatched individuals, samples 6 and 11, were found to cross-match consistently against data from sites principally in the West Midlands region (Tables 4–7). This cross-matching provided consistent calendar dates for each sequence. A summary of the results for the component samples from the site are provided in Table 1 and Figure 6.

One individual series failed to provide any consistent dating evidence.

The measurement data for all the measured samples are listed in Appendix 1.

DISCUSSION

The dated samples are derived from different parts of the building, and produce a range of results. Their interpretation is not straightforward, due to the likely reuse and/or recycling of earlier timbers in the nineteenth- and twentieth-century remodelling of the house. These results are discussed by area below. All the datable material matches consistently with other local reference data, and it is likely that these timbers were derived from the general vicinity of Boscobel.

North Range

The North Range is a two-storey four-bay building. The external walls have been almost entirely rebuilt. This probably occurred during the twentieth century, since it is

constructed of machine-sawn timber. Internally there are three trusses, labelled here T1–T3, and on different alignments there is another ground-floor timber partition, and a very large fireplace. The ceiling beams are a rather confusing mixture of large heavily chamfered beams, and a number of much slighter roughly squared timbers. The material suitable for sampling was principally from around T1 at the north-east end, samples 1–4 and 8, and around T3 at the south-west end, samples 5–7. In addition, two of the three large heavily chamfered floor beams were also suitable, samples 9 and 10. The third of these beams, to the north-west of sample 9, was clearly derived from the same tree as sample 9 (see below), but this timber had no surviving sapwood. Truss T2 was inaccessible behind presentation panels and later plasterwork.

North-East Truss

The five samples from the north-east end around truss T1 comprise a stud, a storey post, a tiebeam, a purlin, and a lower girt (Figs 3 and 4). Four of these samples were found to cross-match to form the composite sequence NR1, which was found to date and thus provides tree-ring dates for these structural elements. The 88-year composite sequence was found to strongly match at AD 1609 to AD 1696 inclusive. This material comprised fast-growing and short-lived oaks.

The tree-ring analysis dates the rings present in the cores. The correct interpretation of those dates relies upon the characteristics of the final rings in them. Bark-edge survived on three of these timbers, and a small amount of sapwood on the fourth. Making allowances for minimum and maximum likely amounts of missing sapwood provides individual felling dates, or felling date ranges for each of the datable timbers. Figure 6 and Table 1 includes the felling date or interpreted felling date ranges for each of the datable samples.

The interpretation of this material is straightforward. The three samples complete to bark edge each retain a complete ring for AD 1696. These three timbers were therefore felled in the winter of AD 1696 or early spring of AD 1697. The calculated felling date range for the remaining sample indicates this timber was either precisely or broadly contemporaneous. The three timbers with precise felling dates comprise a stud, a tie beam, and a purlin. There is no suggestion any of this material is either reused or secondary.

South-West Truss and associated Ceiling Beams

Two samples came from truss T3, comprising two full-height posts (Fig 4). This truss contained timbers with noticeably distorted growth patterns, quite unlike those in truss T1. Sampling was not considered feasible for most of the timbers in this truss. One of these two samples contained very distorted sequences that could not be resolved. The remaining sample, 5, although having some narrow growth bands, was successfully analysed, and it is one of the components of the NR2+HL group (Table 3, Fig 6).

Between truss T3 and the south-western wall is a single large ceiling beam, with large chamfers and simple curved chamfer stops. This beam crosses through an otherwise almost empty bay of the building. It is jointed to a couple of ceiling joists but has empty mortises for a complete floor, and it is rebated on the upper surface to take floorboards. Sample 10 was obtained from this beam (Figs 3 and 4). Further north-east, between T2 and an intermediate partition, in the 'salting room', are two more large ceiling beams with large chamfers and simple curved chamfer stops. Both these timbers have later parts added at one end to give the impression that they have chamfer stops at both ends. Visual inspection suggested that there were derived from two parts of the same quartered tree. One of these was sampled, as sample 9.

Both these samples, 9 and 10, although having some narrow growth bands were successfully analysed, and both are components of the NR2+HL group (Table 3, Fig 6). The high levels of cross-matching between samples 5, 9, and 10 (Table 3) make it likely they were derived from a single tree, thus linking truss T3 and the three ceiling beams. The 229-year composite sequence that they are part of was found to strongly match at AD 1367 to AD 1595 inclusive. This material comprised slow-growing and long-lived oaks, quite twisted in character, with narrow bands of growth similar to those seen in unmeasured samples 7, 13, and 16. This characteristic suggests the possible widespread use of former pollards in this phase of construction, and supports observations made during both the assessment and the coring that the buildings at Boscobel contained a lot of this type of material.

The interpretation of this material is straightforward. Sample 5 is complete to bark edge and retains a complete ring for AD 1595. This timber was therefore felled in the winter of AD 1595 or early spring of AD 1596. The calculated felling date ranges for the samples from the ceiling beams indicates this material was either precisely or broadly contemporaneous. Whilst there is no suggestion the timbers that provide samples 5 or 10 are either reused or secondary, it seems quite likely that the two beams associated with truss T2, one of which provided sample 9, are reused in their present position.

