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Tree-ring Analysis of Oak Timbers

Martin Bridge and Cathy Tyers

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SOUTHAM ROAD
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Martin Bridge and Cathy Tyers

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SUMMARY
Timbers from three roofs and a beam in the cellar were investigated. The roof of the east range included an inserted principal rafter to one truss and an inserted elm purlin, neither of which dated. Dated timbers from this roof gave a likely felling date range for the group of AD 1354–83, although evidence from the detached, but complete sapwood from one sample suggests the actual felling date was likely to be in the early part of this range.

Two timbers from the roof of the north range dated, one retaining the heartwood/sapwood boundary at AD 1468, giving a likely felling date range of AD 1477–1509. Two other principal rafters were thought to have originated from a single tree, but could not be dated.

The majority of timbers in the roof of the west range were of elm and, although three elm samples matched each other, none of the timbers dated.

A beam in the cellar retained the heartwood/sapwood boundary and gave a likely felling date range of AD 1558–90.

CONTRIBUTORS
Martin Bridge and Cathy Tyers

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INTRODUCTION

Hardwick House lies on the north side of the town of Banbury (Fig 1). This Grade II* listed farmhouse (LEN 1200559) is thought to be largely sixteenth century in date but with later alterations and extensions, although it is reputed to contain elements of an earlier manor house that was thought to lie to the north of the present building. It consists of three main elements, a long central (northern) range of stuccoed ironstone with a chimney stack at the west end, with shorter wings to the east and west, projecting southwards. The west range has a very similar roof style to that of the north, albeit in mostly elm rather than oak, although there are some important differences described later in this report. The west-range roof appears to have had the stack inserted into it, whilst the north-range roof is built around the stack (Clark *et al* 2017 unpubl). The east-range roof has comparatively small trusses and thought to be older. From the fifteenth to the seventeenth century the estate was in the hands of the Cope family, prominent in local and national affairs.

Dating was requested by David Brock (Historic England Inspector of Buildings and Areas) to inform Listed Building consent, and the building was also being investigated by the Oxfordshire Buildings Record (OBR) group (Clark *et al* 2017 unpubl).

METHODOLOGY

An assessment of the timbers for dendrochronological study sought accessible oak and elm timbers with more than 50 rings and where possible traces of sapwood, although slightly shorter sequences are sometimes sampled if little other material is available. Those timbers judged to be potentially useful were cored using a 16mm auger attached to an electric drill. The cores were labelled, and stored for subsequent analysis.

The cores were polished on a belt sander using 80 to 400 grit abrasive paper to allow the ring boundaries to be clearly distinguished. Those samples which had more than the 40 rings considered suitable for ring-width analysis had their tree-ring sequences measured to an accuracy of 0.01mm, using a specially constructed system utilising a binocular microscope with the sample mounted on a travelling stage with a linear transducer linked to a PC, which recorded the ring widths into a dataset. The software used in measuring and subsequent analysis was written by Ian Tyers (2004). Cross-matching was attempted by a process of qualified statistical comparison by computer, supported by visual checks. The ring-width series were compared for statistical cross-matching, using a variant of the Belfast CROS program (Baillie and Pilcher 1973). Ring sequences were plotted on the computer monitor to allow visual comparisons to be made between sequences. This method provides a measure of quality control in identifying any potential errors in the measurements when the samples cross-match.

In comparing one sample or site master against other samples or chronologies, *t*-values over 3.5 are considered significant, although in reality it is common to find demonstrably spurious *t*-values of 4 and 5 because more than one matching position is indicated. For this reason, dendrochronologists prefer to see some *t*-

value ranges of 5, 6, and higher, and for these to be well replicated from different, independent chronologies with both local and regional chronologies well represented, except where imported timbers are identified. Where two individual samples match together with a *t*-value of 10 or above, and visually exhibit exceptionally similar ring patterns, they may have originated from the same parent tree. Same-tree matches can also be identified through the external characteristics of the timber itself, such as knots and shake patterns. Lower *t*-values however do not preclude same-tree derivation.

Ascribing felling dates and date ranges

Once a tree-ring sequence has been firmly dated in time, a felling date, or date range, is ascribed where possible. With samples which have sapwood complete to the underside of, or including bark, this process is relatively straightforward. Depending on the completeness of the final ring (ie if it has only the spring vessels or earlywood formed, or the latewood or summer growth) a precise felling date and season can be given. If the sapwood is partially missing, or if only a heartwood/sapwood transition boundary survives, then an estimated felling date range can be given for each sample. The number of sapwood rings can be estimated by using an empirically derived sapwood estimate with a given confidence limit. If no sapwood or heartwood/sapwood boundary survives then the minimum number of sapwood rings from the appropriate sapwood estimate is added to the last measured ring to give a *terminus post quem* (*tpq*) or felled-after date.

A review of the geographical distribution of dated sapwood data from historic timbers has shown that a sapwood estimate relevant to the region of origin should be used in interpretation, which in this area is 9–41 rings (Miles 1997). Appropriate sapwood estimates for elm are as yet unknown, but the results of the elm research project (Bridge 2020) suggest that the range of the number of sapwood rings in elm timbers is likely to be much lower than for oak in the same area. One problem that has been encountered in considering elm is that it has often proved very difficult to determine the position of the heartwood/sapwood boundary, even when it is known that the complete sapwood is present on a timber. It must be emphasised that dendrochronology can only date when a tree has been felled, not when the timber was used to construct the structure or object under study.

RESULTS

Following the initial assessment of dendrochronological potential, samples were taken from timbers from the three roofs (Figs 2, 3, 5, and 7), as well as a beam in the cellar below the north range (Fig 9). A number of floor timbers that were not exposed at the time of the original assessment were inspected when sampling was undertaken, but these had too few rings to be considered useful for ring-width dendrochronology, and were not sampled.

All samples are oak (*Quercus* sp.) unless otherwise stated. Details of the samples are given in Table 1, with the approximate positions of the roof samples being shown in Figure 2. Two samples were taken from an oak collar in the north-range roof (hwkb14a and hwkb14b), two from an elm (*Ulmus* sp.) collar in the west-range roof (hwkb20a and hwkb20b), and two from the oak beam in the cellar (hwkb30a and hwkb30b) to maximise the length of data available from these timbers. Four of

the samples taken (hwkb08, hwkb14a, hwkb14b, hwkb17, and hwkb18), had less than 40 rings, and were discarded from further study. Samples hwkb20b and hwkb30b also had less than 40 rings but, as the other samples from these timbers had in excess of 40 rings, both were measured. Sample hwkb09 had broken into two pieces during coring and whilst it was thought that no rings had been lost it was measured in two sections, hwkb09i and hwkb09ii. The ring-width data for each measured sample are given in the Appendix.

