

RESEARCH REPORT SERIES no. 108-2011

# THE READER'S HOUSE, LUDLOW, SHROPSHIRE

## TREE-RING ANALYSIS OF TIMBERS

SCIENTIFIC DATING REPORT

Martin Bridge and Dan Miles



INTERVENTION  
AND ANALYSIS



ENGLISH HERITAGE

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Research Report Series 108-2011

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LUDLOW,  
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## **SUMMARY**

Investigations were carried out over a number of years, resulting in 18 timbers being dated. One tiebeam was from a tree felled in the summer of AD 1553, but this appears to be either a long-term stockpiled or reused timber incorporated into a later building. Whilst some timbers have actual or likely felling dates in the late AD1590s and early AD1600s, there is a preponderance of material felled in the period AD 1613–16, and the logic of the building construction suggests that the porch, some of the framing and floors, and the roof, were constructed in the mid AD 1610s, which coincides with the '1616' date inscribed on the porch. This indicates a hitherto unrealised major reconstruction at this time.

## **CONTRIBUTORS**

Dr M C Bridge and Dr D W Miles

## **ACKNOWLEDGEMENTS**

This work was commissioned by Dr Peter Marshall (English Heritage Scientific Dating Team). We would like to acknowledge the hospitality and patience of the owners, Mr and Mrs Buteux, and the input of several people involved with investigating the property, Ric Tyler (who supplied the drawings adapted for this report), Duncan James, Mike Page, and Tim Potts. Cathy Tyers (English Heritage Scientific Dating Team) made useful comments on earlier drafts of this report.

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## INTRODUCTION

The Reader's House is a Grade I listed building located on the eastern side of the churchyard, in the heart of historic Ludlow (Figs 1 and 2). It is discussed in more detail in several works (eg Hussey 1946, Lloyd 1999, and Moran 2003) from which the following information has been extracted.

It derives its name from the fact that in the eighteenth century it became the official residence of the 'Reader', one of the curates of the adjacent church. It is medieval in origin, but today appears to be largely Elizabethan, with modifications and repairs, the most prominent of which is a three-storied timber-framed porch added to the stone-built rear wall by Thomas Key, chaplain to the Council of the Marches, with a date of '1616' inscribed. The house is basically a four-bayed timber-framed house, although it is thought that a further bay existed to the north side. In 1330 it was described as '*2 solars under 1 roof with a lantern*'. In the fifteenth century it was owned by the Palmers' Guild, and used to accommodate a grammar school. In the 1550s it was largely rebuilt, and became associated with the Council of the Marches (Lloyd 1999). Externally, the framed part is jettied at two levels, square-framed with long angle braces and with a large dormer-gable which has diagonal strutting. The bressumer moulding is of triple-ovolo-and-quirk form. Internally there are some reused timbers, but good double-ovolo-and-quirk moulding on the doorframes. In the cellar there are reused moulded posts on stone plinths.

A small scale dendrochronological investigation was undertaken in 2006 when just five timbers were dated (Miles *et al* 2006), partially funded by the Ludlow Historical Research Group. This investigation highlighted the potential complexity of the phasing. Two conflicting dates were found for what were thought to be primary framing timbers. Purlins in the roof seemed to date to the same time as the addition of the porch, indicating more extensive work at this time than had been previously recognised. Relatively recently the building came under new ownership and has been repaired and renovated, and as part of this process the English Heritage Inspector of Historic Buildings and Areas, John Yates, requested a more extensive dendrochronological investigation to enhance the understanding of the development of this building and inform future works. This included the north wall of the property which has a different, more basic style of framing, using less well finished timbers of smaller scantling, and reused elements within the house, including the moulded timbers in the cellar.

## METHODOLOGY

Fieldwork for the present study was carried out in June and September 2009, with some additional work in September 2010. In the initial assessment, accessible oak timbers with more than 50 rings and where possible traces of sapwood were sought, although slightly shorter sequences are sometimes sampled if little other material is available. Those timbers judged to be potentially useful were sampled using a 15mm auger attached to an



Figure 1: Map to show the location of Reader's House, Ludlow. ©Crown Copyright and database right 2014. All rights reserved. Ordnance Survey Licence number 100024900

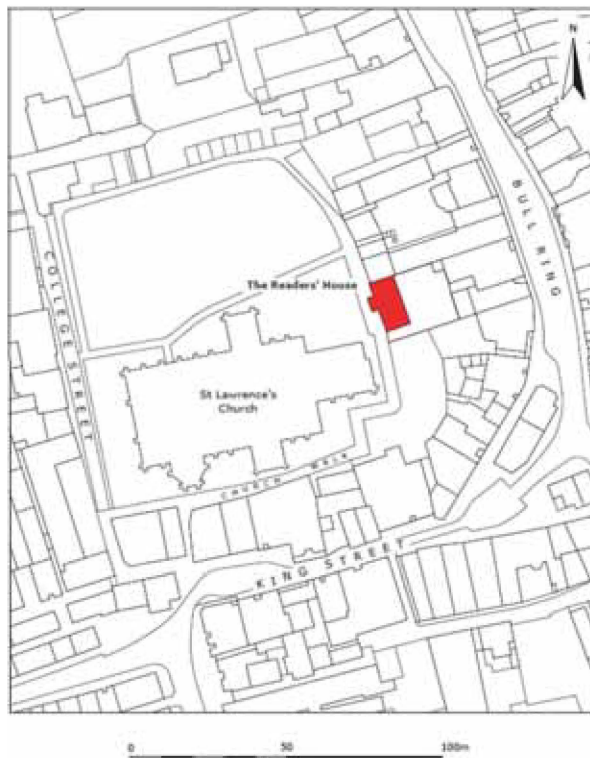


Figure 2: Map showing the location of the Reader's House within its immediate environs (supplied by R Tyler, Birmingham Archaeology)

electric drill. The resulting cores were glued to wooden laths, 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. The cores 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 Tyers (2004). Cross-matching was attempted by a combination of visual matching and a process of qualified statistical comparison by computer. 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 and compared on the computer monitor. 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 felling 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 early wood 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* 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 11–41 rings (Miles 1997a). 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 AND INTERPRETATION

Basic information about the samples taken is presented in Table 1. The samples taken in 2006 retain their site code 'ludl', whilst samples taken specifically for this investigation are given the site code 'rh'. A number of cores fragmented (i, ii, iii) and some timbers had duplicate cores taken (a, b). Approximate locations of the samples taken are shown in Figures 3 – 11, all adapted from drawings supplied by Ric Tyler. The sampling strategy for this second more extensive phase of analysis in this complex building firstly involved reassessment of the various areas of interest bearing in mind that the earlier small scale study found two different dates for what appeared to be primary framing members. It was felt important therefore to take sufficient samples from primary timbers to try to resolve this apparent contradiction.

In addition, it had been suggested that the porch may have been a later addition, and samples were therefore sought to confirm or deny this hypothesis. It was noted during the assessment that the north wall of the property was rather different in character, having generally much smaller timbers, and whilst it would have been of interest to date this wall, none of the timbers were found to be suitable, as they contained too few rings. There was some question from the building analysis as to whether the second-floor ceilings were primary or inserted, and sampling was directed to timbers that may be capable of answering this question. Two octagonal posts in the basement were almost certainly brought into the house from elsewhere, but their dates were of intrinsic interest to the property, so these too were sampled.

Twenty-five timbers were sampled, in addition to the original six from the 2006 study. Of these, one (rh04) was rejected from further study as it contained too few rings (<45), although duplicate cores or sections from fragmented cores with fewer rings are generally measured. The ring width data for each sample is given in the Appendix.

The ring sequences from duplicate cores were combined to form single timber sequences where a combination of acceptable statistical and visual cross-matching was obtained. Two samples from timbers from the south wall (rh17 and ludl5) matched each other very well ( $t = 13.1$ , with 134 years overlap) and were thought to represent two timbers derived from the same parent tree. These series were therefore combined to form a new series, rh17l5, used in subsequent analysis. As well as rh17 and ludl5, and a further 16 individual series were successfully cross-matched (Fig 12; Table 2) and dated by a combination of intra- and inter-site cross-matching. The level of the intra-site cross-matching is somewhat variable, perhaps suggesting different sources for the trees used which is not uncommon in an urban context. The 18 dated samples, representing 17

trees, were combined to form a 210-year site chronology, READERS1, dating to the period AD 1406–1615. The dating evidence for this is presented in Table 3.

## DISCUSSION

This complex site shows the importance of extensive sampling in order to assist interpretation of a building through the provision of independent dating evidence for different elements of a building. As indicated above, the first, very limited analysis, carried out in 2006 (Miles *et al* 2006) revealed a potentially more complex history than anticipated. As part of this, subsequent, more extensive analysis the sampling carried out in 2009 led to the conclusion that the early date found for a tiebeam was a one-off timber that was either stockpiled long-term or reused, although there were no signs of this, and it was initially thought that from the distribution of felling dates, it looked as though there had been a building phase in the later AD 1590s or early AD1600s, with the porch and roof added in the mid AD 1610s. However, following on from this in 2010, it was decided to target a small number of additional timbers considered potentially vitally important with respect to their ability to aid the overall interpretation of the dendrochronological evidence which led to further reinterpretation of the dendrochronological results.

