TREE-RING ANALYSIS OF TIMBERS FROM LEIGH BARTON, CHURCHSTOW, DEVON

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<u>SUMMARY</u>

Dendrochronological analysis was undertaken on samples from 98 timbers, of which 32 have been successfully dated. Those associated with the south range indicate a major phase of construction shortly after felling in the late-fifteenth or early-sixteenth century, whilst those from the north range indicate phases of modification/repair in the early-seventeenth century and the late-eighteenth century. A single timber from the north range may be associated with an earlier phase of building activity in the mid-fifteenth century. The successful dating of relatively few of the sampled timbers emphasises the continued difficulties encountered during dendrochronological analysis in parts of Devon.

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INTRODUCTION

This document is a technical archive report on the dendrochronological study of timbers from Leigh Barton, Churchstow, Devon (SX 7202 4671) undertaken in the late 1990s. It is beyond the dendrochronological brief to describe the building in detail or to undertake the production of detailed drawings. However basic information concerning the history, development and description of the complex has been summarised below from Brown (1998) and Morley (1983). This analysis formed a component part of a wider study of the building undertaken by Stewart Brown (1998).

Dendrochronological analysis was commissioned by English Heritage at the request of Francis Kelly, Inspector of Historic Buildings. It was undertaken with the aim of providing independent dating evidence for several of the major phases of building activity and hence adding to the understanding of the historic development of this complex. In addition, as Leigh Barton is one of a group of local, late medieval farmhouses and manor houses with similar lodgings/service ranges and/or courtyard plans, the dating evidence was expected to facilitate further comparison within this group.

History and development

Leigh Barton is a grade I listed building and a Scheduled Monument. It is located in a small sheltered valley in the north of the parish of Churchstow and lies approximately 2 km north-west of Kingsbridge (Figs 1 and 2). The complex consists of the gatehouse, the farmhouse (north range) and a pair of rear ranges (south and west) (Fig 3). The gatehouse and rear ranges are contemporary and relatively ostentatious, whereas the farmhouse is of a more modest character.

The Leigh family, free tenants of the Manor of Churchstow held by Buckfast Abbey, are known to have settled on the site back in the thirteenth century, but the earliest parts of the extant structure probably date from the fifteenth century, or possibly slightly earlier. This comprised a modest, rubble-built farmhouse with open hall and cross-passage plan. The Leighs prospered and the farmhouse was enlarged and upgraded with the addition of at least two ranges to its rear forming a courtyard and the construction of a curtain wall containing a gatehouse to the front. Prior to the dendrochronological analysis this set of major building works had been ascribed by Morley (1983) to the fifteenth century. The farmhouse, or north range, was subsequently reroofed and substantially altered internally so that it was two-storied throughout. These changes had been ascribed by Morley (1983) to the early-seventeenth century by which time Leigh had passed by marriage to John Croker who nevertheless resided at Lyneham near Yealmpton. By AD 1635 John and Joan Ryder, possibly the daughter from the marriage of John Croker and Joan Leigh, occupied Leigh. By AD 1746 Leigh was leased out as a tenant farm by the Ryder family but in AD 1768 it passed out of the Ryder's ownership. Leigh (Barton being a relatively modern addition to the name of the farmstead) remained a tenanted farm but ownership passed through a number of families. Alterations were mostly minor with the largest addition dating to the nineteenth century when a lean-to kitchen was added to the north face of the farmhouse. In 1950 Devon County Council recognised the historic interest of Leigh and purchased the farm. Twenty five years later the house and garden were purchased by the precursor of English Heritage within the Department of the Environment who in 1999, following a major programme of repair works, returned them to private ownership.

Brief description of the ranges under investigation

The west range and gatehouse were excluded from the dendrochronological investigation as the historic timber elements were no longer extant. The available evidence does however strongly indicate that the west and south ranges are integral and thus of the same date.

The south range, formerly extending further to the east, provided service rooms and lodgings. Prior to the dendrochronological analysis it was thought to have dated to the fifteenth century. It had undergone extensive renovation during the early 1980s but, unlike the west range, a significant number of historic timber elements were retained *in situ*. The surviving part of the south range was two storied and housed a kitchen to its east end and a storage area to its west end. The two chambers above are both open to the roof. There are nine jointed cruck trusses with the principals morticed and tenoned and pegged at the apex (Figs 4 and 5). There is no ridge piece but there are three rows of threaded purlins, variously joined with splayed-scarfing and halving. The collars are cambered. A timber-framed partition standing on a solid wall below divides the two chambers which clearly differ in quality. The west chamber is taller, its floor being set lower in the walls, with a finer roof and its own fireplace. The cambered collars of the five trusses in this chamber are supported by chamfered arch braces, each in two pieces. The four trusses in the east chamber are less elaborate and lack the arch braces. The chambers are accessed through a pair of doors leading from an external gallery and stone stairway which also provides access to the west range (Figs 6 and 7). The gallery roof consists of five shore-type trusses abutting the south range wall (Figs 6, 7, and 8). These are not uniformly spaced and rest in mortices that appear to be hacked crudely in the front edge of the stone wallplate along the south range wall. The floor of the gallery runs from the top of the stone stairs to the west range with the frame consisting of substantial heavily moulded timbers. The gallery arcade was formed by a series of jowled posts and three-centred arches and a hand rail ran along its length below which vertical plank panelling was inserted. The main openings had plain-chamfered surrounds but evidence survives which indicates that more delicate bead moulds framed the entire structure on its front face.