The east-range roof (Figs 2 and 3) was seen to have had a replacement principal rafter inserted on the west side of the northern truss (truss 1) and this was sampled (hwkb08) in the hope that it might provide the date of this intervention. Nine other timbers were sampled from this roof, including an elm purlin (hwkb10) that was thought possibly to have been inserted at the same time as the new principal rafter. The samples from three of the timbers had additional unmeasured sapwood sections, one (hwkb04) of which was detached but complete to the bark edge. Samples hwkb02 and hwkb04, from two principal rafters of the same truss, matched each other well (t = 12.8), and were thought to be from the same tree. A new mean series hwkb0204m was formed and used in subsequent analysis. Samples hwkb09i and hwkb09ii matched with other series and showed that there was no rings missing, and they were subsequently combined to form a single series hwkb09. The series from four cross-matched timbers (Table 2a) were combined to form a single site chronology HWKBeast, which was subsequently dated to the period AD 1184–1343, a selection of the strongest matches being shown in Table 3a. In addition, cross-matching was also identified between the ring series from hwkb03 and hwkb07 (t = 8.0 with 54 years of overlap; Fig 4). These were combined (hwkb0307) for further analysis but could not be dated. Two further measured samples from this roof also failed to date.

Nine timbers were sampled from various elements of the north-range roof (Figs 2 and 5). Two samples (hwkb11 and hwkb12), representing both principal rafters from truss 4, matched each other well (t = 8.1 with 86 years of overlap; Fig 6). The two ring series were combined (hwkb1112m) for further analysis, but could not be dated. The samples from a principal rafter (hwkb15) and a tiebeam (hwkb16) from truss 3 matched each other (t = 4.4 with 54 years overlap) and these too were combined (hwkb1516m) for further analysis. The new sequence, hwkb1516m, dated to the period AD 1355–1468, a selection of the strongest matches being shown in Table 3b. Neither of the two remaining measured samples could be dated individually when compared with the reference material.

The roof timbers of the west-range roof (Fig 7) were found to be of both oak and elm, although the purlins were all noted as oak. These were sampled as they were relevant to the then on-going Historic England funded project on elm timbers from historic buildings (Bridge 2020). The two samples from the truss 4 collar, hwkb20a and hwkb20b cross-matched (t = 5.7 with 36 years of overlap) and were combined to produce a single timber series. Three of the series from elm timbers cross-matched with each other (Table 2b; Fig 8) and were combined into a single site chronology, HWKBelm. This elm site chronology was compared with the oak reference database, as well as the few extant dated elm site chronologies, but could not be dated. The remaining four measured elm timber series and three measured oak series could not be dated by ring-width dendrochronology either.

The two samples, hwkb30a and hwkb30b from the beam in the cellar (Fig 9) were known to overlap by only a small number of rings, 30b having been taken to reach the h/s boundary. Series hwkb30a was initially dated and the overlap confirmed by the comparison of hwkb30b to reference chronologies as well, thus they were combined to form a single series, hwkb30, which dated to the period AD 1460–1549. A selection of the strongest matches is shown in Table 3c.

INTERPRETATION AND DISCUSSION

Much useful discussion of the development of the building is given in report by the Oxfordshire Buildings Record (Clark *et al* 2017 unpubl). This provides evidence that the earliest dated roof in the east range (Fig 3) may have been dismantled and re-assembled at some point, and has certainly undergone changes in more recent times. Its lack of sooting is of interest, given the dating evidence obtained from the dendrochronological analysis. The mean heartwood/sapwood boundary date for the three dated trees (Fig 10) is AD 1342, giving a likely felling date range of AD 1354–83, allowing for the unmeasured sapwood rings on hwkb02. The evidence from sample hwkb04, however, suggests that felling probably occurred in the early part of this range as it was noted during coring that only a very small number of rings were likely to have been lost from the main heartwood section of the core and the detached sapwood section. Strong cross-dating for the site chronology HWKBeast is obtained against chronologies from the southern midlands region, but a very high level of similarity is found with the site chronology from Warden's Hall at Merton College, Oxford (Table 3a). This may suggest the timbers grew in close proximity, if not in the same woodland. The Merton College records show that at least some of the timber for the Warden's Hall was bought from Woodstock, about 25km from Hardwick House (Bott 2006).

Timbers hwkb03 and hwkb07 from the roof of the east range cross-match (see above, and Fig 4), but do not date, meaning that it is not possible to confirm or deny the potential late fourteenth-century date for this range, or whether these timbers are later insertions, replacements, or modifications.

The north-range roof (Fig 5) is dated by just two timbers, with one retaining the heartwood/sapwood boundary, giving a likely felling date range of AD 1477–1509 for both timbers assuming that they are coeval (Fig 10). Documentary research presented by Clark *et al* (2017 unpubl) shows the Cope family acquired the property in AD 1496, and it seems quite likely that major work at the site would have occurred soon after this. The matches for these timbers (Table 3b) are widely spread and, apart from a likely English origin, little more can be said about their geographical origin.

Two further timbers from the north range, hwkb11 and hwkb12 cross-match (Fig 6), but cannot be dated by ring-width dendrochronology. So, while they are clearly coeval, it is not possible to confirm whether they are also late-fifteenth/early sixteenth century in origin, or later replacements or modifications.

Superficially the west- and north-range roofs look very similar (Figs 5 and 7), with many medieval characteristics such as curved collars, curved windbraces, and scratched assembly marks. Neither shows any sign of sooting, but the timbers of the

west range have well preserved coverings of red ochre and red lead. Fabric analysis, however, reveals differences between the two roofs, the west range having the windbraces supporting the lower tier of purlins, whilst in the north range they support the upper tier. There are also differences in the way the principal rafters support the purlins, and the joints where the principals meet. The chimney stack at the junction of the two roofs looks to have been inserted into the west-range roof, whilst the north-range roof appears to have been built around the stack. All of this evidence shows that the west-range roof was built before the north-range roof, but Clark *et al* (2017 unpubl) suggests that the difference in date was not great. The west-range roof was constructed predominantly of elm but, although three of the elm timbers were shown to be coeval (Table 2b and Fig 8), none of the elm or oak timbers sampled from this roof could be dated. Bridge (2020) concluded that elm can only very rarely be dated against oak chronologies and, thus, its failure to date in this case is therefore not unusual.