When considered overall there is a preponderance of material felled in the AD 1610s throughout the building and the disparate nature of the felling dates or felling date ranges obtained for the other dated timbers suggests, at the very least, a major rebuild and more likely indicates that the building was actually constructed in the mid AD 1610s (Figs 12 and 13). This would certainly agree with the inscribed date of '1616' on the porch. In this instance the earlier material would therefore appear to have been either stockpiled or reused, although evidence of reuse is clearly lacking on some of these earlier timbers. Nevertheless it seems unlikely that the tiebeam (Iud14) felled in the summer AD 1553 had been stockpiled for over 60 years.

There had been considerable discussion as to whether the large gable on the east side of the main roof was a primary part of the present roof or whether it was a later addition based on the fact that it runs across a truss. The lay board (rh24) on the south side of this dormer produced a felling date range of AD 1614–5 (Figs 12 and 13; Table 1), having lost either two or three sapwood rings during preparation. As the lay board is plank-like in cross-section, it was not likely to have been reused from another part of the building, and there was no other evidence for it having been recycled, thus the most logical explanation is that the gable is primary to the present roof. This felling date range of AD 1614–5 is clearly coeval with the three purlins dated from what appears to be the primary construction phase of the main roof.

The question as to whether the ceilings to the second floor were inserted or were primary was also raised. The sample from an axial beam (rh23) in the southern bay failed to date, but a common joist (rh25) in this same bay did date to the summer of AD1611.

The east-west chamfered ceiling beam appears primary, and it is most likely that the ceilings were part of the primary roof construction.

Following the completion of this analysis, Michael Page found a letter from Thomas Kaye to Ludlow Corporation in the Shropshire Archives (LB4/3/1999). Although not dated it is almost certainly from about 1620 (Page pers comm) and refers to '*the house in the Church Yard... that he hath new builded to his great charges*'. This clearly supports the conclusion reached from the dendrochronological evidence that Reader's House was constructed in the mid AD 1610s.

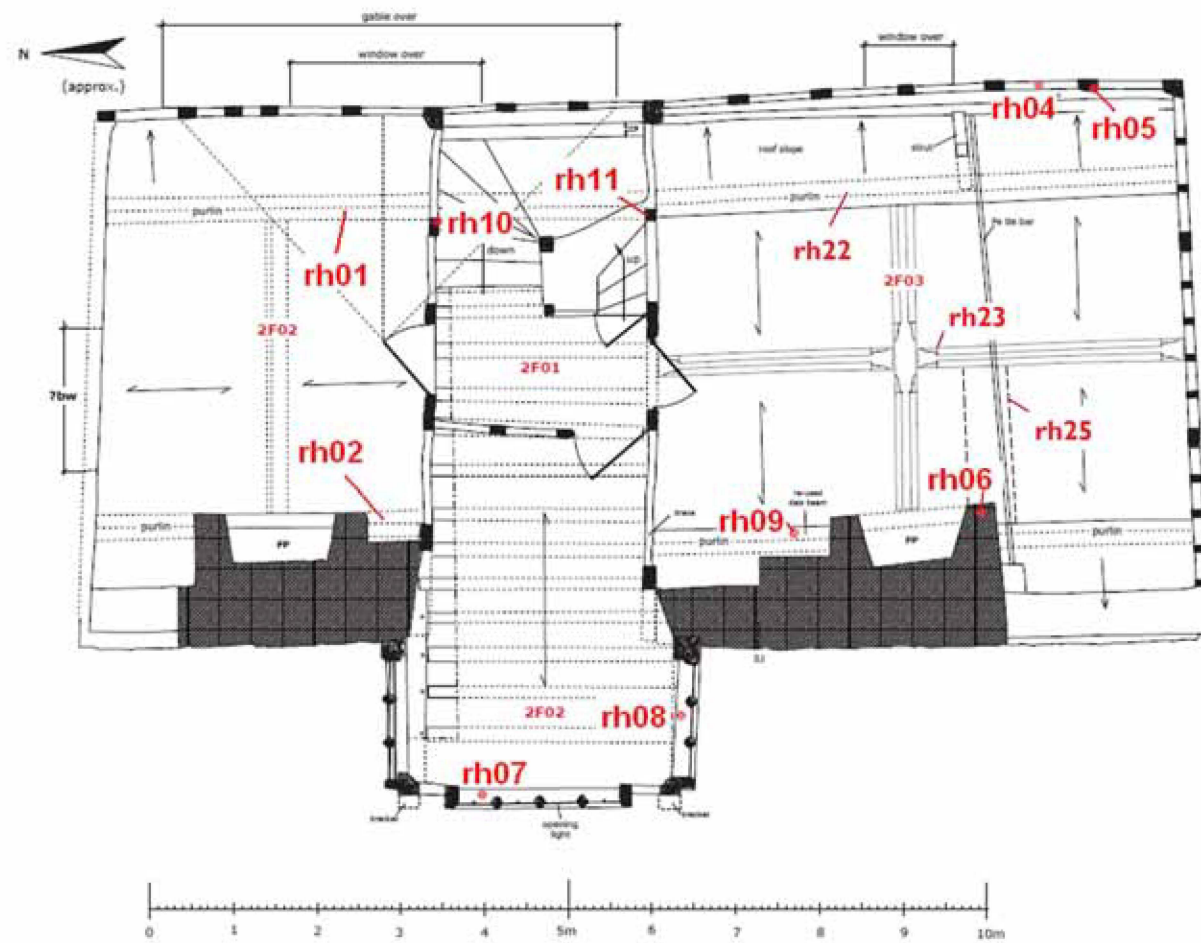


Figure 3: Second-floor plan, showing timbers sampled for dendrochronology (after Tyler).

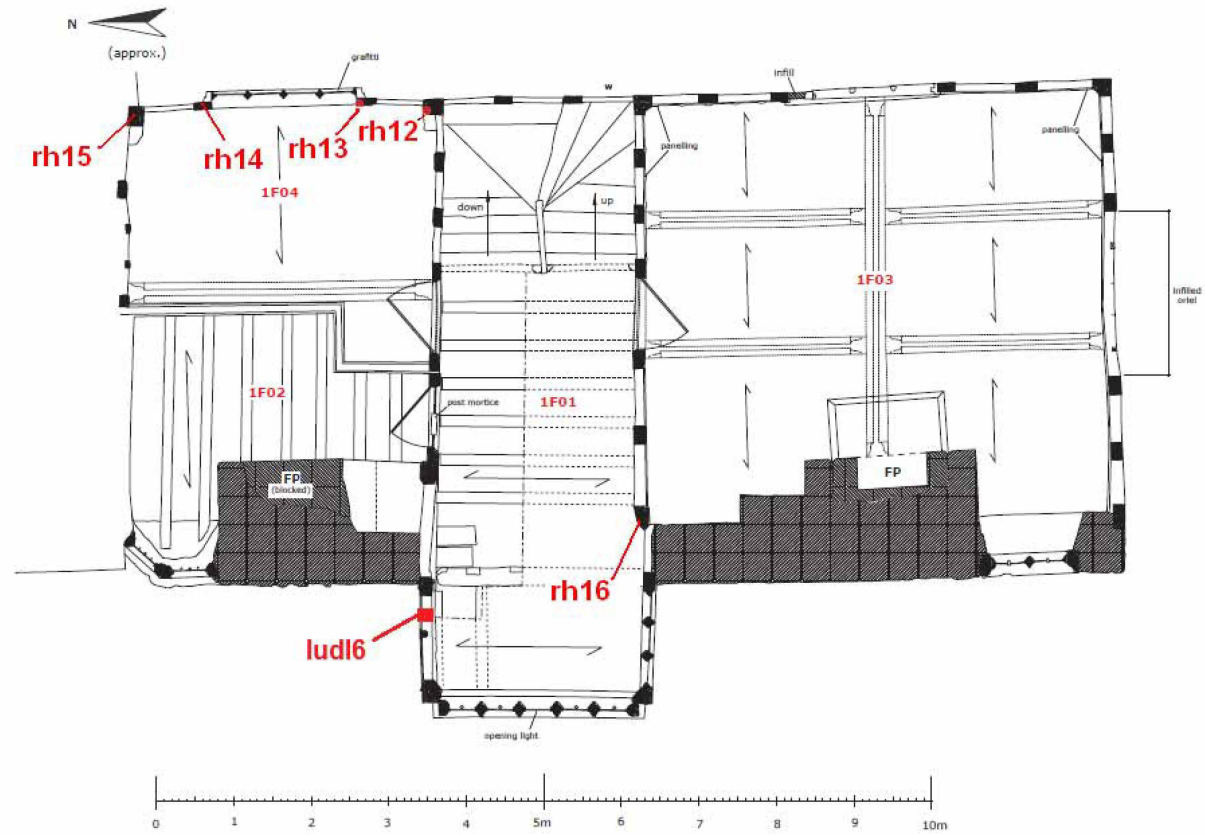


Figure 4: First-floor plan, showing timbers sampled for dendrochronology (after Tyler)