Another Ceiling Beam

The final sample from the north range was derived from one of the other ceiling beams. Most of these beams throughout the range were derived from fast-grown young trees. A single short small beam adjacent to truss T3 was of slightly different characteristics and appeared to be suitable for sampling (Fig 4). This sample, 6, although fairly short-lived was successfully dated to AD 1682 to AD 1756 inclusive, and is hence of a different date than any of the other samples obtained from the site (Table 6, Fig 6).

The interpretation of this sample is straightforward. Sample 6 is complete to bark edge and retains a complete ring for AD 1756. This timber was therefore felled in the winter of AD 1756 or early spring of AD 1757. It is unknown whether this beam is primary, secondary, or reused in its present position.

Hunting Lodge

The Hunting Lodge is also a two-storey building, but with very tall storeys compared with the North Range; it also has a walk-in attic space converted into accommodation. Very few of the structural timbers are accessible in the ground and first floors due to the decorative panelling and plasterwork. The building has a three-bay roof with dormers, at right angles to the North Range. This roof had several accessible timbers, although this area used relatively slight timbers, which unfortunately had been defrassed at some stage. This had removed most of the sapwood from the visible timbers. There are two 'priest holes' in the Hunting Lodge, one accessible from the attic floor, and one through a hole on the second floor. Careful assessment of both of these concluded that neither contained timbers suitable for analysis. The material suitable for sampling was principally from the attic; elsewhere, the only suitable timbers that could be located were a large vertical post in one of the first-floor bedrooms, and one of the floor-supporting beams in the cellar. No other structural elements could be identified within the Hunting Lodge that were suitable and accessible for sampling.

Attic

The four samples from the attic (Trusses T4–T7, samples 11–14) comprise two queen posts and two purlins (Fig 5). Only two of these samples were suitable for analysis. One of these, sample 12, was found to form part of the NR2+HL group (Table 3). As is the case with the rest of this material, this timber contained some narrow growth bands.

Sample 12 is a queen post, which has a defrassed surface that appears to be the heartwood/sapwood boundary along its back edge. Visible below the floorboard is a further outer 20–25mm of growth that appears to be sapwood, which presumably was not accessible when defrassing took place. If this interpretation is correct, the calculated felling date range for this sample, AD 1562–98?, indicates this material was either precisely or broadly contemporaneous with samples 5, 9, and 10 from the North Range T3 and ceilings, which includes one timber felled AD 1595/6.

The second suitable sample from the attic, sample 11 from a purlin, was also successfully analysed and was determined to be of a different date to any of the other samples obtained from the site (Table 7, Fig 6).This timber certainly includes sapwood and this provides a calculated felling date range of AD 1607–43.

The interpretation of the date of the attic area must proceed with caution, since it is based on only two timbers. The result from the purlin may indicate that the queen post discussed above does not end at the heartwood/sapwood boundary, or may indicate that the purlins of this roof were modified a few decades after the original construction, perhaps relating to the insertion of the dormers, which, because of some differences in construction, may be secondary. The building is traditionally stated to have been built in the AD 1630s, but the tree-ring evidence hints it may actually have been remodelled from

a late sixteenth-century structure in this period, or that it was constructed with reused timbers.

Other structural elements

A single datable sample was obtained from across the entire structure below the roof. This was derived from a vertical post through a first-floor room (sample 15, Fig 5). This post was probably originally the north-east side wall of the building, before the addition of the chapel or oratory. This sample, although it also contained narrow growth bands, was successfully analysed, and is one of the components of the NR2+HL group (Table 3, Fig 6). This timber contained no sapwood, but was targeted at the request of Richard Lea. The calculated *terminus post quem* date for this timber indicates a date no earlier than AD 1522. It matches strongly to the other elements that are dated to AD 1595/6 (Table 3). Again this piece of tree-ring evidence hints the Hunting Lodge may actually have been remodelled from a late sixteenth-century structure, or was built using late sixteenth-century timbers.

The only other sampled timber from the structural elements of the Hunting Lodge was obtained from the cellar, and this proved to be unsuitable for analysis. This timber (sample 16, Fig 5) is another of the Boscobel samples dominated by narrow bands of unmeasurable rings, similar to the material dated elsewhere in the structure to AD 1595/6.