The farmhouse, or north range, underwent extensive renovation during the late 1990s. The low end of the original hall and cross-passage plan structure survives as the western, service end of the extant farmhouse. At least part of this service end was floored and the original roof level was at least as high, if not higher than the later replacement roof. This represents Phase 1 of the development dating to the fifteenth century, or possibly earlier. The first-floor room above the service end was subsequently refurbished and modified but this phase (Phase 2) is also thought to date to the fifteenth century or earlier. Further alterations including the insertion of the extant stone stair in the service end and a new first-floor room over the east of the service end, beyond the likely extent of the Phase 1 flooring, represent the third phase of development. Prior to the dendrochronological analysis Morley (1983) suggested that these modifications probably dated to the fifteenth century. Fragments remain of a richly decorated two-tiered plank and muntin screen (Brown 1998, Plates 10, 12, and 13) which is thought to have been inserted into an existing open hall, possibly in the early- to mid-sixteenth century but certainly before the major alterations of the early-seventeenth century (Phase 4). The floor joists for the room over the passage clearly date to this phase as they form an integral part of the screen construction. The next phase (Phase 5) of development, dating to the early-seventeenth century, represents the rebuilding of the hall, or east, end of the farmhouse, the entire replacement of the roof, and the insertion of new internal partitions. The farmhouse thus became two-storied throughout. The exposed ceiling beams in the ceiled-over hall and the probable parlour to the east have plain angled chamfers with stepped runout stops. The replacement roof consisted of seven trusses of A-frame construction (Fig 9). Short wall posts were joined onto the feet of most of the principals with pegged, halved and notched lap joints. The collars were attached to the principals in the same fashion as the wall posts. The principals were joined at the apex with a mortice and tenon joint with a single peg. There was no wallplate and no original ridge piece, although there were three rows of threaded purlins which were scarved and pegged together. At first-floor level the rooms were once again rearranged with the insertion of new internal partitions. The final phase (Phase 6) of development encompasses the numerous minor alterations made to the structure from the late seventeenth or early-eighteenth century onward. This includes the enlargement and insertion of window openings, blocking and insertion of doorways, and the construction of lean-to outbuildings against the north and east walls.

METHODOLOGY

The general methodology and working practises used at the Sheffield Dendrochronology Laboratory are described in English Heritage (1998). The following summarises relevant methodological details used for the analysis of the samples from Leigh Barton.

An assessment of the historic timbers was undertaken prior to sampling in order to identify the presence of timbers suitable for analysis and to allow a suitable sampling strategy to be formulated. Oak (*Quercus* spp.) is currently the only species used for routine dating purposes in the British Isles, though research on other species is being undertaken (Tyers 1998a; Groves 2000). Timbers with less than 50 annual growth rings are generally considered unsuitable for analysis as their ring patterns may not be unique (Hillam *et al* 1987). Thus oak timbers were sought which had at least 50 rings and if possible had either bark/bark edge or some sapwood surviving as this is important in the production of precise dating evidence (see below). The sampling strategy was designed to take in as wide a range of structural elements as possible within the dendrochronological brief and was discussed with both Stewart Brown and Francis Kelly in order to ensure that there were no obvious omissions with respect to the current understanding of the building.

In standing buildings samples are generally removed from selected timbers in the form of either cross-sectional slices or cores. Slices are taken from timbers that are either wholly or partially replaced during restoration, whereas cores are removed from timbers that will remain *in situ*. The cores are taken, using a 15mm diameter corer attached to an electric drill, in a position and direction most suitable for maximising the numbers of rings in the sample, whilst ensuring the presence of sapwood and bark edge whenever possible.