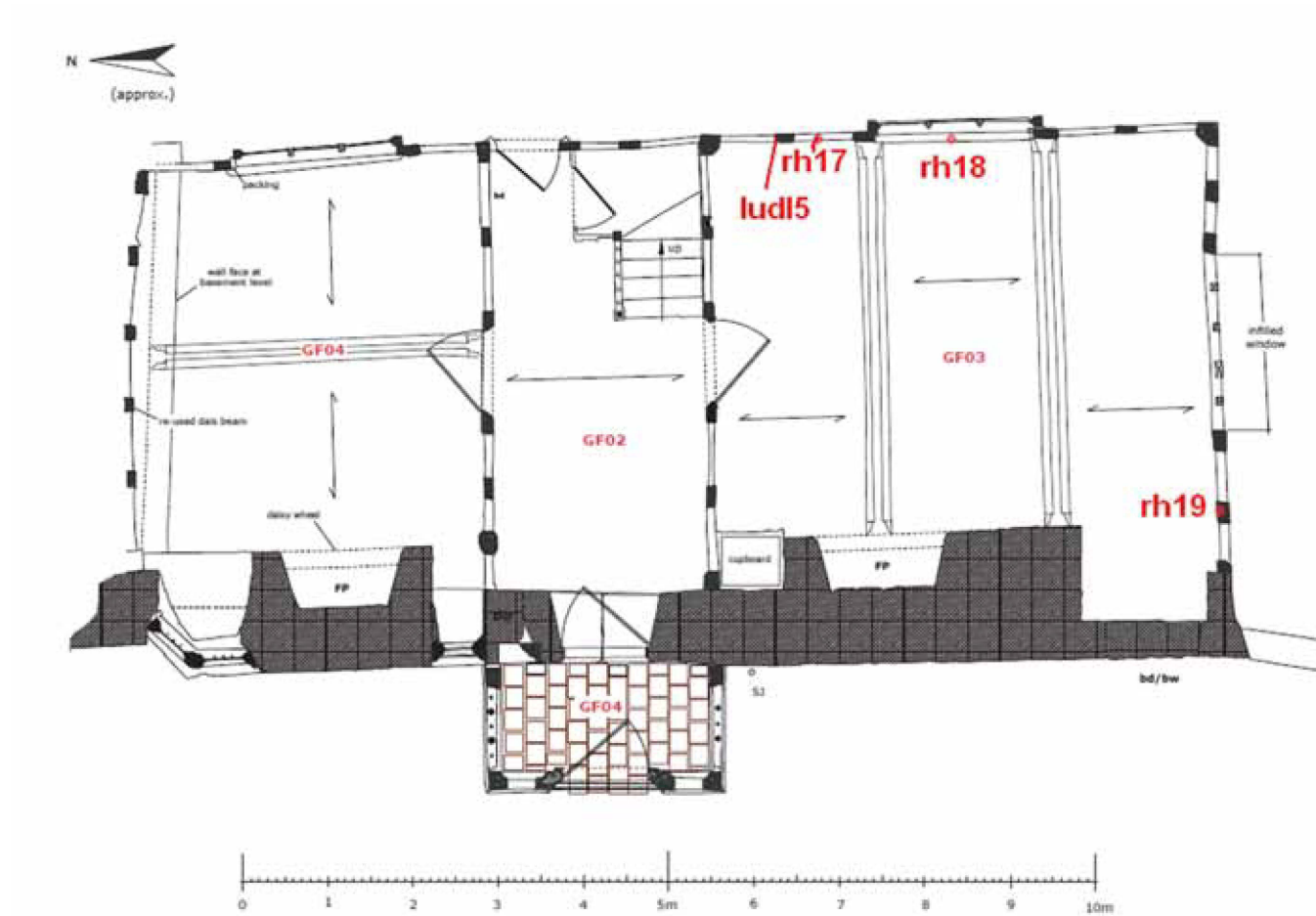


Figure 5: Ground-floor plan, showing timbers sampled for dendrochronology (after Tyler)

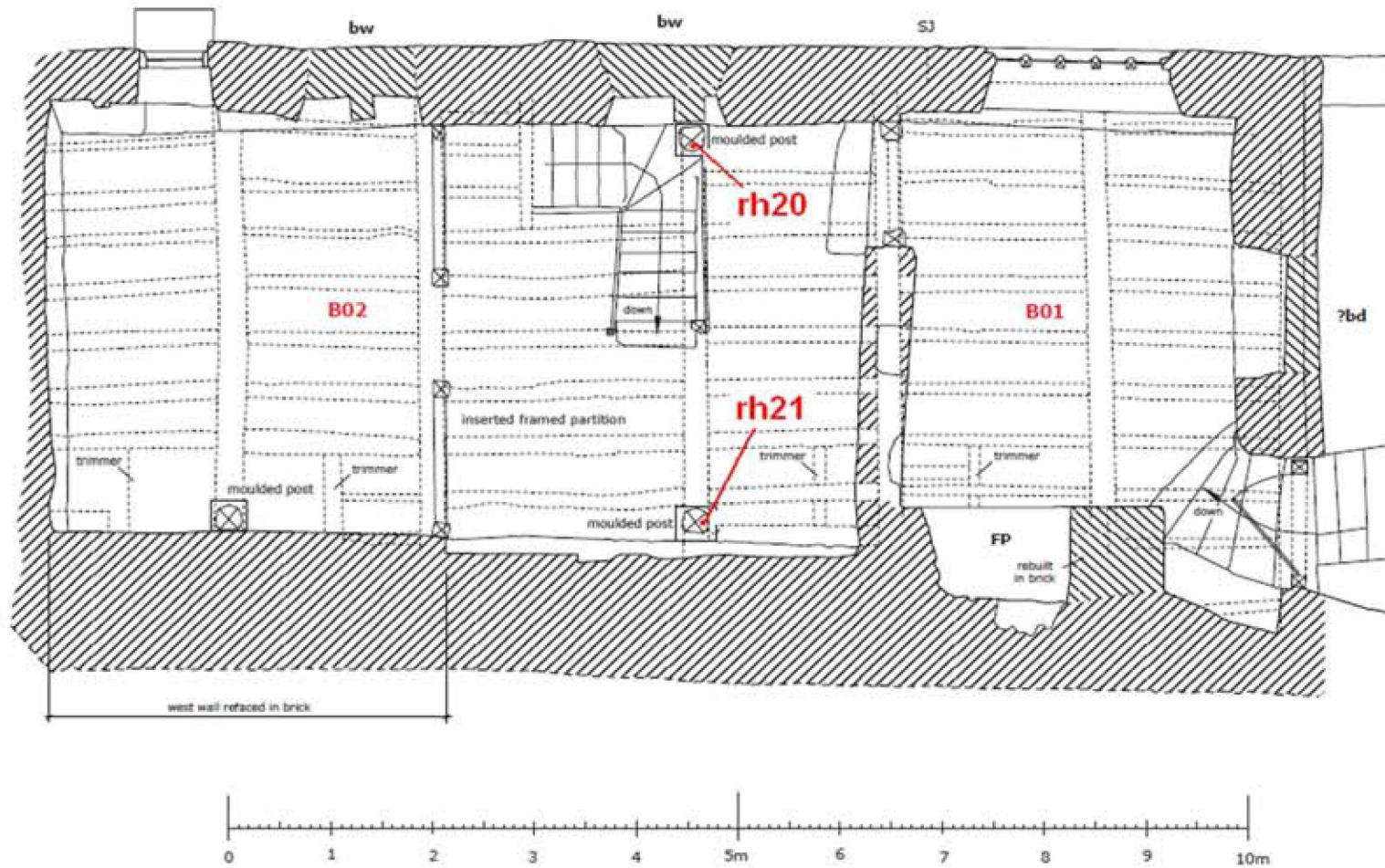


Figure 6: Basement plan, showing timbers sampled for dendrochronology (after Tyler)



Figure 7: South elevation, showing timbers sampled for dendrochronology (after Tyler). Sample rh03 is shown in its approximate position, and is therefore shown in a different colour