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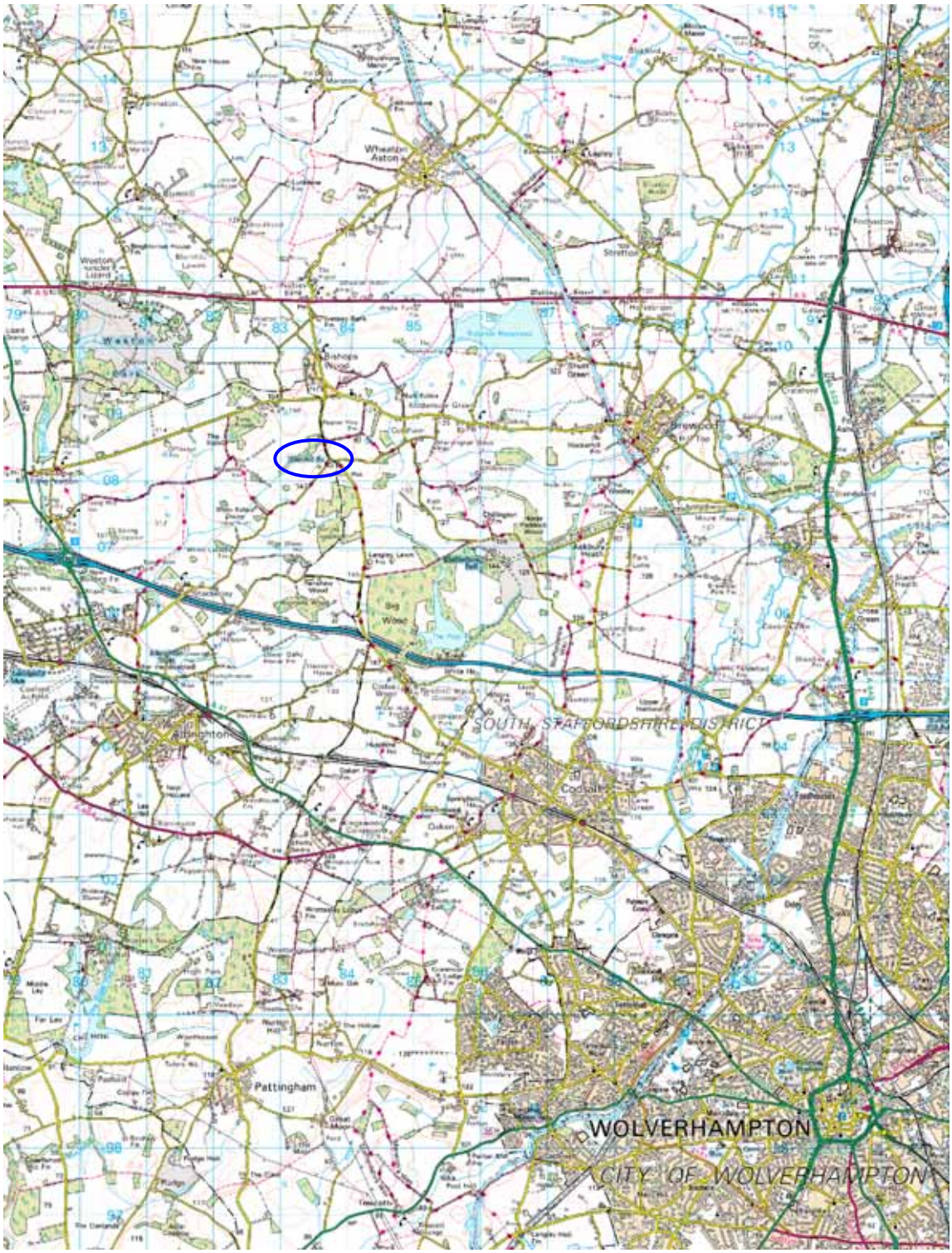

Figure 1. Location of Boscobel House. © Crown Copyright. All rights reserved. English Heritage 100019088. 2010

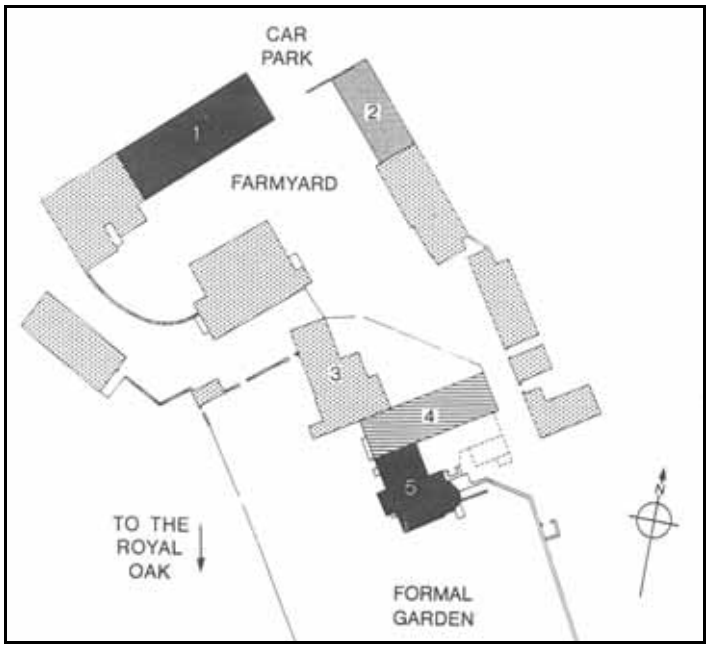

Figure 2. Sketch plan of the site showing the location of the 2 sampled buildings. The North Range, or Dairy, labelled 4, and the Hunting Lodge, labelled 5. Based on a figure in the EH Guidebook, supplied by EH