The ring sequence of each sample was revealed by a combination of sanding and paring until the annual growth rings were clearly defined. Any samples that fail to contain the minimum number of rings or have unclear ring sequences are rejected. The sequence of growth rings in suitable samples was measured to an accuracy of

0.01mm using a purpose-built travelling stage attached to a microcomputer-based measuring system (Tyers 2004a). The ring sequences were plotted onto semi-logarithmic graph paper to enable visual comparisons to be made between them with the aid of a lightbox. In addition, cross-correlation algorithms (Baillie and Pilcher 1973; Munro 1984) were employed to search for positions where the ring sequences were highly correlated. The Student's *t*-test is then used as a significance test on the correlation coefficient. The *t*-values quoted below are derived from the original CROS algorithm (Baillie and Pilcher 1973). A *t*-value of 3.5 or over is usually indicative of a good match (Baillie 1982), provided that high *t*-values are obtained at the same relative or absolute position with a series of independent sequences and that the visual match is satisfactory.

Dating is usually achieved by comparing, or crossmatching, ring sequences within a phase or structure and combining the matching patterns to form a phase or site master curve. This master curve and any remaining unmatched ring sequences are then tested against a range of reference chronologies, using the same matching criteria as above. The position at which all the criteria are met provides the calendar dates for the ring sequences. A master curve is used for absolute dating purposes whenever possible as it enhances the common climatic signal and reduces the background 'noise' resulting from the local growth conditions of individual trees.

During the crossmatching stage an additional potentially important element of tree-ring analysis is the identification of 'same-tree' timber groups. The identification of 'same-tree' groups is based on very high levels of similarity in year to year variation, longer term growth trends, and anatomical anomalies. Such information ideally should be used to support possible 'same-tree' groups identified from similarities in the patterns of knots/branches during detailed recording of timbers for technological and woodland characterisation studies. Timbers originally derived from the same parent log generally have *t*-values of greater than 10.0, though lower *t*-values do not necessarily exclude the possibility. It is a balance of the range of information available that provides the 'same-tree' link.

The crossdating process provides precise calendar dates only for the rings present in the timber. The nature of the final (youngest) ring in the sequence determines whether the date of this ring also represents the year the tree from which the timber was derived died. Oak consists of inner inert heartwood and an outer band of active sapwood. If the sample ends within the heartwood of the original tree, a *terminus post quem* for the felling of the tree is indicated by the date of the last ring plus the addition of the minimum expected number of sapwood rings that are missing. This is the date after which the timber was felled but the actual year of felling may be many decades later depending on the number of outer rings removed during timber conversion. Where some of the outer sapwood or the heartwood/sapwood boundary survives on the sample, a felling date range can be calculated using the maximum and minimum number of sapwood rings likely to have been present. The sapwood estimate applied throughout this report is a minimum of 10 and maximum of 46 rings, where these figures indicate the 95% confidence limits of the range and are applicable to oak trees of all periods from England and Wales (Tyers 1998b). Alternatively, if bark-edge survives, then a felling date can be directly obtained from the date of the last surviving ring. In some instances it may be possible to determine the season of felling according to whether the ring immediately below the bark appears to be complete or incomplete. However the onset of growth can vary within and between trees and this, combined with the natural variation in actual ring width, means that the determination of felling season must be treated cautiously. The delicate nature of sapwood increases the likelihood of damage/degradation to the outermost surface of the sample and hence increases the difficulties of positive identification of bark-edge.

The felling dates produced do not by themselves necessarily indicate the construction date of the structure from which they are derived. At this stage, factors such as seasoning, reuse, and stockpiling have to be considered. Evidence suggests that seasoning of timber for structural purposes was a fairly rare occurrence until relatively recent times and timber was generally felled as required and used whilst green (Hollstein 1980; Rackham 1990; Charles and Charles 1995). However, the reuse of timber has been a common practice since prehistoric times and stockpiling, albeit potentially short-term, may occur. Therefore, although the production of tree-ring dates is an independent process, the interpretation of these dates may be refined by drawing on other archaeological evidence.

RESULTS

Assessment and Sampling

An initial assessment of both ranges under investigation was carried out in December 1997. Sampling was undertaken during a number of site visits in 1998 and 1999 during the major restoration work to the north range and the retiling of the south range. The vast majority of historic timber elements throughout the north and south ranges were oak, though some lintels were ash (*Fraxinus excelsior* L.)

South range

During the extensive renovation of the south range in the early 1980s the southern side of the roof structure had been almost entirely replaced by modern timbers. The northern side was a mixture of replacement timbers, historic timbers repaired with modern inserts, and intact historic timbers. The trusses therefore survived in only a very fragmentary form and the westernmost truss was actually entirely modern timber. Other historic elements, including lintels, floor beams and door-framing, had also survived within this range and the associated gallery structure.

The assessment, carried out in December 1997, ascertained that there were sufficient numbers of historic timbers with an adequate number of rings to justify analysis. The majority of extant historic timbers were derived from trees that were less than 100 years old when felled, though there were clearly some older trees used. Sapwood was extremely rare and even then the small areas of it which had survived were in an extremely fragile condition precluding successful sampling. The boundary between the heartwood and sapwood was however somewhat more common. The survival of sapwood appears likely to have been adversely effected by the dilapidated state of the building by the early 1980s and the subsequent water seepage through the new roof laid as part of the early 1980s works. It is quite likely that sapwood that survived to this point was in such a poor state of preservation that it was removed from the timbers during the early 1980s renovation works.