The cellar timber under the north range (Fig 9) gives a likely felling date range of AD 1558–90, although the brick lining suggests construction in the nineteenth century. Although this series matches over a quite wide geographical area (Table 3c), it is likely the timber was of local origin.

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TABLES

Table 1: Details of samples taken from Hardwick House, Southam Road, Banbury, Oxfordshire (all sampled timbers are of oak, Quercus sp., unless otherwise indicated)

Sample number	Timber and position	No of rings	Mean ring width (mm)	Dates spanning (AD)	h/s boundary (AD)	Sapwood rings	Mean sensitivity	Felling date ranges (AD)
East-range Roof (trusses numbered from the north)								
hwkb01	Collar, truss 2	160	1.05	1184–1343	1342	1	0.22	1351–83
hwkb02	East principal rafter, truss 2	143	1.01	1198–1340	1340	h/s (+14NM)	0.25	1354–82†
hwkb03	East lower purlin between truss 2 and south wall	64	1.58	-	-	9 (+9NM)	0.26	-
hwkb04	West principal rafter, truss 2	150	1.18	1193–1342	1342	h/s (+11CNM)*	0.26	1354–82†
hwkb05	West lower purlin between truss 2 and south wall	90	1.17	-	-	-	0.30	-
hwkb06	West lower purlin, middle bay	43	2.81	-	-	-	0.18	-
hwkb07	West lower purlin, north bay	66	1.71	-	-	2	0.22	-
hwkb08	West principal rafter, truss 1 (replacement)	<40	NM	-	-	-	-	-
hwkb09i	Collar, truss 1 (inner)	103	1.13	1200–1302	-	-	0.27	-
hwkb09ii	Collar, truss 1 (outer)	41	0.64	1302–1342	1342	h/s	0.18	-
hwkb09	Collar, truss 1 (combined 09i and 09ii)	143	0.99	1200–1342	1342	h/s	0.24	1351–83
hwkb10	West upper purlin, north bay (replacement) (elm, *Ulmus* sp.)	<40	NM	-	-	-	-	-
North-range Roof (trusses numbered from the west)								
hwkb11	North principal rafter, truss 4	101	1.86	-	-	h/s	0.20	-
hwkb12	South principal rafter, truss 4	86	1.72	-	-	h/s	0.20	-
hwkb13	Lower south purlin, bay 3-4	56	2.32	-	-	h/s	0.21	-

Sample number	Timber and position	No of rings	Mean ring width (mm)	Dates spanning (AD)	h/s boundary (AD)	Sapwood rings	Mean sensitivity	Felling date ranges (AD)
hwkb14	Collar, truss 3	<40	NM	-	-	-	-	-
hwkb15	South principal rafter, truss 3	91	1.94	1355–1445	-	-	0.23	after 1454
hwkb16	Tiebeam, truss 3	77	1.20	1392–1468	1468	h/s	0.17	1477–1509
hwkb17	North lower purlin, bay 3-4	<40	NM	-	-	-	-	-
hwkb18	Collar, truss 2	<40	NM	-	-	-	-	-
hwkb19	North principal rafter truss 1 (against stack)	59	1.51	-	-	?h/s	0.30	-
West-range Roof (trusses numbered from the south)								
hwkb20	Collar, truss 4 (elm, *Ulmus* sp.)	56	2.38	-	-	2	0.22	-
hwkb20a	Collar, truss 4 (elm, *Ulmus* sp.)	55	2.41	-	-	-	0.22	-
hwkb20b	Collar, truss 4 (elm, *Ulmus* sp.)	37	2.14	-	-	2	0.22	-
hwkb21	West principal rafter, truss 4 (elm, *Ulmus* sp.)	72	2.02	-	-	h/s	0.39	-
hwkb22	East principal rafter, truss 4 (elm, *Ulmus* sp.)	47	2.32	-	-	-	0.36	-
hwkb23	Collar, truss 3 (elm, *Ulmus* sp.)	52	2.09	-	-	h/s	0.23	-
hwkb24	West principal rafter, truss 3 (elm, *Ulmus* sp.)	53	2.09	-	-	9	0.27	-
hwkb25	Collar, truss 2 (may not be primary)	47	1.32	-	-	-	0.23	-
hwkb26	West principal rafter, truss 2 (elm, *Ulmus* sp.)	52	1.96	-	-	h/s	0.43	-
hwkb27	East principal rafter, truss 2 (elm, *Ulmus* sp.)	40	2.67	-	-	h/s	0.34	-
hwkb28	Tiebeam, truss 2	43	3.30	-	-	-	0.20	-
hwkb29	Tiebeam, truss 3	63	1.26	-	-	-	0.20	-
Cellar								
hwkb30	Large beam embedded in wall	90	1.51	1460–1549	1549	h/s	0.23	1558–90
hwkb30a	Large beam embedded in wall	74	1.63	1460–1533	-	-	0.22	-
hwkb30b	Large beam embedded in wall	24	1.05	1526–1549	1549	h/s	0.24	-

Key: NM = not measured; h/s = heartwood/sapwood boundary; C = complete sapwood, winter felled; * = a small number of rings may have been lost between the heartwood only core section and the detached sapwood; † date range based on same-tree pair

Table 2a: Cross-matching between the samples from the east-range roof included in the site master chronology HWKBeast, values of t = 3.5 are considered significant

	t-value (number of years overlap)		
Sample No	hwkb02	hwkb04	hwkb09
hwkb01	5.2 (143)	5.5 (150)	7.9 (143)
hwkb02		12.8 (143)	8.9 (141)
hwkb04			7.5 (143)

Table 2b: Cross-matching between the elm samples from the west-range roof included in the site master chronology HWKBelm

	t-values (number of years overlap)	
Sample No	hwkb22	hwkb27
hwkb21	7.4 (38)	5.7 (29)
hwkb22		4.3 (38)