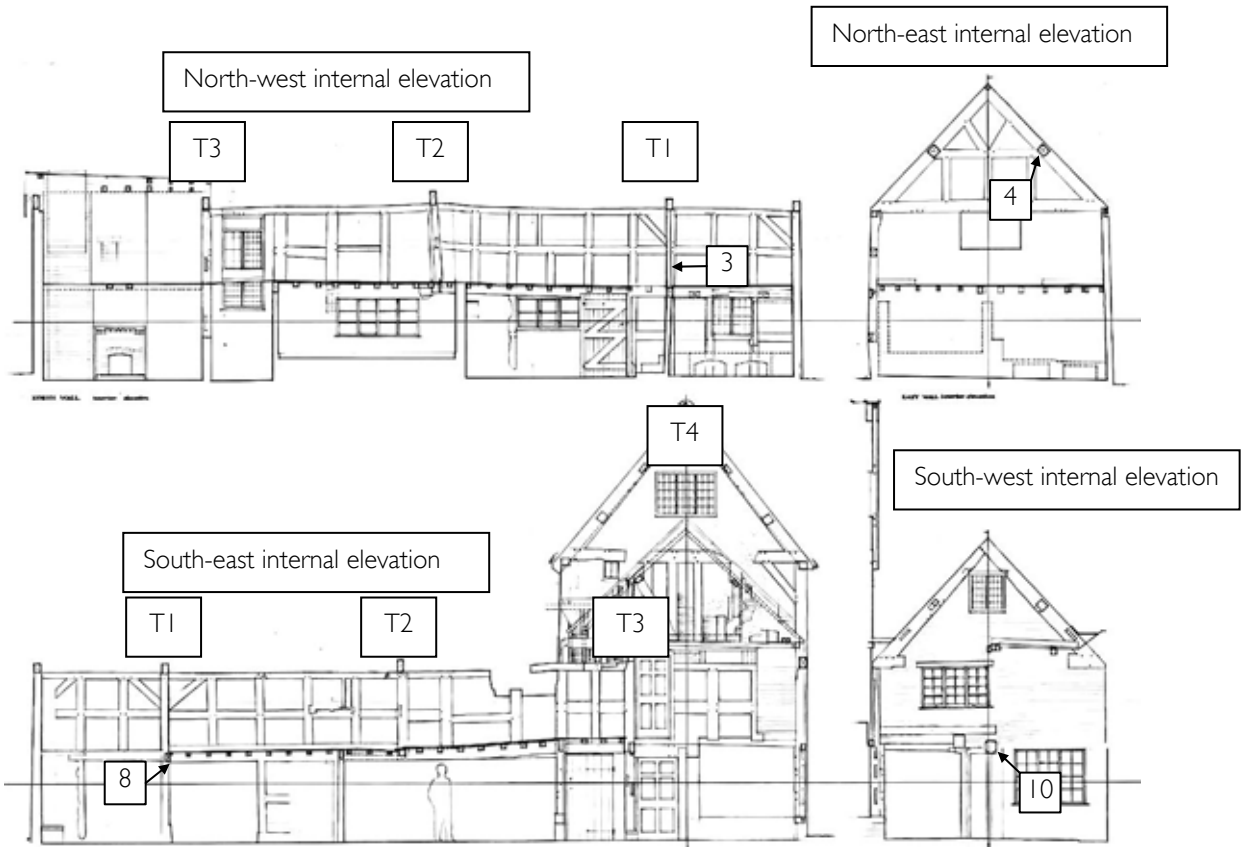

Figure 3. Four internal elevations of the North Range of Boscobel House showing the approximate location of some of the sampled timbers. Based on a figure supplied by EH