The nine trusses in the south range roof were labelled T101–T109 from east to west (Fig 10). It was noted that carpenters marks of IIII, III, and II were present on trusses T101 to T103 respectively, whilst truss T105 which divides the two chambers was marked with a V. This could potentially suggest that the two sets of trusses for the chambers were marked up separately. The timbers appear to have been trestle sawn with saw marks and a triangular snap off point being particularly obvious on the north principal of truss T105. The lack of a deliberate retention policy during the renovation in the 1980s meant that sampling would have to rely on the removal of core samples from the extant historic elements. The presence of so much modern material clearly restricted sampling of the roof structure. Sampling was further restricted by the observation that the extant historic elements in the more highly decorative roof over the west chamber appeared to be generally derived from slightly faster-grown younger trees, hence less suitable for dendrochronological analysis, than those used in the roof structure over the east chamber. The extant historic wall-plates were all rejected as unsuitable but a series of 11 samples was taken from this roof structure. The ceiling beams were labelled B101–B106 from east to west (Fig 11) but only one was considered suitable for sampling. However a cross-sectional slice was obtained from an offcut present on-site that was thought to be part of a ceiling beam originally from the south range or possibly the west range. Six other cores were taken from lintels and door frames.

The principals in the gallery roof structure were labelled T201–T205 from east to west (Fig 10). Two of these were considered suitable for coring in addition to two of the posts and the top rail. A cross-sectional slice was obtained from an offcut present on-site that was thought to be part of the mid-rail that was no longer *in situ*. Unfortunately none of the moulded beams forming the frame for the gallery floor were suitable for analysis as the earlier renovation process had left little of the historic timber extant. The surviving fragments rather frustratingly suggested that the timbers may well have contained sufficient rings for analysis prior to them having had large sections of modern timber spliced in.

The approximate location of the samples taken from the south range, with the exception of sample ***25*** from the *ex situ* ceiling beam, are indicated in Figures 12, 13, and 14. Details of the samples are provided in Table 1.

<u>North range</u>

The major programme of restoration work on the north range in 1998/99 allowed extensive access to the historic timber elements. In addition the advantage in this range was that any timber elements that were to be partially or wholly replaced during renovation were labelled and retained until they had been assessed for their dendrochronological potential. Samples in this range consequently consisted of a mixture of cross-sectional slices and cores.

The bulk of the timbers were thought to be associated with Phase 5, the major rebuilding of the east end and associated remodelling, with the possibility that some may be from later minor alterations or repairs. The exceptions to these were: firstly the westernmost ceiling beam which, as it showed no obvious signs of insertion and retained a series of disused joist sockets presumably for an earlier floor, was thought may be an original feature from the primary phase of construction; and secondly the decorated screen and associated timbers which represent Phase 4. The obvious reuse of timbers present in the western first floor partition and the reuse of a medieval or early post-medieval window head in the upper section of the eastern partition highlight the potential for reuse of timber throughout the north range. The assessment established that there were enough timbers with a sufficient number of rings for analysis from the later phases but that the timbers potentially associated with the earlier phases were also suitable as they may well link up with the material obtained from the south range. Again the majority of timbers appeared to be derived from trees that were less than 100 years old when felled, though once more there were clearly some older trees used. The presence of the heartwood/sapwood boundary was relatively widespread but whilst sapwood had more commonly survived in this range it was also generally in such a fragile state that it only rarely survived intact during coring and when present on the cross-sectional slices it was often unmeasureable due to the extensive damage caused by woodworm and subsequent rot. The timber elements in this range had also clearly suffered from water seepage and damp over an extended period.

The seven trusses in the north range roof were labelled T1–T7 from west to east (Fig 10), though it should be noted that truss T1 was no longer extant and trusses T2 and T3 survived in only a very fragmentary form. Twenty five samples representing 20 timbers were obtained. Several duplicate samples were obtained in the form of cross-sectional slices following the decision to replace the entire roof structure. The few surviving rafters did not have enough rings and were therefore rejected.

The ceiling beams in the parlour, ceiled-over hall and service end were labelled B1–B9 from west to east but included a B2a and a B2b (Figs 11 and 15). All were sampled. They were expected to be contemporary with the reroofing with the exception of B1, the westernmost ceiling beam, thought to be potentially associated with the initial building of the farmhouse.

Ten samples were obtained from ceiling joists above the parlour following their removal and a further five samples were obtained from four ceiling joists above the passage.

Ten samples were taken from nine lintels: one in the parlour, four in the hall and four in the service end. The precise location of one of the sampled lintels from the hall is not known as the label on the timber removed was ambiguous.