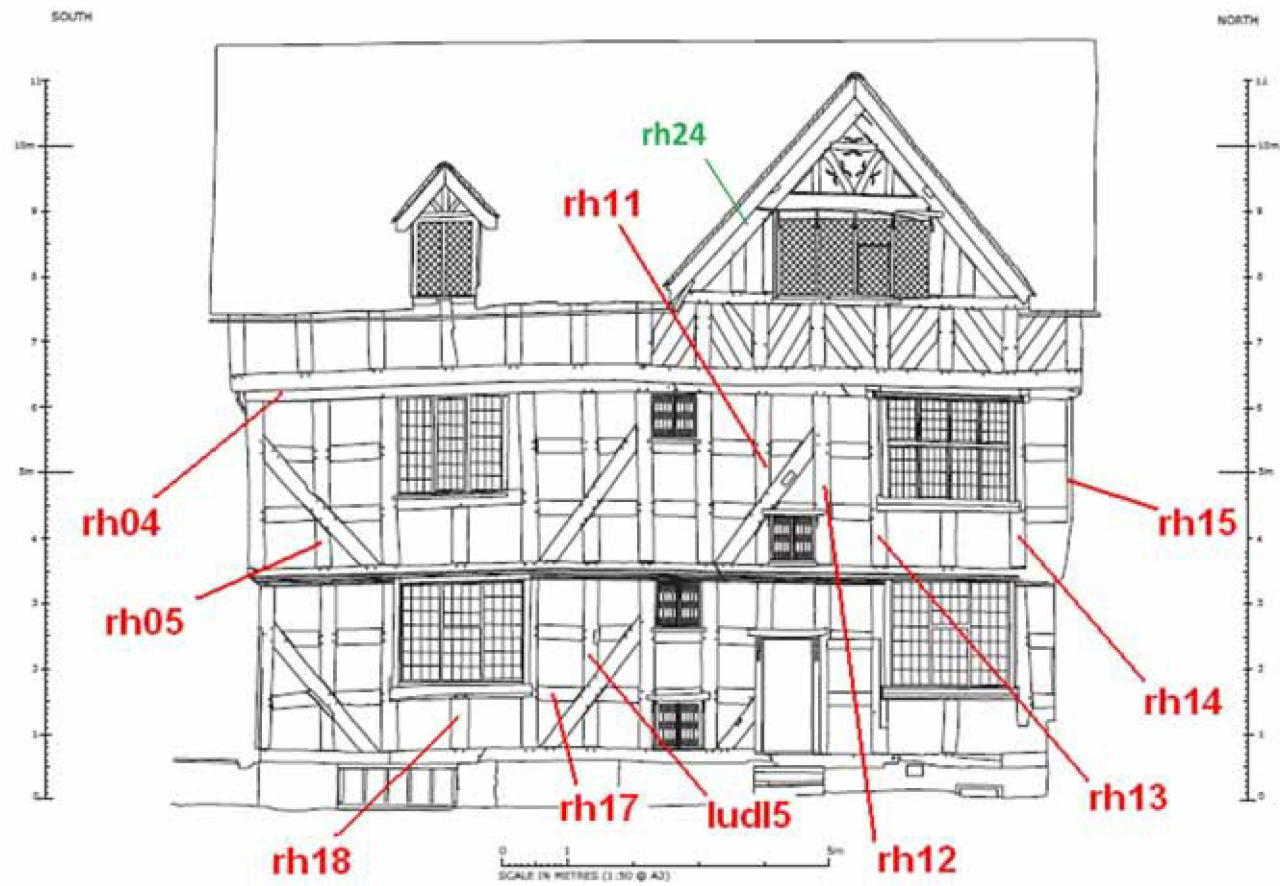


Figure 8: East elevation, showing timbers sampled for dendrochronology (after Tyler). Sample rh24 lies behind the position shown, and is therefore shown in a different colour

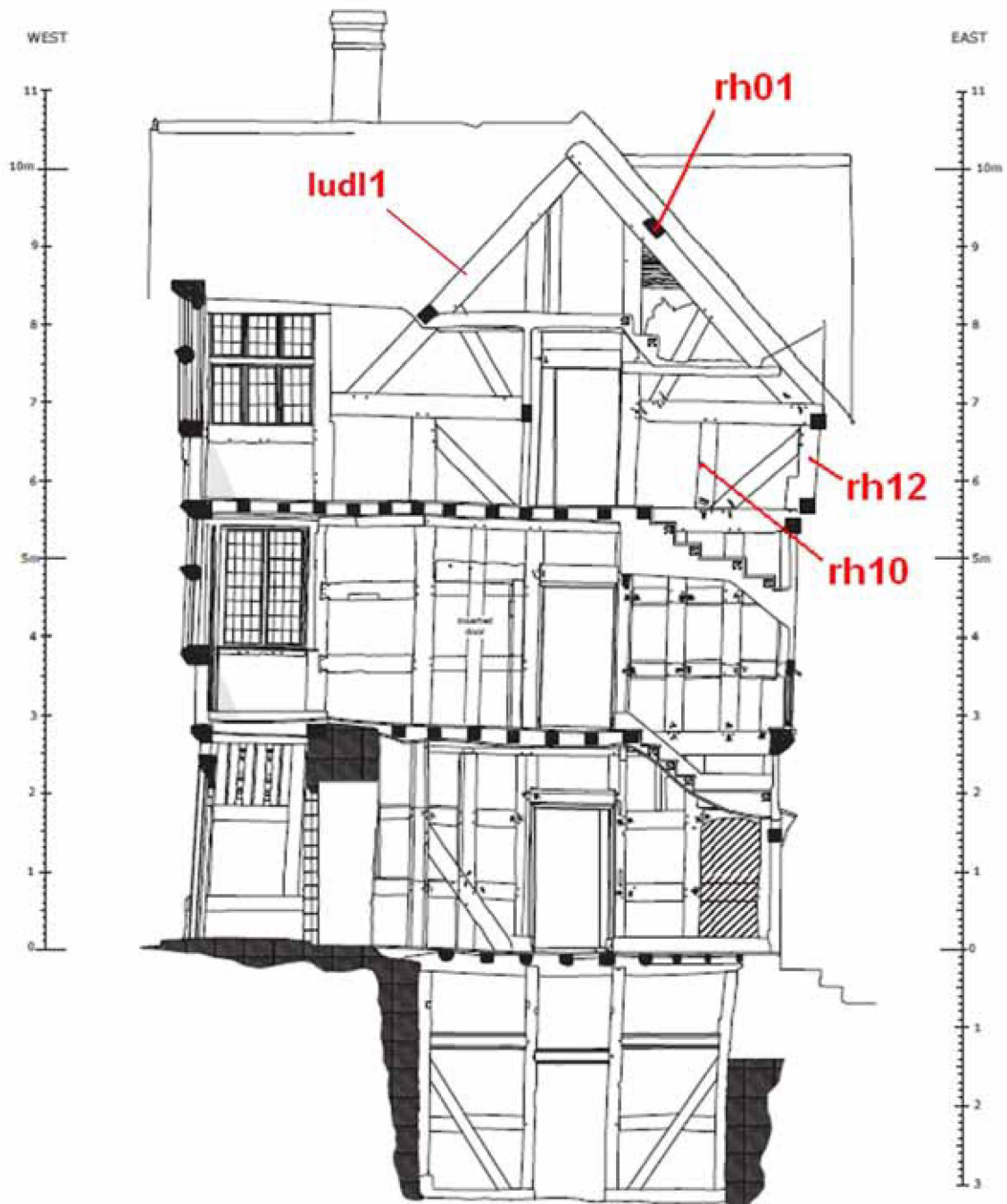


Figure 9: Cross-section, showing timbers sampled for dendrochronology (after Tyler)

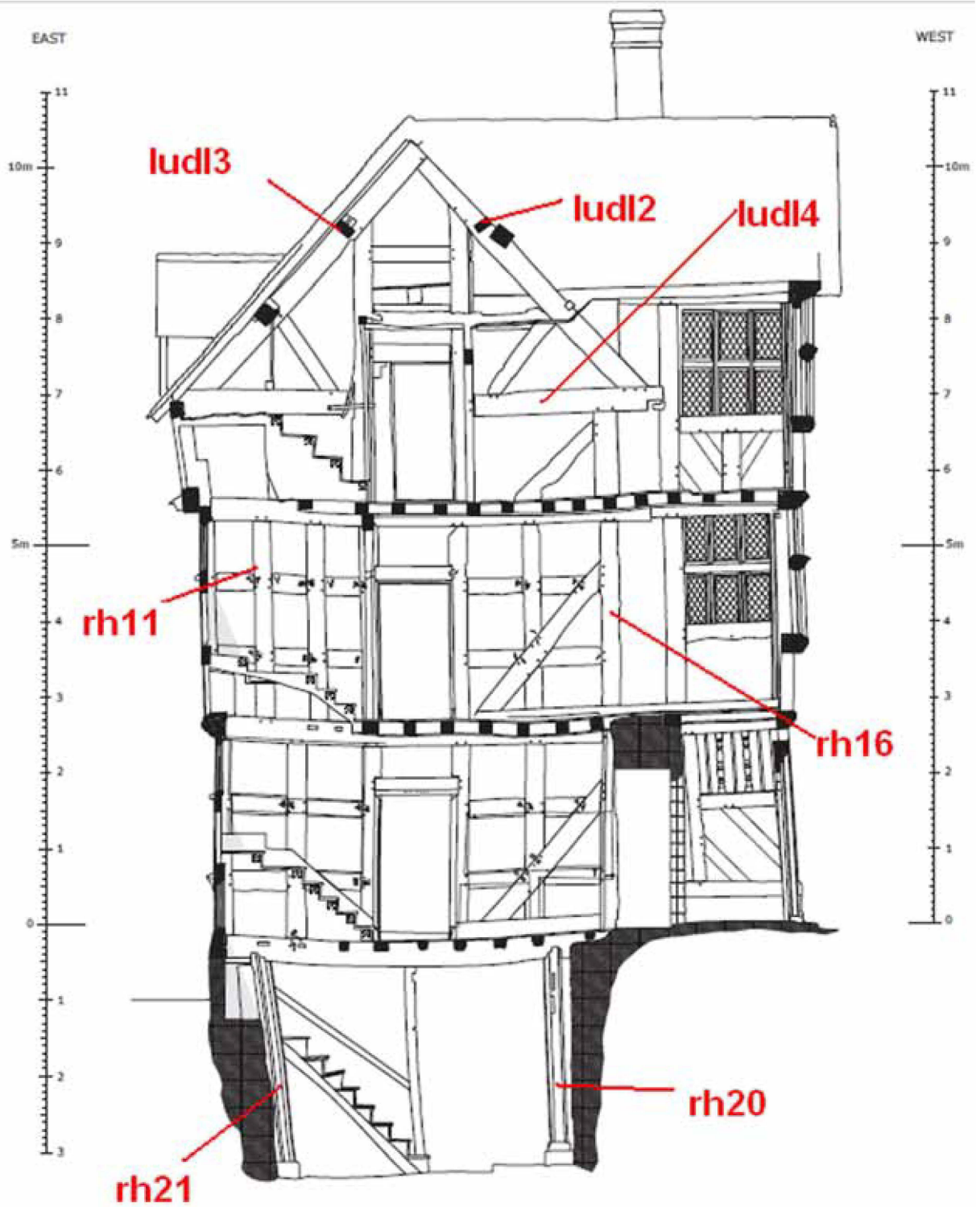


Figure 10: Cross-section showing timbers sampled for dendrochronology (after Tyler)