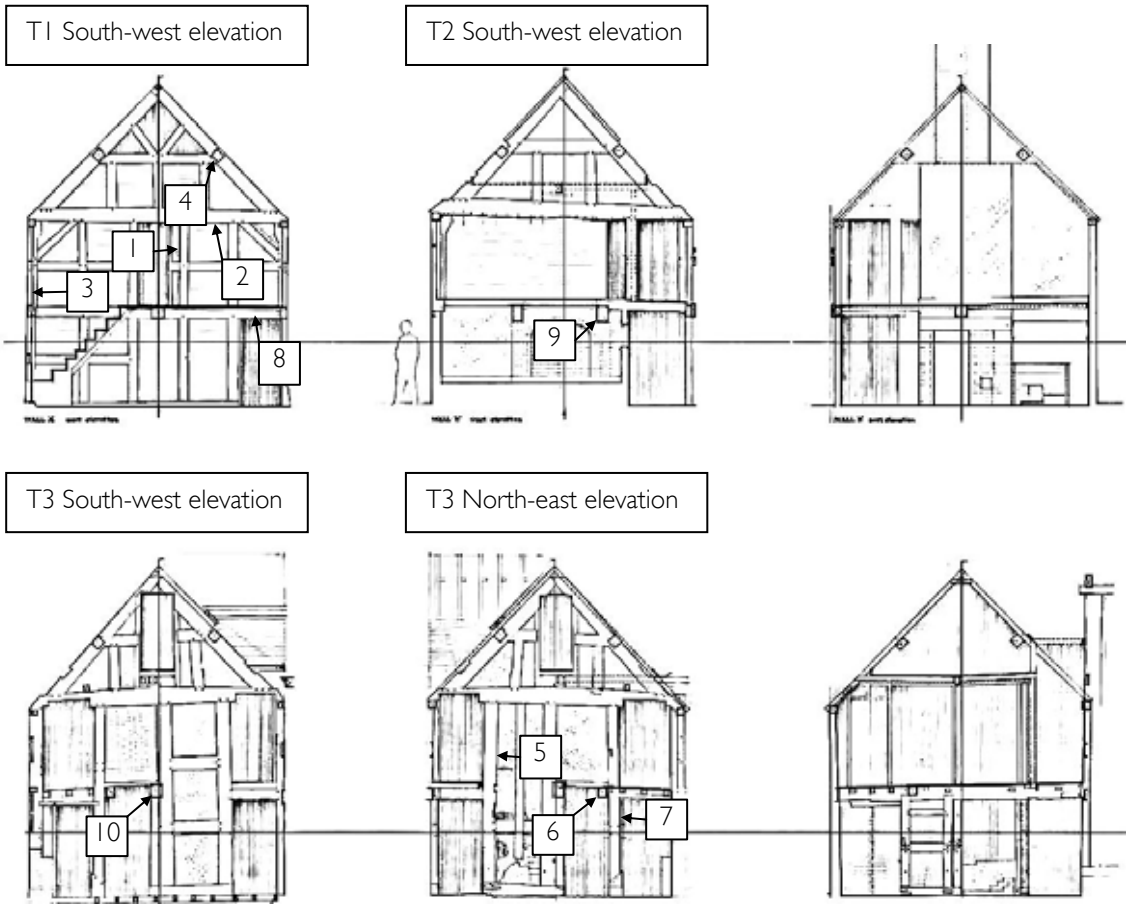

Figure 4. Trusses elevations from North Range of Boscobel House showing the approximate location of some of the sampled timbers. Based on a figure supplied by EH

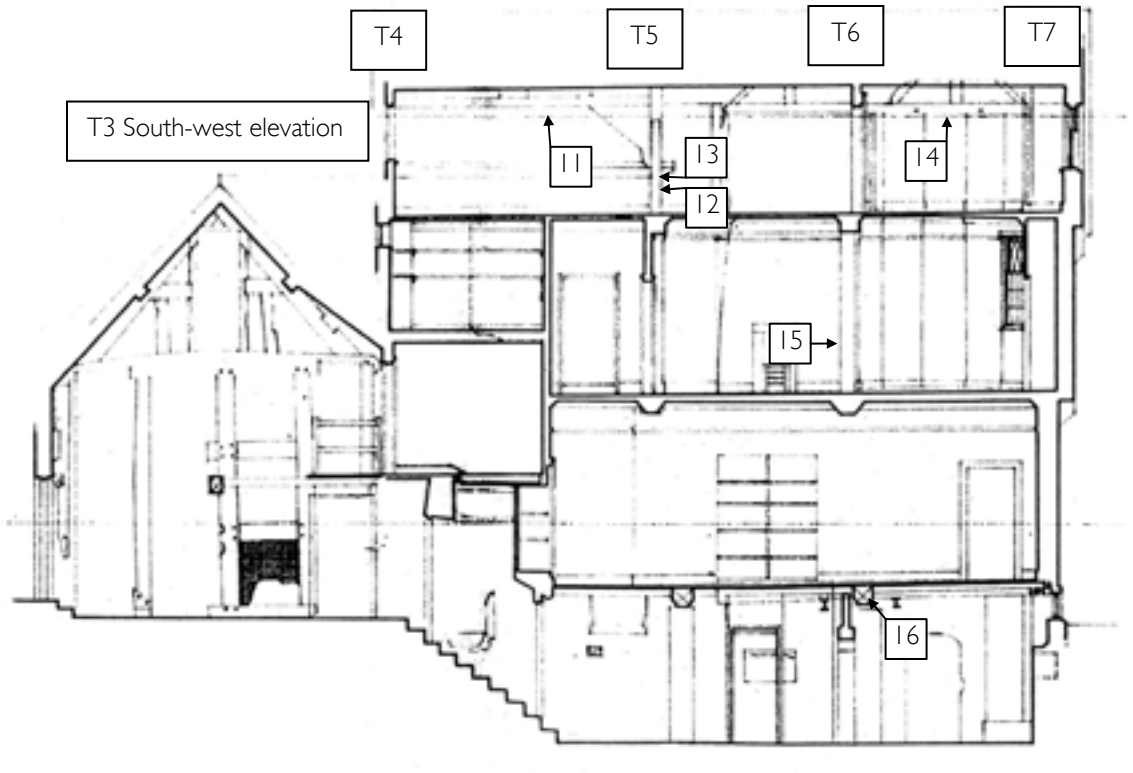

Figure 5. Section through the Hunting Lodge at Boscobel House, with North Range T3 to the left, showing the approximate location of the sampled timbers. Based on a figure supplied by EH