Eight samples were obtained from door posts: one from the doorway from the hall to the stairs, four from the doorways from the stairs into the chambers above the hall and parlour, two from the doorway in the western partition between the two chambers at the west end of the farmhouse over the service end and passage, and one from the doorway leading from the south-west corner of the service end into the west range (Figs 12, 13 and 16). The latter doorway is thought to have been inserted when the west and south ranges were constructed. In addition to the two samples from the doorframe, three studs in the western partition were also sampled (Fig 16).

Another timber from the chamber over the hall was also sampled but again the description on this *ex situ* timber was unclear.

Seven samples from five muntins and two rails from the decorated screen were sampled but unfortunately none of the planks contained sufficient numbers of rings to justify sampling. The muntins were labelled M1–M10 from south to north (Fig 17).

The approximate location of all of the samples taken from the north range are, where known, indicated in Figures 12, 13, 16, and 17. This excludes the individual parlour and passage ceiling joists and the *ex situ* timbers with ambiguous location descriptions given on the labels. Details of the samples are provided in Table 1.

Analysis

South range

Five samples from the south range were rejected prior to measurement because they contained too few rings for reliable dating purposes, or had fragmented during coring, or contained bands of very narrow rings whose boundaries could not be reliably distinguished. All 20 measured ring sequences were compared with each other in order to determine whether similarities in the growth patterns could be found which might indicate contemporaneity. Fifteen of these were found to crossmatch (Fig 18; Table 2). Samples ***2*** and ***13***, both purlins, matched with a *t*-value of 14.08 which, combined with the high levels of similarity in both year to year variation and longer term growth trends apparent from the visual comparison, indicates that the two purlins are likely to have been derived from a single tree. Their ring sequences were therefore combined to produce a single tree sequence before being incorporated into the 140-year master curve, ***LBC-A***, which also includes a single timber from the north range (see below). This site master chronology was tested against an extensive range of dated reference chronologies spanning the last millennium from the British Isles. Consistent results were obtained when ***LBC-A*** spans the period AD 1345–1484 inclusive (Table 3). The data for this site chronology are given in Table 4. Each individual ring sequence included in the site master chronology was therefore assigned a date which indicates when the tree from which the timber was derived was growing (Fig 18; Table 1).

The ring sequences from samples ***1*** and ***8*** matched (Fig 19; Table 5) and were combined to form a 69-year two timber site master chronology, ***LBC-B***. This sequence and the remaining unmatched individual series were compared with the north range site master curves (see below) and all unmatched individuals but no matches were identified. They were also compared to the same extensive range of reference chronologies used above, as well as various chronologies from elsewhere in Europe, but no reliable results were obtained, so they remain undated.

North range

Seventeen samples from the north range were rejected prior to measurement. Two were rejected as they were ash, whereas the oaks were rejected because they contained too few rings for reliable dating purposes, or had fragmented during coring, or contained bands of very narrow rings whose boundaries could not be reliably distinguished. The remaining 62 samples, representing 57 timbers, were all measured. The duplicate samples were combined to produce single timber sequences, ***4270***, ***4457***, ***4585***, ***8384***, and ***103104*****,** prior to comparison with the other individual ring sequences.

The crossmatching process identified five groups of samples:

- six series crossmatched to form a 79-year site master chronology, ***LBC-C*** (Fig 20; Table 6);
- 16 series crossmatched to form a 120-year site master chronology, ***LBC-D*** (Fig 21; Table 7). Two of these series, ***4270*** and ***4457*****,** from principals, are likely to have been derived from the same tree and were therefore combined to produce a single tree sequence before being combined into the site master chronology;

- 10 series crossmatched to form a 112-year site master chronology, ***LBC-E*** (Fig 22; Table 8). Three of these series, ***94***, ***96*,** and ***98***, are likely to have been derived from the same tree and were therefore combined to produce a single tree sequence before being combined into the site master chronology
- three series crossmatched to form a 110-year site master chronology, ***LBC-F*** (Fig 23; Table 9);
- two series, probably derived from the same tree, crossmatched to form a 85-year site master chronology, ***LBC-G*** (Fig 24; Table 10).

These five site master chronologies were tested against an extensive range of dated reference chronologies spanning the last millennium from the British Isles and elsewhere in Europe. Consistent results were obtained for ***LBC-C*** and ***LBC-E*** when they span the periods AD 1527–1605 and AD 1672–1783 inclusive respectively (Tables 11 and 12). Data for these site master chronologies are given in Tables 13 and 14. Each individual ring sequence included in these two site master chronologies was therefore assigned a date which indicates when the tree from which the timber was derived was growing (Figs 20 and 22; Table 1). The *t*-values obtained for the site master chronology ***LBC-C*** are relatively low but all six individual timber sequences included in this site master can also be dated at the same relative positions even though there are few reference chronologies for this period from the region (Table 11). A possible date was identified for ***LBC-D*** but this cannot as yet be statistically proven.