Table 3a: Dating evidence for site chronology HWKBeast AD 1184–1343

Source region:	Chronology name:	Publication reference:	File name:	Span of chronology (AD)	Overlap (years)	*t*-value
Regional chronologies						
Somerset	Somerset Master Chronology	Miles 2004 unpubl	SOMRST04	770–1979	160	13.6
Central England	South Central England	Wilson *et al* 2012	SCENG	663–2009	160	13.2
Hampshire	Hampshire Master Chronology	Miles 2003	HANTS02	443–1972	160	11.4
Devon	Devon Master Chronology	Tyers and Groves 2004 unpubl	DEVN2004	775–1799	160	9.0
Site chronologies						
Oxfordshire	Merton Wardens Hall	Miles and Bridge 2016	MERTON1	1169–1298	115	12.4
Berkshire	Reading Waterfront	Groves *et al* 1999	READING	1160–1407	160	10.9
Devon	Exeter Cathedral	Mills 1988	EXCATH1	1137–1332	149	10.5
Somerset	Wells Cathedral, St Catherine's Chapel	*Arnold et al* 2004	WLSC0203	1169–1325	142	10.3
Gloucestershire	Winterbourne Tithe Barn	Miles and Worthington 2000	WNTERBRN	1177–1341	158	9.8
Oxfordshire	The Great Barn, Lewknor	Haddon-Reece *et al* 1990	LEWKNORx	1188–1343	156	9.6
Hampshire	Prior's Hall roof	Bridge and Miles 2018	DWCx2	1284–1375	60	9.4
Somerset	Manor Farmhouse, Meare	Bridge 2002	MEAREMNR	1156–1314	131	9.4
Oxfordshire	Manor Farm, Stanton St John	Miles and Worthington 1998	STNSTJN1	1131–1304	121	9.4
Oxfordshire	Christ Church Chapter House, Oxford	Worthington and Miles 2003	CHCHCH	1142–1260	77	9.2
Somerset	North Cadbury Court	Miles and Worthington 1998	NCADBRY3	1243–1343	101	9.1

Table 3b: Dating evidence for site chronology hwkb1516m AD 1355–1468

Source region:	Chronology name:	Publication reference:	File name:	Span of chronology (AD)	Overlap (years)	*t*-value
Shropshire	Council House, Shrewsbury Castle	Miles and Worthington 1997	COUNCLHS	1368–1500	101	7.3
Tyne and Wear	Rigging Loft, Trinity House, Newcastle upon Tyne	Howard *et al* 2002	NWCASQ01	1397–1524	72	6.3
Oxfordshire	Chequers Inn, Chipping Norton	Bridge and Tyers 2020	CNCHQ345	1362–1438	77	6.1
Shropshire	Aston Eyre, gatehouse	Miles and Worthington 1998	ASTNEYR3	1357–1612	112	5.8
Essex	Park Farm Barn, Liston	Bridge and Miles 2017	LISTON	1340–1464	110	5.6
London	Martin Tower, Tower of London	Bridge 1983	MARTIN	1379–1534	90	5.6
Gloucestershire	Owlpen Manor Barn	Bridge and Miles 2017	OWLPEN2	1337–1445	91	5.6
Warwickshire	Kenilworth Castle	Howard *et al* 2006	KNWESQ01	1354–1532	114	5.6
London	Forty Hall, Enfield	Bridge 1997a	FORTYHLL	1364–1475	105	5.6
Herefordshire	Olde Salutation Inn, Weobley	Tyers and Groves 1999	WEOB_T6	1355–1580	114	5.5

Table 3c: Dating evidence for site series hwkb30 AD 1460–1549

Source region:	Chronology name:	Publication reference:	File name:	Span of chronology (AD)	Overlap (years)	*t*-value
Oxfordshire	The Stores, East Hendred	Miles and Worthington 2001	ehh4	1481–1535	55	5.7
Cheshire	The Round House, Nantwich	Lageard 2000 unpubl	NANTRHM	1388–1538	79	5.7
Worcestershire	Granary, Meadow Farm, Redditch	Miles *et al* 2007	REDGRAN	1402–1597	90	5.6
Warwickshire	Baddesley Clinton	Miles and Worthington 2002	BADESLY3	1423–1577	90	5.6
Warwickshire	Palmer's Farm, Wilmcote	Miles and Worthington 2000	ARDEN2	1371–1568	90	5.5
Warwickshire	Leicester's Gatehouse, Kenilworth Castle	Arnold *et a*l 2007	KNWCSQ02	1390–1547	88	5.4
Berkshire	Greenham Mill, Newbury	Miles and Worthington 2002	GREENHAM	1373–1589	90	5.4
Buckinghamshire	Nos 3 & 4 High Street, West Wycombe	Miles *et al* 2014	WWG	1464–1553	86	5.3
London	Bruce Castle, Tottenham	Bridge 1997b	BRUCE2	1421–1544	85	5.1
Shropshire	Merchant's House, Ludlow	Miles *et al* 2008	LUDLOW15	1479–1585	71	5.1