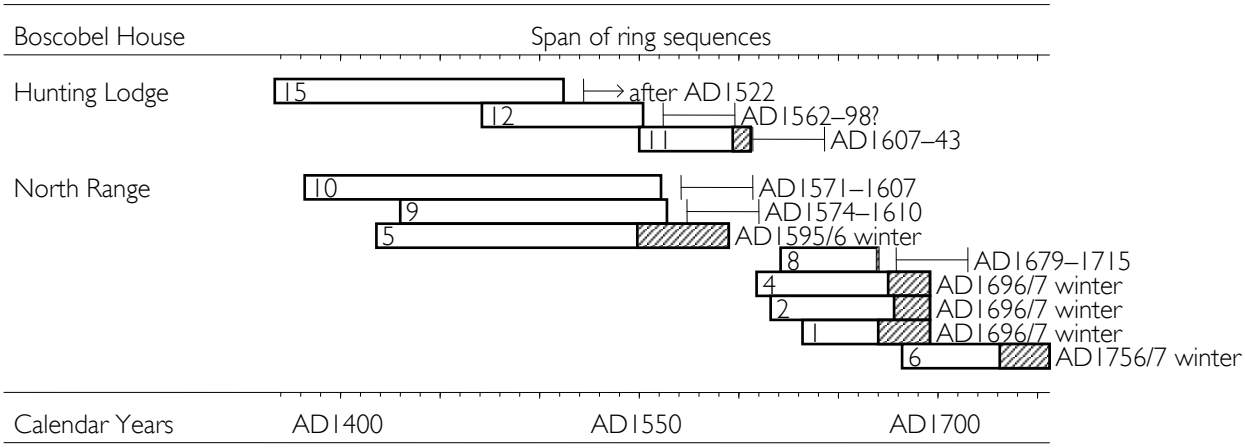

Figure 6. Bar diagram showing the absolute dating positions of the 11 dated tree-ring sequences for samples from Boscobel House. The interpreted felling dates are also shown for each sample.

KEY White bars are oak heartwood, hatched bars are sapwood.

Table 1. Details of the 16 samples from timbers from Boscobel House.

Sample	Location	Rings	Sap	Date of measured sequence	Interpreted result
1	NR T1, wall stud	65	26+Bw	AD 1632–1696	AD 1696/7
2	NR T1, tie beam	81	18+Bw	AD 1616–1696	AD 1696/7
3	NR T1, NW post	77	23+Bw	not dated	-
4	NR NE end wall-T1, SE purlin	88	21+Bw	AD 1609–1696	AD 1696/7
5	NR T3 SE full height post	178	46+Bw	AD 1418–1595	AD 1595/6
6	NR T2-T3, NE/SW ceiling beam	75	25+Bw	AD 1682–1756	AD 1756/7
7	NR T3 NW full height post	-	-	not measured	-
8	NR T1 NW/SE ceiling beam	50	1	AD 1621–1670	AD 1679–1715
9	NR T2-T3, NE/SW ceiling beam	135	H/S	AD 1430–1564	AD 1574–1610
10	NR T3-SW end wall, ceiling beam	180	H/S	AD 1382–1561	AD 1571–1607
11	HL T4-T5, NE upper purlin	57	9	AD 1550–1606	AD 1607–43
12	HL T5, NE queen post	82	?H/S	AD 1471–1552	AD 1562–98?
13	HL T5, SW queen post	-	-	not measured	-
14	HL T6-T7, SW upper purlin	-	-	not measured	-
15	HL 1st floor bedroom post	146	-	AD 1367–1512	after AD 1522
16	HL Cellar, NE/SW ceiling beam	-	-	not measured	-

KEY For locations see Figures 2–5. NR; North Range, or North-East Range or Dairy, trusses T1–T3 from north-east. HL; Hunting Lodge, T4–T7 from north-west. N north, S south, E east, W west, H/S is heartwood/sapwood edge, ?H/S is possible heartwood/sapwood edge, Bw bark after complete ring.

Table 2. The t-values (Baillie and Pilcher 1973) between 4 sampled timbers from Boscobel House. - t-value less than 3.0. These were combined to form the composite sequence NR1 used in Table 4.

	2	4	8
1	-	5.14	3.25
2		-	3.56
4			-

Table 3. The t-values (Baillie and Pilcher 1973) between 5 sampled timbers from Boscobel House. These were combined to form the composite sequence NR2+HL used in Table 5.