The remaining unmatched individual series were compared with all of the site master chronologies and the unmatched individuals from the south range. This resulted in the successful dating of sample ***36*** which matched the dated timbers from the south range (Fig 18; Table 2). The rest were also compared to the same extensive range of reference chronologies used above but no reliable results were obtained so they remain undated.

Interpretation

Figure 25 shows all of the dated samples with their estimated felling dates. The samples are grouped according to location and function.

Where sapwood disintegrated during coring a note was made of the amount lost and whether bark edge was present. This was so that, rather than using the 10–46 sapwood estimate on these timbers, the number of sapwood rings lost could be estimated in order to produce a more accurate indication of the felling date. Where possible an attempt to count the number of rings lost was carried out *in situ* on the actual timber. If this was not possible then the amount of sapwood lost was estimated in millimetres. This could subsequently be converted into an estimate of the number of rings lost by dividing the millimetres lost by the average width of the outermost 10 measured rings. This had been found to be more accurate than using the overall average ring width.

In the absence of any evidence for reuse it is assumed that the timbers are primary to the relevant phase of construction. Hence as they were generally used whilst green it is assumed that construction will have occurred shortly after felling. The possible exception to this is the lintel, sample ***36*** (see below).

South range

The results indicate that all 15 dated samples from the south range are likely to be coeval. These include roof timbers, ceiling beams, lintels, doorframes and two timbers from the gallery. The heartwood-sapwood boundary was present on five samples and probably present on a sixth sample. The felling date ranges obtained for these six samples indicate that they are broadly contemporary (Fig 25). They appear likely to be the product of a single period of felling and thus have a combined felling date range of AD 1494–1514 (see Fig 25). The *terminus post quem* for felling calculated for each of the remaining samples is consistent with the AD 1494–1514 felling date proposed. This implies that the extant historic timber elements in both the main south range structure and the gallery are the product of a single period of construction in the late-fifteenth or early-sixteenth century, allowing Morley's (1983) broad fifteenth-century date for the erection of the south and west ranges to be refined. This also implies that the associated alterations in the farmhouse (Phase 3) are likely to date to the late-fifteenth or early-sixteenth century.

The lack of bark edge prevents the production of precise felling dates and consequently any minor differences in felling dates are not highlighted. It therefore remains a possibility that the gallery could have been constructed towards the end of the construction period for the main south range from timber felled a year or two later, though from the same woodland source, which would explain the awkward junction between the gallery roof timbers and the south range masonry highlighted by Morley (1983).

Samples ***1*** and ***8*** are clearly coeval but the inability to date these and the remaining unmatched samples from the south range does not necessarily imply that these timbers are of a different date to the dated material. There is no evidence that indicates that any of these represent either earlier reused material or later insertions. The undated timbers are simply part of a group of material that cannot be successfully dated. The nationwide success rate for the dating of suitable samples is in the region of 70% but some areas, including Devon, have significantly lower success rates and appear reliant on a more localised network of reference data (Groves 2004; Groves 2005).

North range

Seventeen timbers have been successfully dated from the north range. These represent three distinct periods of felling.

The outermost 10mm of sapwood, including bark edge, had been lost from sample ***36***, a lintel from the service end. This represents approximately 11 sapwood rings. Consequently a felling date of *c* AD 1469 is obtained. The lintel is the outer of two over a recess in the east wall of the service room that other evidence indicates is associated with the third phase of development in the farmhouse which is likely to date to the late-fifteenth or early-sixteenth century (see above). There were no obvious signs of reuse apparent on this lintel. However this is a plain lintel inserted rather than jointed into the structure and therefore would not necessarily have any obvious signs of reuse. It is therefore feasible that it was reused during the Phase 3 alterations, but the dendrochronological analysis can neither confirm nor refute this possibility. What is clear is that this timber was first used shortly after felling in *c* AD 1469 and therefore could have been initially associated with an earlier phase of development on the site.

The results indicate that five samples from the roof and a ceiling beam are coeval (Fig 25). The outermost 35–40mm sapwood, including bark edge, had disintegrated during coring from sample ***45***. This represents approximately 26–29 sapwood rings. Consequently a felling date of *c* AD 1621–24 is obtained. The heartwood-sapwood boundary was present on four other samples and probably present on a fifth. The felling date ranges obtained for these samples are consistent with the early AD 1620s felling date proposed. These timbers are thought to be associated with the major alterations connected to the rebuilding of the hall end of the north range, thus potentially refining the early-seventeenth century date suggested for this phase (Phase 5) of reconstruction. The ceiling beam (B2a) is associated with the raising of the ceiling level in the easternmost bay of the service end, whilst the other five dated timbers, all principals, from the roof represent trusses, T5, T6, and T7. Consequently, although the roof of the entire north range is thought to be the product of a single building campaign, it has only been possible to date elements from the eastern half over the hall and parlour end.