FIGURES

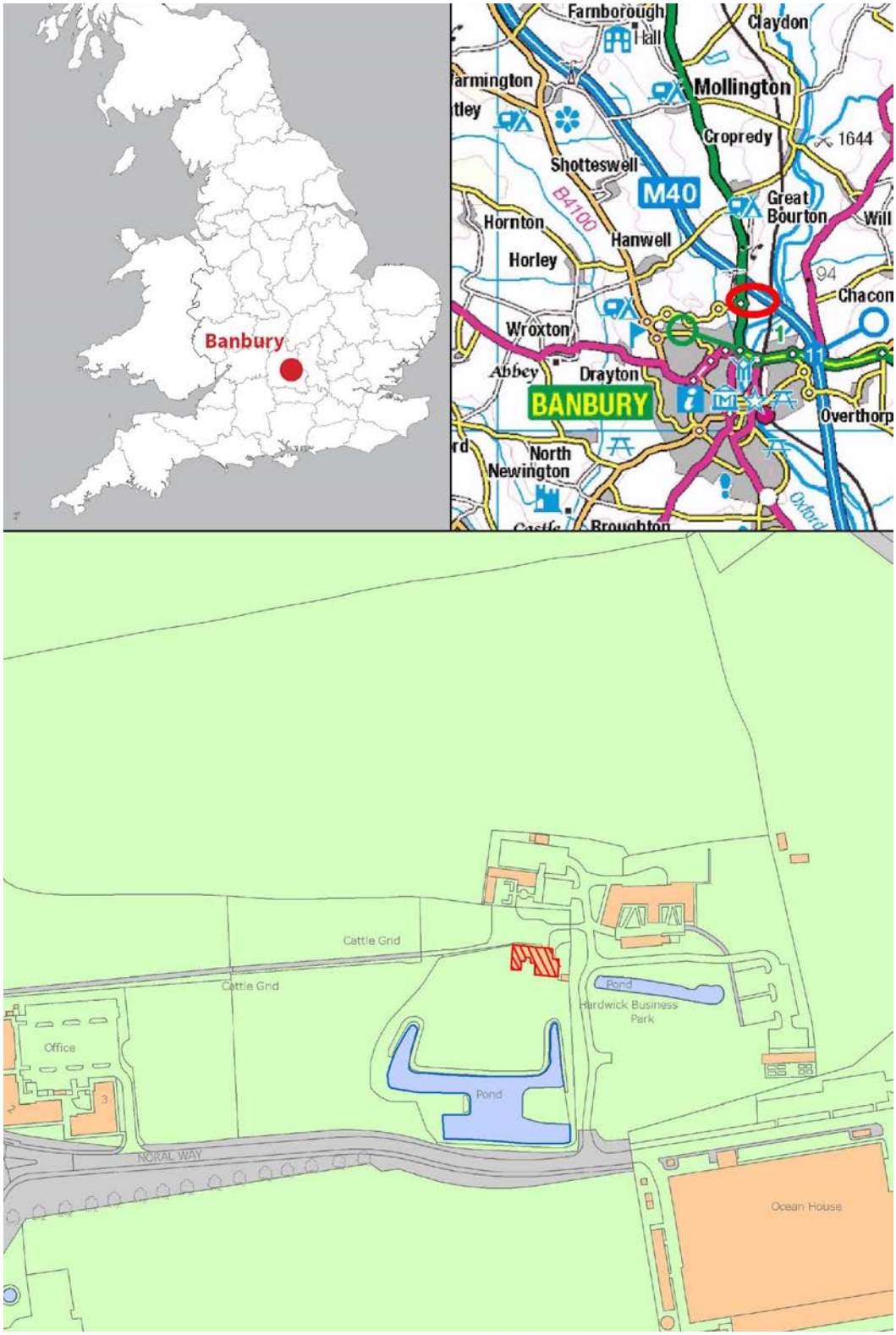

Figure 1: Maps to show the location of Hardwick House, Banbury in Oxfordshire, marked in red. Scale: top right 1:115000; bottom 1:3000. © Crown Copyright and database right 2020. All rights reserved. Ordnance Survey Licence number 100024900. © British Crown and SeaZone Solutions Ltd 2020. All rights reserved. Licence number 102006.006. © Historic England

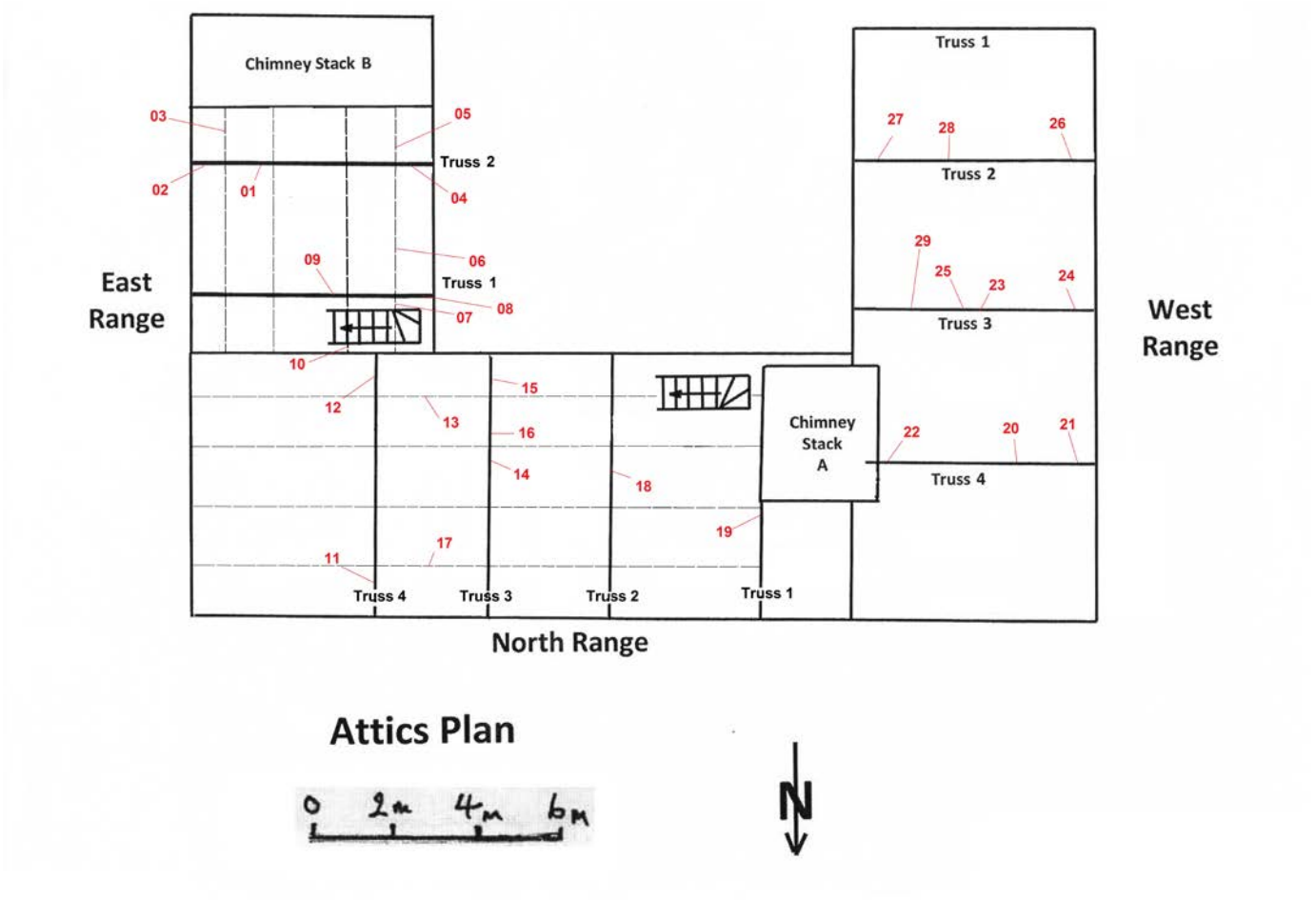

Figure 2: Plan of the attics, showing position of samples taken for dendrochronology, after a plan supplied by the Oxfordshire Buildings Record (Clark et al 2017 unpubl)