Figure 11: The porch, showing timbers sampled for dendrochronology (after Tyler)

**Table 1: Details of oak (*Quercus spp*) timbers sampled from the Reader's House, Ludlow. Truss numbering follows that used by Ric Tyler in his survey**

Sample	Timber and position	No of rings	Mean width (mm)	Mean sens (mm)	Spanning Dates (AD)	H/S bdry (AD)	Sapwood	Felling seasons and dates/date ranges (AD)
Roof Structure								
rh01	Upper east purlin, north end	51	1.78	0.25	undated	-	-	unknown
rh02	Upper west purlin, north end	54	2.65	0.19	undated	-	-	unknown
rh03	South purlin, rear stair bay.	91	2.07	0.19	1481–1571	1551	20	1572–92
lud1a	West principal rafter Truss 4	130	1.31	0.16	undated	-	18	unknown
lud1b	<i>ditto</i>	21	1.36	0.14	undated	-	21½C	unknown
lud2	West upper purlin Truss 3 - Truss 2	193	0.77	0.19	1421–1613	1573	40½C	summer 1614
lud3	East upper purlin Truss 3 - Truss 2	209	0.96	0.17	1406–1614	1582	32C	winter 1614/15
rh22	East lower purlin Truss 3 - Truss 2	180	0.97	0.18	1435–1614	1584	30C	winter 1614/15
rh24a	South lay board to east gable Truss 3 - Truss 4	97	1.54	0.24	1514–1610	1597	13	
rh24b	<i>ditto</i>	40	1.50	0.24	1573-1612	1596	16+2 or 3 NM to C	
rh24	Mean of rh24a and rh24b	99	1.53	0.24	1514–1612	1596	16+2 or 3 NM to C	1614–15
Second floor								
rh04	South room (2F03), east wall plate Truss 1 - Truss 2	<45	NM	-	undated	-	-	unknown
rh05	South room (2F03), 1st stud from south in east wall	57	1.24	0.25	undated	-	30¼C	unknown
rh06	South room (2F03). Fireplace lintel	182	0.91	0.21	1432–1613	1576	37C	winter 1613/14
rh09	South room (2F03), reused moulded dais beam	55	3.53	0.22	undated	-	-	unknown
rh10	Stud in north wall of stair bay (2F01)	74	1.53	0.19	1507–80	1580	h/s+c 25 NM to C	c 1605
rh11	Stud in south wall of stair bay (2F01)	78	1.60	0.23	undated	-	4	unknown

**Table 1: (cont)**

Sample	Timber and position	No of rings	Mean width (mm)	Mean sens (mm)	Spanning Dates (AD)	H/S bdry (AD)	Sapwood	Felling seasons and dates/date ranges (AD)
ludl4i	Tiebeam at north end of 2F03 (Truss 3)	38	1.86	0.17	undated	-	-	-
ludl4ii	<i>ditto</i>	106	1.15	0.16	1447–1552	1522	30½C	summer 1553
rh23	Axial ceiling beam Truss 1 - Truss 2 (2F03)	108	1.40	0.25	undated	-	3	unknown
rh25	Ceiling joist, 2nd south of tiebeam to Truss 2, west side, over 2F03	144	0.69	0.18	1467–1610	1567	43½C	summer 1611
Second floor Porch								
rh07a	Porch (2FO2), mid-rail on west wall	54	1.54	0.24	1562–1615	1582	33½C	
rh07b	<i>ditto</i>	41	1.17	0.24	1575–1615	1582	33½C	
rh07	Mean of rh07a and rh07b	54	1.35	0.24	1562–1615	1582	33½C	summer 1616
rh08	Porch (2FO2), mid-rail in south wall	103	1.68	0.24	1475–1577	1570	7	1581–1611
First Floor Porch								
ludl6a1	Stud	37	NM	-	undated	-	-	unknown
ludl6a2	<i>ditto</i>	28	NM	-	undated	-	19½C	unknown
First Floor								
rh12a	East principal post Truss 4	79	1.73	0.18	undated	-	-	
rh12b	<i>ditto</i>	77	1.45	0.17	undated	-	h/s	
rh12	Mean of rh12a and rh12b	88	1.68	0.17	undated	-	h/s	unknown
rh13ai	Room 1F04, south window jamb	42	1.12	0.09	undated	-	-	unknown
rh13aii	<i>ditto</i>	64	0.79	0.13	undated	-	-	unknown
rh13aiii	<i>ditto</i>	56	0.88	0.12	undated	-	-	unknown
rh13b	<i>ditto</i>	63	0.84	0.14	undated	-	-	unknown
rh14	Room 1F04, north window jamb	90	1.40	0.20	1496–1585	1585	h/s+23 NM	1609–26
rh15	Room 1F04, north-east corner post (Truss 5)	87	1.64	0.16	1518–1604	1581	23	1605–22
rh16	West principal post Truss 3	51	1.04	0.14	1514–64	-	-	after 1575

**Table 1: (cont)**

Sample	Timber and position	No of rings	Mean width (mm)	Mean sens (mm)	Spanning Dates (AD)	H/S bdry (AD)	Sapwood	Felling seasons and dates/date ranges (AD)
Ground Floor								
rh17a	South room GF03, mid-rail in east wall at north end	113	1.14	0.18	1462–1574	1561	13	
rh17b	<i>ditto</i>	35	0.92	0.17	1561–95	1563	32	
rh17‡	Mean of 17a and 17b	134	1.11	0.18	1462–1595	1563	32	winter 1598/99
rh18	South room GF03, central stud in east wall	62	2.29	0.16	1511–72	-	-	after 1583
rh19i	South room GF03, west stud in south wall (Truss 1)	57	0.93	0.15	undated	-	-	
rh19ii	<i>ditto</i>	64	0.87	0.14	1521–84	1584	h/s	1595–1625
ludl5a1	South room GF03, stud in east wall	155	0.93	0.20	1431–1585	1561	24	
ludl5a2	<i>ditto</i>	22	0.71	0.16	1577–98	unknown	22C	
ludl5b	<i>ditto</i>	109	0.65	0.20	1489–1597	1561	36	
ludl5‡	Mean of ludl5a1, ludl5a2, and ludl5b	168	0.88	0.19	1431–1598	1561	37C	winter 1598/99
Cellar								
rh20i	South-east reused moulded post under Truss 3	77	1.93	0.21	undated	-	2	
rh20ii	<i>ditto</i>	93	1.75	0.22	undated	-	18	unknown
rh21	South-west reused moulded post under Truss 3	86	2.40	0.17	undated	-	21C	unknown

Key: NM = not measured; h/s = heartwood-sapwood boundary; C = complete sapwood, winter felled; ½C = complete sapwood, felled the following summer; ‡ = from same-tree. A sapwood estimate of 11–41 is used (Miles 1997a)

**Table 2: Cross-matching between the dated series from *The Reader's House*; t-values of 3.5 and over are considered significant**

	t-values																
Sample	ludl3	ludl4ii	ludl5	rh03	rh06	rh07	rh08	rh10	rh14	rh15	rh16	rh17	rh18	rh19ii	rh22	rh24	rh25
ludl2	4.8	1.8	0.5	1.4	5.0	4.9	2.8	2.2	4.7	2.5	2.0	1.8	1.2	3.2	4.7	0.2	3.6
ludl3		3.6	2.8	2.4	5.1	2.2	5.5	1.2	2.9	1.0	1.9	1.0	1.0	1.8	6.9	1.4	3.5
ludl4ii			2.6	3.0	1.8	*	2.5	1.5	1.8	1.0	0.3	2.2	1.5	0.7	1.2	1.4	1.4
ludl5				2.2	5.3	0.5	2.1	3.7	1.6	5.7	0.9	13.2	3.2	3.5	2.9	4.4	2.4
rh03					0.8	*	4.3	1.4	2.4	2.9	2.2	1.6	3.5	1.5	2.4	2.6	1.6
rh06						5.2	4.0	5.1	4.1	5.4	3.9	3.3	3.5	3.3	5.1	2.6	4.0
rh07							*	*	3.7	4.7	*	0.9	*	2.9	0.9	-0.8	-0.8
rh08								1.4	3.6	2.6	1.8	2.1	2.9	1.8	3.3	3.1	0.9
rh10									3.4	6.3	3.4	3.2	4.5	2.4	2.7	4.7	3.5
rh14										4.5	4.8	2.6	2.4	4.1	3.9	2.4	1.9
rh15											4.9	5.1	5.4	3.6	2.6	5.5	2.7
rh16												1.0	3.5	1.9	5.1	2.9	2.3
rh17													1.7	2.4	0.4	3.0	2.3
rh18														3.4	3.3	5.3	1.7
rh19ii															1.9	3.3	1.0
rh22																2.4	3.6
rh24																	2.0