The ten remaining dated timbers from the north range are joists from the parlour ceiling (Fig 25). Three of these have bark edge and were felled in the winter of AD 1783/84. Samples ***91***, ***94***, and ***99*** also had bark edge but the outermost rings were not measurable due to severe degradation. The outermost measured rings date to AD 1766, AD 1782, and AD 1772 respectively. The estimated number of unmeasured rings indicates that they were also likely to have been felled in the early AD 1780s. The remaining four joists all had the heartwood/sapwood boundary present and the felling date ranges obtained are consistent with felling in the early AD 1780s. The joists were therefore likely to be inserted in the parlour ceiling shortly after felling in AD 1783/84. They are therefore not part of the Phase 5 alterations which included the ceiling over of the hall and parlour to create two chambers above, but represent a modification to the ceiling some 160 or so years later.

Again the inability to date the remaining samples from the north range does not necessarily imply that these timbers are of an entirely different date to the dated material. They are simply part of a group of material that cannot be successfully dated. However within this undated material there are three groups of timbers of potential interest to the overall interpretation of the dendrochronological analysis.

The first group is composed of the three timbers which formed the undated site master chronology ***LBC-F*** (Fig 23). Beam B3 is located at the west end of the hall ceiling, whilst beam B2b is located towards the eastern end of the service end above the dated beam B2a (Fig 15). The structural evidence indicates that these two beams were part of the major alterations connected to the rebuilding of the hall end of the north range for which dendrochronological analysis has indicated a date of *c* AD 1621–24. It had previously been suggested that beam B1, the westernmost ceiling beam, could, in the absence of any clear evidence for later insertion or disturbance, be part of the initial construction of the farmhouse. However the dendrochronological analysis shows that these three ceiling beams are actually coeval and therefore represent a single felling period and phase of building work, although it has not been possible to provide calendar dates for this event.

The second group of undated material is the 16 timbers that formed the site master chronology ***LBC-D*** (Fig 26). This material is dominated by timbers associated with the roof structure but also includes a lintel from the hall and three timbers associated with the partition between the two west chambers. The results indicate that all of these timbers appear likely to be coeval showing that the bulk of the material from the roof, a hall lintel, and the western partition are the product of a single period of felling. Structural evidence indicates that the roof and the western partition should be contemporary and are associated with Phase 5 of the development of the north range. However the dendrochronological analysis cannot produce statistical evidence to conclusively link this group of timbers with the dated timbers from roof trusses T5, T6, and T7, nor can it independently date this group of material, even though it includes timbers from all six extant trusses and purlins from bays T4/5 and T5/6. Thus the analysis can neither confirm nor refute whether this group of timbers are part of the Phase 5 alterations. If they are, as the structural evidence strongly suggests, then they appear likely to come from a different woodland source to the dated timbers from the roof. The growth conditions in this woodland may be dominated by more localised environmental factors, natural or anthropogenic, that are masking the more general climatic signal required for successful dating, a problem which is relatively common in parts of Devon (Groves 2004; Groves 2005). Another possible explanation of the presence of two distinct groups of timber in the roof could be through reuse of timber. However there were no obvious signs of reuse or resetting so this seems unlikely.

The third group of undated material is the two timbers that formed the site master chronology ***LBC-G***. These timbers are likely to be derived from the same tree and therefore clearly demonstrate that the muntins and the upper rail of the decorated screen are coeval.

CONCLUSION

The dendrochronological analysis has been successful in that it has provided dates for four separate felling phases. A single timber from the north range was felled and initially used in *c* AD 1469, though it is thought likely to be reused in its current position. The south range and external gallery appear likely to be the product of a single period of construction using timbers felled in the late-fifteenth or early-sixteenth century. The constructional anomalies between the south range and the gallery suggest that it is possible that this single period of construction spanned more than a year, with the covered gallery possibly being built towards the end of this period. A series of timbers from the eastern half of the roof over the north range and a single ceiling beam in the service end were felled *c* AD 1621–24 suggesting that the major remodelling of the north range indicated by architectural and structural evidence occurred at this time. Further alterations or repairs were carried out on the parlour ceiling some 160 years later using timbers felled in AD 1783/4.

The relative shortness of the ring sequences (ie the use of relatively fast grown, young trees) and the frequency of bands of very narrow rings must be major contributory reasons to the relatively poor success rate as far as the dating of individual samples is concerned, particularly from the north range. Whilst such problems are not unusual in parts of Devon, the inability to date a 120-year site master chronology including data from 16 timbers is somewhat frustrating. It emphasises the continuing problems of successful dendrochronological analysis in parts of Devon, highlighting the apparent need for a strong network of local reference data, particularly for some periods, and hence the importance of the English Heritage research project aimed at addressing these problems (Groves 2005).