Figure 3: View of the east-range roof, looking south (photograph Martin Bridge)

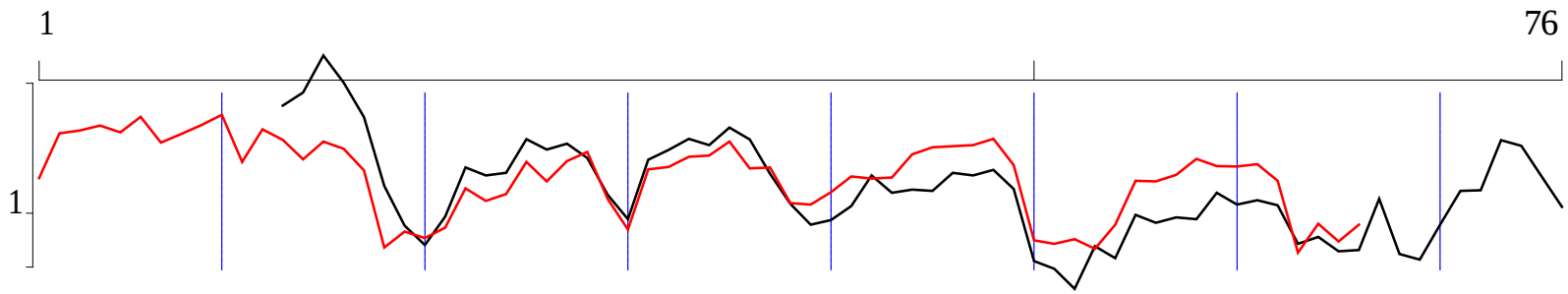

Figure 4: Plots of hwkb03 (black) and hwkb07 (red) where they align, showing similarity in growth pattern between the two series, the x-axis is relative years and the y-axis ring-width (mm) on a logarithmic scale

Figure 5: View of truss 3 in the north range, looking south-west (photograph Oxfordshire Buildings Record)

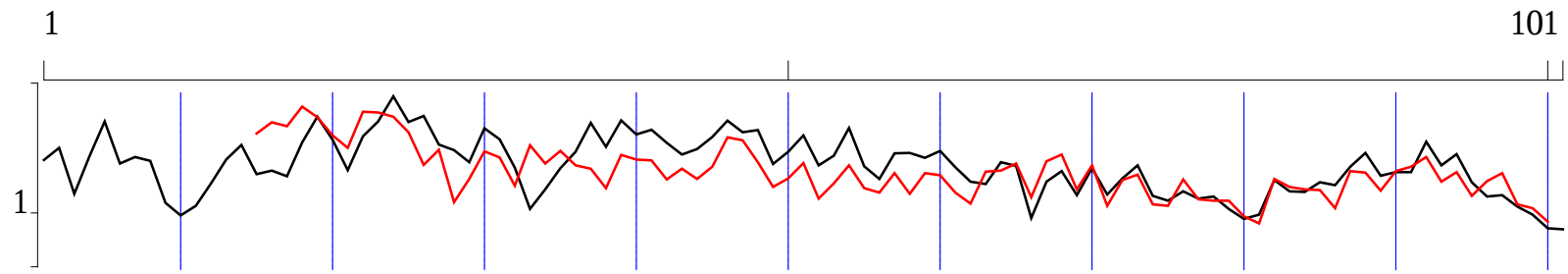

Figure 6: Plots of hwkb11 (black) and hwkb12 (red) where they align, showing similarity in growth pattern between the two series, the x-axis is relative years and the y-axis ring-width (mm) on a logarithmic scale

Figure 7: View of the west-range roof, looking south, with the inserted stack to the left (photograph Martin Bridge)

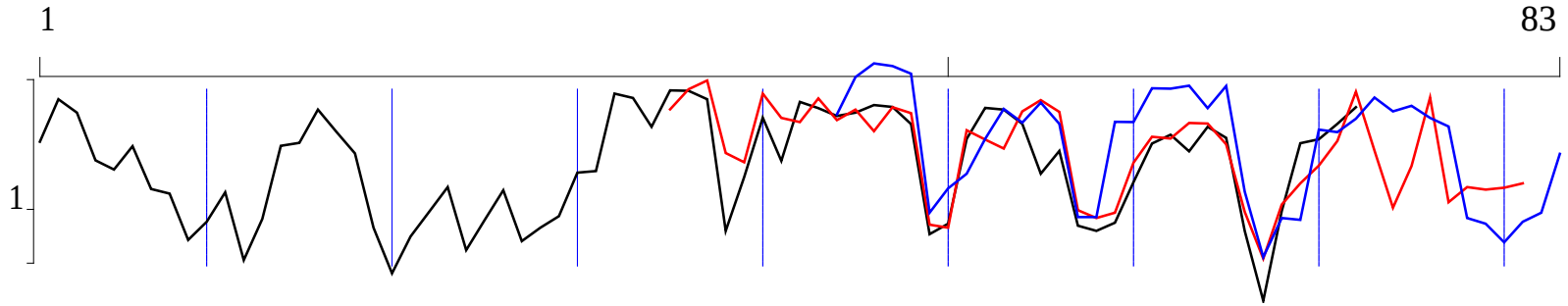

Figure 8: Plots of the three elm series hwkb21 (black), hwkb22 (red), and hwkb27 (blue) where they align, showing similarity in growth pattern between the three series, the x-axis is relative years and the y-axis ring-width (mm) on a logarithmic scale

Figure 9: View of the exposed end of the beam in the cellar – hwkb30 (photograph Martin Bridge)