\* = less than 20 years overlap, no calculation made



**Table 3: Dating evidence for the site master chronology READERS1, AD 1406–1615, file names in BOLD represent regional chronologies**

County/region:	Chronology name:	Short publication reference:	File name:	Spanning: (yrs AD)	Overlap (yrs)	t-value
Wales	Welsh Master Chronology	(Miles 1997b unpubl)	<b>WALES97</b>	404–1981	210	13.8
Shropshire	Shropshire Master Chronology	(Miles 1995 unpubl)	<b>SALOP95</b>	881–1745	210	13.3
Worcestershire	Mere Hall, Hanbury	(Miles <i>et al</i> 2005)	MEREHALL	1408–1610	203	11.6
Wales/borders	Hillside oaks	(Siebenlist-Kerner 1978)	<b>GIERTZ</b>	1341–1636	210	10.5
Warwickshire	Kingsbury Hall	(Arnold <i>et al</i> 2006)	KNHHSQ01	1391–1564	159	10.4
Worcestershire	Upwich, Droitwich	(Groves and Hillam 1997)	UPWICH3	1454–1651	162	10.3
Shropshire	Clungunford	(Miles 2002 unpubl)	CLNGNFRD	1273–1653	210	10.2
Shropshire	Lydbury North mean	(Miles <i>et al</i> 2007)	LYDBURY	1363–1658	210	10.0
Worcestershire	Plowstall Farmhouse, Bayton	(Miles <i>et al</i> 2008)	BAYTONPF	1410–1570	161	9.9
Gloucestershire	Swan House, Blakeney	(Miles <i>et al</i> 2009)	SWANHS	1386–1628	210	9.6
Shropshire	Alcaston Hall	(Miles and Worthington 1998)	ALCASTON	1389–1556	151	9.3
Staffordshire	Sinai Park	(Tyers 1997)	SINAI	1227–1750	210	9.3
Yorkshire	Kirkburton Church	(Arnold and Howard 2007)	KRKCSQ02	1306–1633	210	9.2

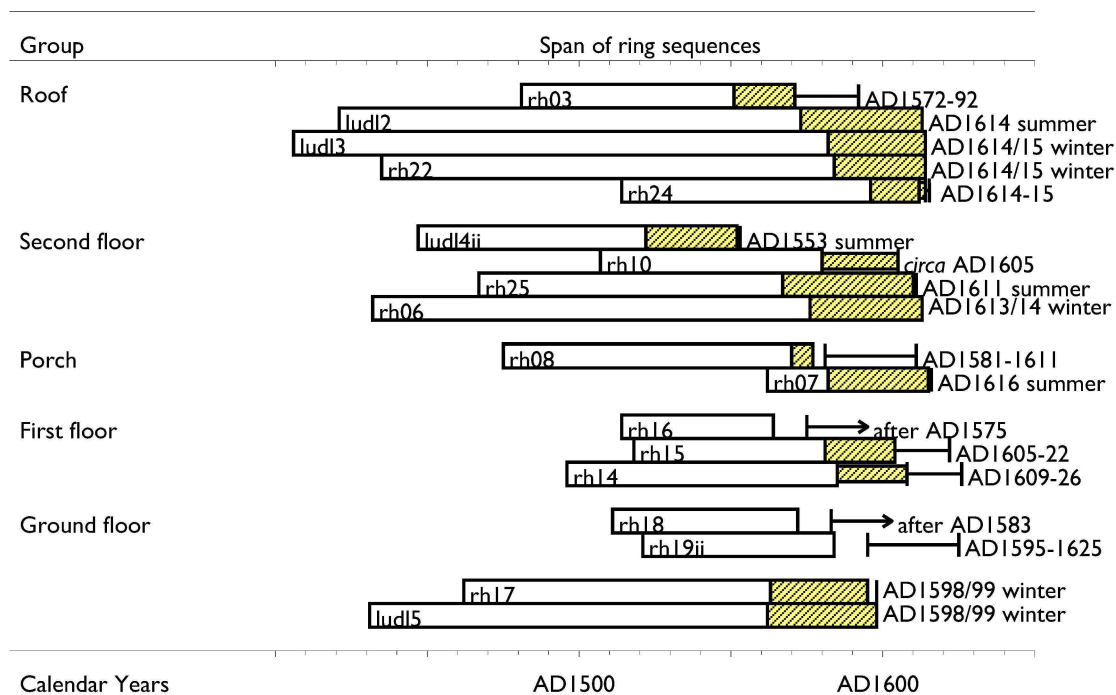


Figure 12: Bar diagram showing the relative positions of overlap between the dated series, along with their likely interpreted felling dates, sorted by area. Yellow hatched sections represent sapwood, and narrow sections are additional unmeasured rings

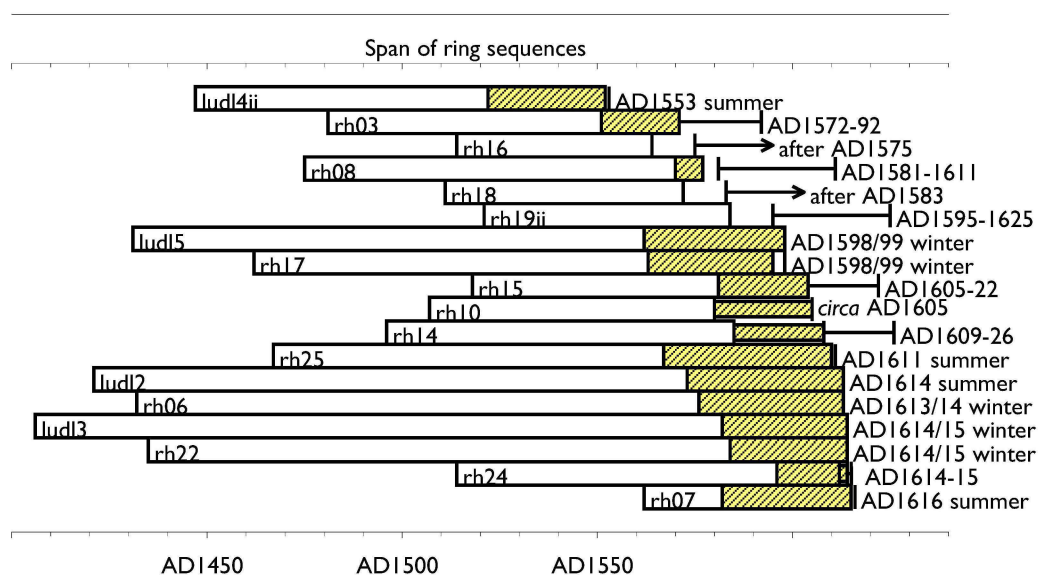


Figure 13: Bar diagram showing the relative positions of overlap between the dated series, along with their likely interpreted felling dates. Yellow hatched sections represent sapwood, and narrow sections are additional unmeasured rings

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## APPENDIX

Ring width values (0.01mm) for the dated samples from Reader's House, Ludlow

### ludl1a

195	140	139	154	193	186	198	230	209	211
259	377	364	311	311	236	207	207	212	197
150	165	202	184	202	211	131	200	122	74
137	171	185	197	278	152	209	119	146	165
164	154	134	168	158	120	131	147	153	166
158	133	146	138	173	167	150	114	97	52
55	82	71	81	57	76	80	101	95	101
85	87	77	65	73	80	83	100	95	85
68	76	90	68	69	75	90	73	86	92
85	76	85	62	47	52	57	77	78	77
93	80	69	68	61	69	52	84	96	104
97	104	100	119	111	152	141	128	123	113
133	128	161	138	146	130	120	83	90	122

### ludl1b

126	109	142	163	172	157	150	157	132	144
108	132	101	117	121	118	138	177	145	117
130									

### ludl2

163	146	222	164	199	151	143	125	129	152
107	143	109	84	108	72	80	70	58	68
67	97	82	95	96	143	101	104	150	96
98	110	121	96	103	126	106	84	65	103
86	110	105	115	121	106	103	119	102	105
116	115	70	88	96	119	57	68	80	98
123	102	93	101	132	98	89	61	66	83
67	63	57	67	79	122	83	100	165	71
73	78	74	77	79	91	66	101	74	60
93	104	93	70	90	57	57	68	101	70
70	82	64	51	53	66	59	66	57	48
70	46	56	39	45	62	58	63	69	71
75	77	62	67	68	87	61	88	67	90
85	65	71	72	73	69	71	57	56	47
48	47	30	26	20	16	16	32	38	29
31	28	34	33	33	26	24	24	36	33
30	34	33	45	45	49	45	67	58	48
56	57	51	47	68	37	46	37	40	43
51	48	59	60	53	64	50	61	64	54
57	51	81							

### ludl3

323	231	264	263	259	145	215	182	192	164
184	134	134	113	197	168	125	170	114	126
88	92	84	87	89	87	143	121	116	105
67	95	77	81	82	90	62	92	91	90
94	92	85	121	92	87	98	105	95	99
114	99	97	88	112	92	106	103	80	105