	9	10	12	15
5	11.97	13.40	5.45	4.97
9		13.24	6.66	5.99
10			6.00	9.01
12				5.49

Table 4. Showing example t-values (Baillie and Pilcher 1973) between composite sequence NR1 constructed from samples from the North Range at Boscobel House and oak reference data.

Reference chronology	Boscobel NR1 AD 1609–96
Cheshire, Combermere Abbey (Howard *et al* 2003)	8.97
Cheshire, Storeton Hall (Tyers 2010)	5.94
Derbyshire, Bretby Hall Bretby (Howard *et al* 1999b)	7.13
Derbyshire, Riding School Bolsover Castle (Arnold *et al* 2005)	6.88
Derbyshire, The Keep/Little Castle Bolsover Castle (Arnold *et al* 2003b)	7.64
Staffordshire, Black Ladies near Brewood (Tyers 1999)	9.35
Worcestershire, Wribbenhall (Tyers and Price 2007)	5.67
Yorkshire, Cookridge Moseley Wood Farm barn (Tyers 2006)	6.25

Table 5. Showing example t-values (Baillie and Pilcher 1973) between composite sequence NR2+HL constructed from samples from both the North Range and the Hunting Lodge at Boscobel House and oak reference data.

Reference chronology	Boscobel NR2+HL AD 1367–1595
Herefordshire, Eardisley The Tram Inn (Tyers 2005)	5.80
Herefordshire, Pembridge Westleigh (Tyers 2004a)	6.20
Herefordshire, Sunnybank Luston (Tyers 2004c)	5.68
Nottinghamshire, etc, regional sequence (Laxton and Litton 1988)	6.32
Shropshire, Brookgate Farm Plealy (Miles *et al* 1993)	6.30
Shropshire, Ightfield Hall Barn (Groves 1997)	6.14
Staffordshire, Black Ladies near Brewood (Tyers 1999)	6.20
Staffordshire, St Margarets Church Wetton (Arnold *et al* 2003a)	6.85

Table 6. Showing example t-values (Baillie and Pilcher 1973) between sample 6 from the North Range at Boscobel House and oak reference data.

Reference chronology	Boscobel #6 AD 1682–1756
Buckinghamshire, Claydon House Middle Claydon (Tyers 1995a)	4.01
Cheshire, Risley Old Abbey Farm (Nayling 1998)	5.42
Devon, Exeter Cathedral (Mills 1988)	4.74
Leicestershire, Kibworth Harcourt Post Mill (Arnold *et al* 2004)	4.37
Nottinghamshire, etc, regional sequence (Laxton and Litton 1988)	6.15
Shropshire, Eaton-under-Heywood (Worthington and Miles 2004)	4.32
Warwickshire, Stoneleigh Abbey (Howard *et al* 2000)	4.78
Yorkshire, Nostell Priory nr Wakefield (Tyers 1998)	4.16

Table 7. Showing example t-values (Baillie and Pilcher 1973) between sample 11 from the Hunting Lodge at Boscobel House and oak reference data.

Reference chronology	Boscobel #11 AD 1550–1606
Cambridgeshire, Sutton-in-the-Isle bellframe (Tyers 1995b)	5.37
Cheshire, Storeton Hall (Tyers 2010)	4.56
Derbyshire, Bretby Hall Bretby (Howard *et al* 1999b)	6.10
Derbyshire, Riding School Bolsover Castle (Arnold *et al* 2005)	4.65
Lancashire, Turton Barn (Tyers 2008)	4.18
Leicestershire, Owston St Andrews church (Howard *et al* 1999a)	5.18
Norfolk, New Buckenham Pinchpot (Tyers 2004b)	7.29
Yorkshire, Cookridge Moseley Wood Farm barn (Tyers 2006)	4.84

APPENDIX 1

bos1

305	316	317	247	206	285	369	264	260	460
140	284	269	294	298	373	293	210	152	195
78	38	89	126	104	75	70	44	58	46
54	62	79	70	55	57	83	89	123	124
105	77	65	75	185	178	183	135	112	118
116	161	84	86	154	159	128	118	68	83
74	107	136	154	142					

bos2

247	362	345	276	304	259	303	257	200	158
120	247	223	372	260	250	166	138	123	126
98	164	240	139	202	193	107	75	83	131
218	125	67	82	79	84	84	163	213	253
218	226	181	101	156	148	138	91	70	112
106	119	119	134	189	206	183	103	73	57
137	136	96	91	83	89	52	37	81	78
121	150	117	137	81	81	63	62	116	127
109									

bos3

717	643	583	538	404	443	511	170	399	355
417	380	311	354	244	244	157	195	247	250
360	272	201	334	107	222	161	150	215	80
56	38	22	48	43	37	43	38	40	83
122	73	96	105	120	124	180	128	178	241
182	233	207	125	154	76	122	104	123	109
69	65	111	68	91	96	201	202	132	90
45	34	44	68	82	105	121			