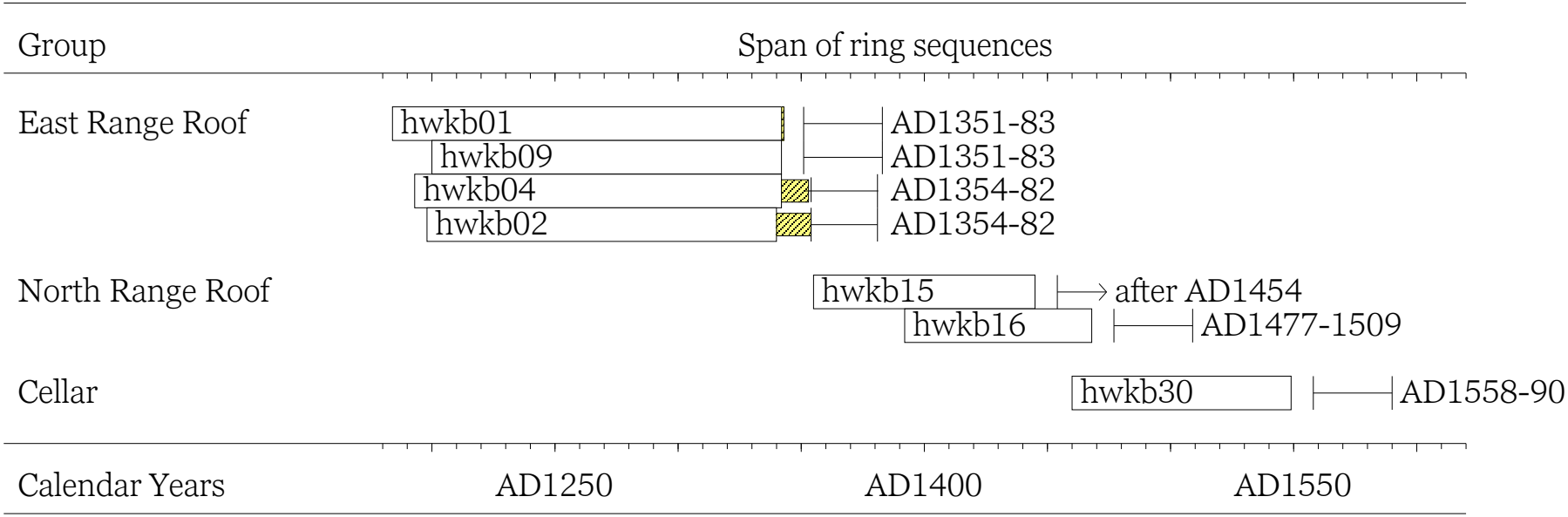

Figure 10: Bar diagram showing the relative positions of overlap of the dated samples, along with their actual felling dates or likely felling date ranges. White bars represent heartwood rings, yellow hatched bars represent sapwood rings, and narrow sections of bar represent additional unmeasured rings

APPENDIX

Ring width values (0.01mm) for the sequences measured

Oak

hwkb01

98	170	140	209	85	89	110	94	72	128
112	136	130	93	136	94	52	84	63	69
51	82	107	68	102	82	83	83	69	89
83	102	81	87	75	90	95	80	63	81
57	75	88	76	93	102	107	78	63	80
140	161	76	147	160	189	179	128	123	155
115	139	154	152	108	152	141	147	128	145
136	148	93	136	98	101	98	103	153	129
106	123	136	122	95	100	122	117	110	138
127	87	100	83	86	92	110	84	84	106
79	80	132	82	65	102	126	99	129	147
116	104	111	100	94	99	104	145	96	73
61	71	95	83	104	95	109	83	85	82
91	123	140	150	72	127	101	119	133	108
106	71	88	101	111	107	82	49	41	99
115	114	79	113	75	117	94	128	124	146

hwkb02

192	199	195	118	111	67	84	117	110	102
134	59	81	141	134	117	125	145	117	132
99	141	189	229	124	138	124	158	189	143
167	215	119	77	69	80	114	125	77	127
112	103	85	68	63	92	64	71	110	125
39	96	95	105	105	135	95	101	110	68
47	34	62	60	75	42	67	51	65	48
44	63	88	89	79	64	65	33	41	57
73	85	101	116	94	54	62	64	90	39
41	59	97	80	68	79	72	63	56	76
72	80	121	108	135	75	83	114	127	125
95	125	127	138	129	125	99	138	171	177
123	105	79	129	151	151	129	80	56	70
99	75	35	47	68	97	103	105	129	101
119	198	137							

hwkb03

368	431	675	486	320	139	86	68	96	174
158	163	245	216	232	195	125	93	191	215
246	228	282	244	161	112	87	92	109	158
128	133	131	163	158	169	134	56	51	40
67	58	98	89	95	93	128	111	117	110
69	75	63	64	119	61	57	87	131	132
242	226	156	108						

hwkb04

70	63	122	105	91	81	125	148	143	118
74	80	87	90	77	96	46	63	88	80
72	76	71	80	98	82	140	207	237	136
163	161	144	268	282	462	361	195	145	98

123 173 207 115 241 120 169 120 94 123
164 107 120 125 157 64 132 114 112 106
142 113 111 136 67 63 46 92 91 119
60 120 117 86 81 41 70 75 103 71
78 40 32 43 44 66 77 76 103 99
67 71 75 86 47 43 68 90 75 74
89 72 66 68 92 70 112 145 157 190
124 75 127 163 190 209 192 157 147 161
147 137 150 182 190 113 96 121 140 182
158 96 89 81 96 104 123 102 81 105
177 123 162 128 169 110 148 119 154 191

hwkb05
249 203 113 49 111 189 371 312 135 128
186 106 114 129 121 167 159 182 224 154
216 112 69 49 71 253 196 121 129 49
74 52 47 42 84 70 75 70 61 79
85 89 88 113 60 61 62 104 80 76
72 170 123 152 114 196 203 164 143 110
195 155 82 126 107 70 70 89 63 68
80 73 86 55 131 118 135 81 60 180
130 107 133 120 89 75 91 78 165 160

hwkb06
711 519 294 469 424 503 524 363 329 219
200 345 351 321 312 330 329 365 325 317
199 191 224 195 302 310 280 261 214 170
122 146 91 146 134 149 187 175 193 180
194 237 231

hwkb07
153 263 272 289 266 321 235 261 291 329
186 276 243 192 238 218 168 66 80 74
84 135 116 126 186 147 188 210 119 82
170 175 198 201 238 172 174 113 111 129
156 152 154 204 222 225 228 246 179 72
69 73 65 87 148 147 159 193 177 176
181 148 62 88 71 87

hwkb09i
101 89 90 129 47 105 85 61 53 63
54 72 61 62 67 78 80 105 68 125
177 159 103 86 117 161 209 145 264 306
197 111 82 87 143 171 93 146 150 128
133 127 124 175 145 111 198 155 76 108
126 134 127 167 174 205 160 229 197 115
146 197 225 122 77 145 91 112 90 78
90 121 91 97 87 54 55 56 64 71
115 110 112 68 107 89 134 64 49 126
103 93 120 99 103 73 54 63 44 54
62 65 82

hwkb09ii
79 49 41 66 76 66 66 59 51 52
55 59 51 79 83 86 59 43 59 50
79 51 51 68 59 63 83 82 43 44