65	77	105	150	109	89	74	112	114	120
115	92	93	97	85	101	83	99	149	126
113	141	93	84	87	87	59	87	92	88
133	106	100	116	94	89	94	95	105	79
75	66	85	115	100	101	105	98	86	76
76	61	85	91	74	86	80	81	72	52
71	69	64	66	55	75	65	62	66	81
63	70	59	71	60	65	66	76	70	79
85	69	154	129	139	105	116	105	122	108
91	96	71	119	113	73	59	46	47	45
32	38	44	67	65	69	81	69	74	65
54	56	43	54	51	61	52	50	63	63
56	61	76	63	71	83	91	92	107	89
63	66	81	78	85	99	118	95	131	84
97	100	87	90	87	77	72	115	110	

ludl4i

159	220	226	206	215	150	143	207	214	214
173	290	302	251	192	227	264	178	230	184
140	164	246	212	261	222	226	191	177	133
113	103	98	108	114	130	99	92		

ludl4ii

120	126	128	96	99	87	122	140	130	183
128	129	105	168	169	156	159	119	109	110
130	149	110	126	96	100	156	107	134	65
60	95	131	86	108	105	116	95	102	90
95	82	88	105	103	109	126	92	103	86
93	63	102	99	89	92	92	111	109	104
87	72	83	80	99	128	107	103	100	97
83	92	99	104	104	112	110	123	96	117
113	136	140	113	132	102	101	130	148	159
131	166	156	129	132	124	162	136	134	144
108	156	141	130	128	144				

ludl5a1

154	178	136	165	191	180	174	146	100	138
145	100	108	135	142	145	136	141	119	112
136	113	125	136	130	137	101	82	111	84
63	86	87	69	74	72	85	103	134	115
112	75	126	113	149	113	76	98	130	122
104	54	106	139	122	135	151	117	116	124
74	59	98	116	106	118	115	89	99	128
136	122	111	116	122	128	107	87	82	74
89	88	101	93	64	63	70	37	48	43
62	66	46	65	43	61	49	83	70	56
74	69	57	77	64	84	80	74	73	97
97	55	81	50	49	102	83	91	84	84
85	69	71	45	59	47	68	73	72	66
69	78	67	71	37	42	52	56	81	93
102	63	78	67	48	79	57	49	67	69
73	47	63	87	71					

ludl5a2

67	60	71	61	69	56	67	87	78	87
79	53	52	51	61	66	78	83	68	84
68	105								

ludl5b

91	124	52	54	93	97	96	160	96	78
96	109	122	102	131	110	113	150	111	84
67	85	119	97	86	72	45	58	55	35
38	38	64	58	49	52	43	46	47	74
52	48	65	59	43	59	52	72	64	56
58	75	80	43	60	37	48	70	78	78
81	65	76	55	54	34	37	39	62	59
56	56	52	64	55	56	34	34	50	50
64	78	81	54	61	56	38	49	54	44
58	48	48	41	44	54	47	48	57	40
38	37	44	46	46	55	49	67	58	

ludl6a1

116	166	228	204	151	173	205	185	199	192
172	138	152	115	116	164	219	208	220	205
141	177	169	127	148	115	152	253	165	128
121	159	169	236	181	103	173			

ludl6a2

240	185	110	181	125	175	156	150	163	193
157	174	191	182	125	147	181	214	251	126
138	125	182	164	146	175	136	127		

rh01

203	191	303	190	216	269	117	232	258	208
164	179	260	305	244	244	195	194	220	285
175	150	203	164	199	171	279	190	91	87
71	97	124	144	149	151	118	141	122	149
79	147	105	151	159	115	126	138	163	221
200									

rh02

605	527	631	523	329	329	290	313	466	348
316	328	431	408	328	369	372	388	394	367
252	273	245	261	279	218	186	194	307	314
322	311	205	128	100	122	123	101	118	127
123	106	190	228	244	154	165	134	206	138
80	118	85	76						

rh03

498	304	370	403	240	418	679	607	607	449
333	260	347	316	396	429	362	266	296	314
230	233	253	329	296	298	161	192	238	223
274	314	130	107	121	92	78	93	93	83
117	121	86	99	97	99	99	152	146	125
122	114	117	139	142	129	112	125	173	180
170	148	145	163	167	149	148	162	152	163
208	145	230	110	124	149	114	110	164	172

194 183 148 156 120 127 95 117 119 121  
118

rh05

276 230 222 255 225 337 302 312 275 255  
186 92 101 57 79 76 110 179 145 112  
90 87 79 79 93 116 70 42 38 60  
84 83 59 47 41 34 50 74 63 82  
112 112 89 74 93 96 93 107 212 156  
122 86 86 97 178 90 45

rh06

266 233 300 268 134 151 109 115 149 158  
127 112 146 134 117 105 112 182 164 142  
144 108 73 63 75 78 113 81 84 98  
170 168 117 106 77 87 84 124 175 150  
89 105 120 149 123 75 63 100 117 110  
106 110 107 127 112 85 50 58 90 72  
51 58 56 67 106 70 52 81 103 89  
97 82 85 76 76 61 74 72 64 89  
83 131 108 96 60 65 58 68 67 88  
114 82 88 55 57 60 77 73 57 84  
67 51 61 86 72 83 63 57 91 111  
69 56 66 59 54 46 60 64 48 41  
36 43 51 60 49 51 46 44 52 50  
81 60 74 47 27 32 54 104 93 120  
94 104 83 83 82 89 77 100 110 92  
109 100 138 120 102 114 73 99 110 145  
112 88 113 110 86 59 50 63 60 87  
78 74 79 90 83 60 68 71 61 65  
43 64

rh07a

222 192 130 118 64 65 130 105 100 117  
86 84 67 73 67 74 72 106 110 110  
111 88 139 151 240 203 172 164 99 196  
177 144 257 308 213 166 161 186 173 316  
237 196 254 184 217 160 224 201 148 213  
122 180 121 96

rh07b

110 70 73 75 133 150 141 120 121 172  
171 211 157 129 152 101 163 126 97 165  
173 130 87 92 126 103 129 132 103 128  
104 98 66 123 94 68 90 83 96 54  
70

rh08

241 160 206 175 174 185 152 206 284 318  
181 129 244 147 139 157 128 112 169 162  
204 251 180 116 142 118 104 160 174 184  
223 150 113 116 127 126 150 166 214 119  
137 115 70 111 108 96 125 206 111 118  
107 116 164 186 192 123 244 211 184 150



156	156	149	175	213	137	199	110	80	73
89	88	76	178	152	133	207	236	246	253
265	190	153	147	206	237	187	273	205	203
157	125	112	132	253	243	435	172	128	211
175	132	140							

rh09

312	313	479	468	406	398	302	261	482	544
704	681	650	514	450	648	561	280	280	233
246	279	426	414	451	530	568	333	310	417
395	336	211	417	396	269	400	342	243	269
222	255	276	259	210	240	312	370	234	254
225	109	60	65	113					

rh10

125	119	118	108	145	186	258	184	191	169
195	146	143	88	120	119	94	109	123	98
110	139	124	131	199	124	105	121	199	195
156	149	177	221	213	142	156	164	135	143
158	166	217	196	175	142	199	174	163	170
188	187	144	152	133	170	102	166	131	107
152	138	208	230	219	183	230	179	117	72
67	69	116	124						

rh11

135	98	129	143	175	172	174	166	115	152
145	97	196	183	113	76	88	85	80	96
105	132	157	175	160	238	159	202	163	100
135	122	166	191	194	149	99	171	135	132
132	135	181	216	154	265	167	127	143	207
203	208	249	196	214	236	217	116	109	98
142	139	140	114	142	208	123	95	222	197
156	297	212	288	209	170	163	187		

rh12a

306	365	336	284	231	281	259	302	249	308
377	329	367	371	238	183	208	208	165	179
196	254	272	261	234	84	78	84	62	72
87	79	72	61	74	66	83	68	67	73
89	118	101	72	113	123	71	73	106	68
102	117	137	108	118	132	107	148	119	132
114	194	168	174	167	201	235	186	187	202
181	252	178	183	210	187	210	210	186	

rh12b

306	324	350	244	213	247	193	173	167	169
207	246	253	200	87	62	53	75	55	73
74	73	50	64	67	77	66	71	71	83
101	83	81	90	101	74	80	90	63	78
110	109	101	119	131	120	151	129	154	124
168	153	168	143	168	203	165	152	167	160
234	164	175	230	196	183	187	178	246	174
168	133	145	125	185	159	148			

## rh13ai

142	148	157	131	123	133	127	124	98	92
120	110	112	108	123	125	116	124	106	113
117	132	126	124	95	102	90	97	95	90
105	89	101	95	91	107	96	104	92	90
93	120								

## rh13aaii

71	107	97	103	98	88	94	115	108	84
87	82	91	97	96	100	110	92	95	77
66	51	47	58	62	47	45	45	52	47
64	63	60	60	75	58	74	68	67	87
74	91	99	76	103	72	80	67	74	63
62	64	70	84	91	97	88	92	80	84
96	121	74	87						

## rh13aiii

80	87	75	93	78	96	87	100	77	79
68	64	79	67	90	89	83	83	83	91
81	67	70	87	85	78	74	77	77	79
83	61	74	77	93	89	105	74	97	89
98	70	67	74	92	108	118	118	104	111
117	117	124	129	97	109				

## rh13b

54	66	58	50	56	58	67	100	85	90
100	80	90	89	101	66	71	51	67	71
71	84	85	86	96	80	97	68	81	69
90	69	79	85	88	83	85	82	71	72
61	90	89	95	84	106	87	87	83	63
65	78	99	122	113	99	93	122	111	120
128	88	105							