bos4

796	571	385	374	288	256	256	264	318	299
237	174	232	281	198	136	126	127	185	180
192	125	133	141	147	137	108	98	145	196
156	210	228	153	167	207	216	245	199	312
257	141	186	208	162	288	315	324	259	231
196	210	159	182	140	126	138	181	162	207
226	275	198	170	153	145	136	159	158	212
241	197	166	176	170	116	112	144	152	143
116	86	97	79	107	131	135	131		

bos5

98	113	123	99	80	101	125	73	82	130
162	202	235	233	206	149	201	151	170	180
265	273	246	203	182	124	156	158	258	240
258	261	337	472	325	246	305	188	217	161
119	104	115	131	158	164	137	121	134	141
187	133	130	113	66	75	93	142	153	96
113	141	89	87	48	117	127	129	135	181
119	61	54	70	86	125	111	128	137	96
103	171	128	121	148	139	162	172	120	109
128	195	173	146	194	158	140	97	59	103
82	91	71	103	127	95	121	117	98	96
82	88	95	96	73	47	80	71	61	71
75	94	121	105	69	78	78	65	83	66
89	63	81	94	86	72	82	70	74	51
62	69	58	57	72	65	60	69	73	75
78	63	75	97	89	61	42	71	56	58
56	46	44	73	43	69	80	86	101	94
96	90	95	97	111	89	102	112		

bos6

311	283	126	212	281	311	317	349	284	366
211	197	207	186	250	175	137	126	92	108
110	139	149	105	92	117	170	191	153	212
140	181	169	158	201	202	143	125	140	185
185	169	148	143	106	127	127	138	160	166
166	140	118	99	88	89	135	132	109	74
58	67	77	94	88	109	91	106	155	166
138	109	187	240	205					

bos8

308	342	338	198	207	202	220	288	404	254
214	201	131	161	213	138	219	265	238	250
277	148	102	132	157	202	223	200	203	164
111	86	82	123	160	149	135	98	112	111
77	133	128	129	134	105	126	92	117	122

bos9

412	357	351	259	338	251	211	326	259	238
285	221	244	190	184	173	229	221	303	264
259	283	281	254	305	212	241	232	189	152
178	184	196	208	164	106	124	162	173	87
70	56	47	62	61	85	97	62	76	110
71	83	36	123	141	169	117	202	123	79
46	91	107	103	103	92	83	55	73	85
87	94	83	93	111	126	68	64	72	133
127	90	115	109	89	47	49	55	53	58
41	51	79	67	82	88	95	104	131	102
91	109	90	58	94	113	130	146	150	131
182	172	76	100	111	114	123	108	118	114
128	127	128	131	118	110	107	79	98	106
108	123	152	144	135					

bos10

171	184	172	222	285	317	323	270	197	177
161	196	211	234	220	160	167	145	175	209
241	302	264	195	201	147	200	215	174	184
173	194	120	159	94	163	176	175	166	169
149	183	181	89	82	152	228	288	369	284
301	290	335	256	231	246	225	166	227	208
213	144	145	139	202	208	232	222	239	244
196	200	207	168	203	214	158	162	149	178
177	200	154	112	125	160	198	147	135	166
106	116	116	143	174	102	113	126	109	99
56	129	153	144	136	159	121	50	58	83
115	129	162	149	173	117	127	161	150	112
149	178	215	195	114	124	173	189	177	175
198	167	156	111	93	125	138	95	95	111
138	108	164	135	138	133	165	162	143	174
159	124	143	178	139	163	181	175	219	166
107	106	134	176	138	144	149	145	136	171
156	165	138	146	135	101	100	131	131	156

bos11

341	347	320	251	237	239	140	120	194	253
284	296	237	237	90	135	160	168	202	266
215	180	100	132	167	130	96	137	133	186
312	248	174	261	464	502	570	575	429	468
324	256	267	386	394	372	321	310	339	291
263	347	272	391	413	281	284			

bos12

87	66	76	72	119	137	104	85	81	98
79	66	116	108	109	110	191	83	79	79
100	135	107	167	197	156	116	128	158	182
154	158	140	197	176	147	96	150	196	152
135	157	107	119	76	82	92	86	110	118
109	153	68	85	66	80	98	107	90	89
148	85	76	73	129	120	120	116	115	97
89	67	87	79	91	73	78	61	76	81
86	71								

bos15

301	343	377	272	245	242	187	145	223	235
210	251	186	179	163	165	167	128	171	201
172	180	135	124	136	119	115	151	127	176
122	154	132	181	165	134	181	134	112	104
77	106	139	107	103	119	111	74	95	63
66	105	84	81	95	85	114	76	66	61
68	79	82	68	53	77	57	62	56	47
60	55	40	66	62	64	70	48	52	59
57	69	76	114	155	210	192	187	174	176
158	149	161	220	234	215	233	178	152	190
225	216	143	140	111	130	97	118	192	236
188	186	87	105	93	98	169	219	201	195
240	135	65	74	96	163	194	188	222	200
129	128	149	132	102	79	128	134	109	80
68	85	120	102	138	150				






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