51 68 91 89 75 62 62 62 64 70
79

hwkb11
194 214 125 192 297 184 192 189 108 102
117 141 192 224 158 175 155 221 319 247
167 254 300 416 320 322 229 209 185 280
247 165 108 126 172 206 298 227 306 255
277 230 204 216 247 305 267 274 185 200
252 184 201 268 179 151 205 208 199 208
170 142 152 183 171 99 143 163 126 169
127 151 176 123 112 132 120 123 104 91
98 145 131 127 147 141 176 202 151 159
168 238 179 198 150 121 121 108 102 82
88

hwkb12
262 290 284 346 323 245 224 334 338 315
268 175 207 112 152 225 197 144 212 177
207 183 191 136 197 180 186 143 170 141
167 247 235 200 136 152 187 122 150 177
136 121 164 128 160 158 127 118 156 173
188 118 181 206 137 175 109 152 155 110
103 155 118 119 112 94 93 151 144 127
133 104 166 164 134 163 173 194 146 165
123 152 161 105 109 93

hwkb13
311 252 179 156 162 173 120 57 77 64
71 50 55 102 231 250 501 468 364 362
358 403 375 305 365 402 333 540 645 421
264 292 264 229 174 186 208 137 160 129
132 151 115 103 169 188 178 235 207 197
169 149 142 168 236 240

hwkb15
212 236 115 145 100 146 365 347 322 275
122 99 259 390 471 442 324 379 284 151
237 310 293 295 425 263 213 223 176 165
161 232 254 228 181 189 161 214 165 124
98 98 143 162 199 107 153 147 196 240
238 250 156 129 180 184 210 193 216 158
162 110 124 117 119 177 182 168 220 196
165 87 97 122 123 84 89 126 110 92
95 80 90 95 110 153 188 179 308 284
207

hwkb16
142 113 124 89 113 121 119 132 104 115
104 156 151 117 118 100 85 91 106 102
91 98 62 80 51 46 49 54 60 87
81 116 130 107 83 69 100 114 109 87
105 77 60 59 54 95 99 76 87 168
138 197 213 147 136 168 176 153 185 208
197 187 171 161 178 192 162 174 180 205
175 179 148 161 86 81 60

hwkb19

345	442	368	411	201	279	261	202	288	307
193	142	163	229	202	221	84	85	60	85
69	51	99	131	248	231	221	240	184	195
232	146	168	178	111	181	138	90	60	104
77	75	61	39	84	44	39	50	76	78
48	81	125	98	54	39	62	84	78	

hwkb25

230	276	290	274	206	216	264	254	159	169
67	44	29	30	40	52	62	88	109	98
113	66	147	131	87	106	105	126	126	114
64	104	118	77	139	139	106	108	116	132
144	139	115	163	143	152	181			

hwkb28

488	544	526	492	407	367	343	359	430	400
538	639	302	150	274	326	299	314	446	504
454	474	524	531	401	431	143	90	71	104
134	158	147	191	224	196	251	277	226	227
223	230	320							

hwkb29

262	320	255	312	312	244	200	191	228	235
170	166	201	96	66	54	57	72	81	67
109	104	92	119	129	158	143	178	135	155
137	101	83	80	71	61	43	36	58	56
51	61	83	66	67	54	72	84	101	132
112	81	61	79	110	96	99	111	151	172
123	134	178							

hwkb30a

205	245	200	172	142	169	179	193	185	152
122	163	134	263	200	258	232	359	177	276
316	310	225	236	228	129	149	212	196	272
246	234	154	258	298	184	218	216	112	96
83	92	91	110	115	136	95	82	102	133
89	92	124	109	102	104	104	78	126	111
68	89	79	77	83	118	166	150	145	149
79	180	146	144						

hwkb30b

128	119	130	113	63	126	118	108	107	179
109	93	64	74	109	93	64	73	57	58
109	128	153	142						

Elm

hwkb20a

281	263	272	338	216	272	348	247	209	331
160	168	376	441	359	257	303	285	221	239
207	269	296	284	291	293	311	184	103	142
211	240	336	335	322	320	297	284	280	198
106	92	91	111	63	84	104	122	172	247
300	245	267	241	234					

hwkb20b

312	351	320	341	287	231	275	305	199	155
129	148	274	351	315	353	356	297	254	258
189	105	76	84	99	61	90	102	122	182
232	203	155	180	241	171	104			

hwkb21

227	380	323	181	162	215	128	121	69	86
123	54	89	216	224	335	256	197	80	46
72	97	131	61	88	126	68	80	92	156
159	407	386	272	423	421	380	77	148	304
180	368	341	310	323	354	346	281	74	84
235	342	335	282	154	203	82	77	85	139
222	247	202	272	238	77	33	98	223	234
282	345								

hwkb22

336	429	477	198	177	407	303	288	384	295
335	258	345	321	83	80	261	233	209	328
376	326	99	90	96	176	241	236	285	283
220	97	55	106	137	170	229	416	204	102
169	388	109	131	127	130	137			

hwkb23

186	244	507	641	464	262	353	441	368	266
247	241	252	237	344	265	282	213	187	203
276	219	162	50	73	73	98	105	108	138
184	195	216	232	213	172	123	122	166	142
134	158	139	150	121	134	92	105	144	126
78	196								

hwkb24

116	151	207	274	278	262	277	306	288	224
198	259	156	100	136	173	249	325	367	264
284	102	136	172	204	238	273	190	106	85
242	292	139	84	101	158	180	265	267	256
208	258	264	265	200	155	186	217	137	297
174	189	162							

hwkb26

160	46	38	220	418	362	429	387	367	478
129	308	442	254	186	98	64	55	239	245
233	208	203	59	40	106	124	191	145	140
340	369	94	69	140	211	157	186	208	114
178	93	77	56	82	128	215	202	178	249
142	310								

hwkb27

316	497	587	568	518	96	129	154	235	338
286	365	282	91	91	289	288	434	432	448
341	446	124	56	90	88	263	255	300	388
328	351	303	273	90	84	67	86	96	196

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