## rh14

333	293	246	455	280	165	139	210	169	128
119	107	133	144	156	173	176	169	171	147
128	180	217	166	115	141	206	116	118	100
144	183	156	121	143	171	105	121	109	136
174	120	117	163	215	183	159	159	132	84
82	72	93	109	112	185	122	130	116	112
93	82	87	101	106	134	150	131	130	93
59	43	66	76	87	120	102	108	130	115
98	110	96	117	133	105	119	107	130	172

## rh15

161	196	175	257	283	198	222	218	182	199
235	240	193	346	242	193	205	242	258	207
174	173	218	240	131	160	183	145	154	180
198	250	223	244	175	193	123	97	105	148
149	125	146	163	167	153	152	103	82	82
127	142	148	186	139	119	115	112	108	119
135	154	182	171	111	94	110	114	141	118
112	107	98	120	141	149	141	135	133	114
141	160	139	159	163	123	194			

rh16

170 153 116 105 155 130 106 111 121 93  
100 91 103 113 96 108 117 147 127 129  
114 139 112 91 80 85 174 151 109 113  
108 107 90 88 122 114 95 106 82 88  
71 63 62 71 60 61 58 69 68 65  
84

rh17a

123 110 67 85 100 109 137 109 119 103  
135 127 147 162 170 108 126 147 156 174  
106 173 172 182 174 174 170 134 158 67  
68 135 158 138 190 126 104 153 177 159  
170 181 144 160 203 131 92 71 93 115  
127 129 129 98 103 103 57 65 63 68  
90 73 89 85 86 88 99 95 82 121  
89 90 94 103 125 101 90 88 113 125  
95 94 60 53 108 118 142 125 124 123  
107 114 70 78 66 105 105 113 115 131  
143 117 101 70 66 67 66 74 116 116  
92 80 98

rh17b

126 136 118 95 67 61 66 84 70 104  
116 82 90 95 55 74 77 71 79 86  
85 78 71 80 94 110 114 85 70 68  
105 101 138 168 105

rh18

219 299 229 179 176 197 168 165 224 201  
286 248 189 259 178 169 197 212 173 177  
236 182 222 225 233 250 223 255 306 366  
324 218 236 247 297 189 225 280 325 283  
322 266 292 207 212 241 246 250 224 218  
239 282 228 243 162 138 148 171 196 249  
222 176

rh19i

118 116 108 109 102 95 115 100 112 94  
111 125 116 103 115 134 124 134 113 133  
123 107 102 104 90 94 102 105 133 99  
96 71 65 51 47 67 64 57 71 49  
53 53 71 85 92 82 84 63 63 81  
44 72 80 91 108 82 122

rh19ii

106 122 92 122 71 99 84 86 64 73  
77 86 87 82 78 79 73 84 91 97  
100 75 71 71 69 89 77 82 102 99  
119 82 118 88 90 75 97 95 103 89  
88 88 89 102 71 64 57 84 93 109  
97 93 79 85 77 61 66 67 91 92  
90 86 83 112

## rh20i

413	389	372	210	296	266	185	155	195	189
132	169	162	220	251	153	130	207	147	174
137	86	94	140	149	121	181	128	166	180
152	244	287	214	219	226	169	166	192	85
85	76	74	120	154	95	102	191	212	224
223	207	171	210	148	241	268	226	270	273
217	188	166	209	186	234	212	257	244	190
188	210	181	267	194	214	202			

## rh20ii

413	389	372	210	296	266	185	155	195	189
132	169	162	220	251	153	130	207	147	174
137	86	94	140	149	121	181	128	166	180
152	244	287	214	219	226	169	166	192	85
85	76	74	120	154	95	102	191	212	224
223	207	171	210	148	241	268	226	270	273
217	188	166	209	186	234	212	257	244	190
188	210	181	267	194	214	202	50	39	41
41	69	105	72	90	104	106	107	106	74
100	137	167							

## rh21

233	262	311	227	284	253	203	199	194	207
225	211	184	190	235	230	228	207	241	177
218	196	181	210	207	228	245	297	253	283
305	204	243	201	220	228	255	305	376	338
253	228	292	208	241	189	142	157	262	182
208	191	169	233	235	272	332	229	220	263
402	359	314	343	240	224	236	206	312	228
201	248	252	254	250	164	204	234	163	282
237	296	250	285	211	222				

## rh22

80	55	69	62	57	65	66	57	56	76
85	95	83	90	110	77	115	92	110	81
132	137	105	138	123	97	99	114	123	111
113	132	120	103	140	116	205	90	171	148
174	161	135	141	127	109	128	96	129	153
155	127	114	86	72	95	72	68	71	101
90	118	96	97	142	104	108	119	116	150
109	100	79	115	145	111	123	113	113	132
109	111	64	122	136	96	139	133	127	103
76	118	98	116	85	83	119	73	87	87
105	103	135	106	121	183	126	83	78	75
71	61	80	131	100	108	105	120	130	125
120	124	106	84	121	76	82	64	46	67
52	59	53	51	63	70	58	64	68	70
65	48	40	45	63	67	51	58	53	75
78	74	65	84	83	79	77	94	86	87
99	75	65	59	71	68	93	93	96	95
87	88	101	82	100	99	81	78	115	92

## rh23

230	225	170	162	108	64	137	176	169	275
259	102	132	78	78	180	100	76	72	66
54	71	54	41	33	53	46	45	29	29
31	43	131	115	129	105	131	119	163	162
151	152	145	166	140	125	105	105	101	101
138	78	110	92	115	174	93	129	128	126
172	154	141	172	144	114	192	226	193	183
233	271	161	226	211	191	239	122	99	116
192	204	142	150	136	180	241	129	103	119
103	121	285	183	190	171	198	184	256	181
174	185	108	173	154	118	166	132		

## rh24a

165	151	149	127	152	108	120	240	247	149
158	61	61	71	119	107	102	321	193	186
170	276	163	157	169	169	211	173	81	75
89	148	138	141	155	185	216	199	220	252
126	94	78	120	134	128	133	118	175	147
158	132	112	134	125	152	160	218	123	137
97	86	96	147	135	150	213	123	102	123
101	101	134	211	177	209	127	136	141	202
181	218	182	183	212	208	100	103	69	131
265	173	192	233	145	152	321			

## rh24b

156	128	88	74	99	102	96	169	97	104
129	104	89	114	219	177	189	120	120	133
179	172	187	184	168	206	208	126	89	92
159	230	167	203	215	138	148	286	208	135

## rh25

195	190	251	274	221	141	190	142	174	155
107	87	126	158	159	110	147	99	111	99
79	81	73	105	70	57	63	82	69	94
92	85	75	58	60	66	87	75	72	57
50	56	54	36	50	51	47	43	46	36
30	34	49	34	62	59	58	42	51	63
52	48	45	45	70	47	39	50	63	57
46	75	72	92	101	84	85	64	58	54
64	63	80	88	50	54	55	42	44	40
52	61	66	55	66	60	51	55	50	41
39	55	63	60	56	74	61	51	41	45
54	85	61	51	63	69	58	43	39	32
28	35	28	38	42	41	45	34	36	36
40	38	39	29	34	38	40	44	43	45
42	41	35	32						



## ENGLISH HERITAGE RESEARCH AND THE HISTORIC ENVIRONMENT

English Heritage undertakes and commissions research into the historic environment, and the issues that affect its condition and survival, in order to provide the understanding necessary for informed policy and decision making, for the protection and sustainable management of the resource, and to promote the widest access, appreciation and enjoyment of our heritage. Much of this work is conceived and implemented in the context of the National Heritage Protection Plan. For more information on the NHPP please go to <http://www.english-heritage.org.uk/professional/protection/national-heritage-protection-plan/>.

The Heritage Protection Department provides English Heritage with this capacity in the fields of building history, archaeology, archaeological science, imaging and visualisation, landscape history, and remote sensing. It brings together four teams with complementary investigative, analytical and technical skills to provide integrated applied research expertise across the range of the historic environment. These are:

- \* Intervention and Analysis (including Archaeology Projects, Archives, Environmental Studies, Archaeological Conservation and Technology, and Scientific Dating)
- \* Assessment (including Archaeological and Architectural Investigation, the Blue Plaques Team and the Survey of London)
- \* Imaging and Visualisation (including Technical Survey, Graphics and Photography)
- \* Remote Sensing (including Mapping, Photogrammetry and Geophysics)

The Heritage Protection Department undertakes a wide range of investigative and analytical projects, and provides quality assurance and management support for externally-commissioned research. We aim for innovative work of the highest quality which will set agendas and standards for the historic environment sector. In support of this, and to build capacity and promote best practice in the sector, we also publish guidance and provide advice and training. We support community engagement and build this in to our projects and programmes wherever possible.

We make the results of our work available through the Research Report Series, and through journal publications and monographs. Our newsletter *Research News*, which appears twice a year, aims to keep our partners within and outside English Heritage up-to-date with our projects and activities.

A full list of Research Reports, with abstracts and information on how to obtain copies, may be found on [www.english-heritage.org.uk/researchreports](http://www.english-heritage.org.uk/researchreports)

*For further information visit [www.english-heritage.org.uk](http://www.english-heritage.org.uk)*