ACKNOWLEDGEMENTS

The analysis was funded by English Heritage. I am extremely grateful to Rick Rowe and all his team, not only for keeping me topped up with tea and chips, but for retaining and labelling all the timbers they removed from the north range and subsequently slicing up those selected for sampling, and lastly for taking the time to discuss which timbers were likely to be replaced during the major renovation of the north range. I would also like to thank Stewart Brown, Francis Kelly, and Robert Waterhouse who provided invaluable discussion both on and off site. Talya Bagwell, an extremely competent MA student, undertook the measurement of the final few timbers.

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Figure 1 Approximate location of Churchstow within England and Wales.

Figure 2 Location of Leigh Barton, Churchstow, Devon

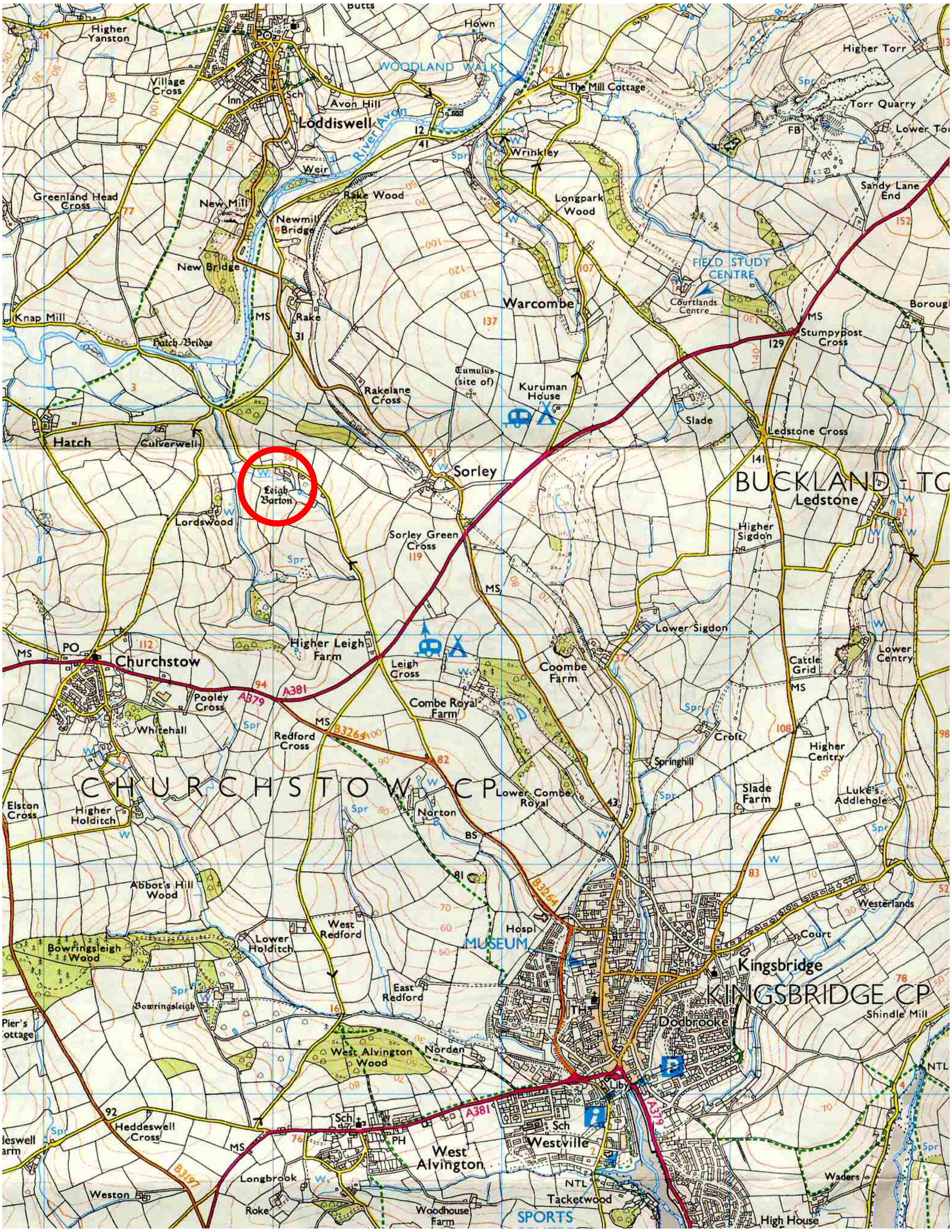


Figure 3 Isometric view from the south-west (after Morley 1983 Fig 2)

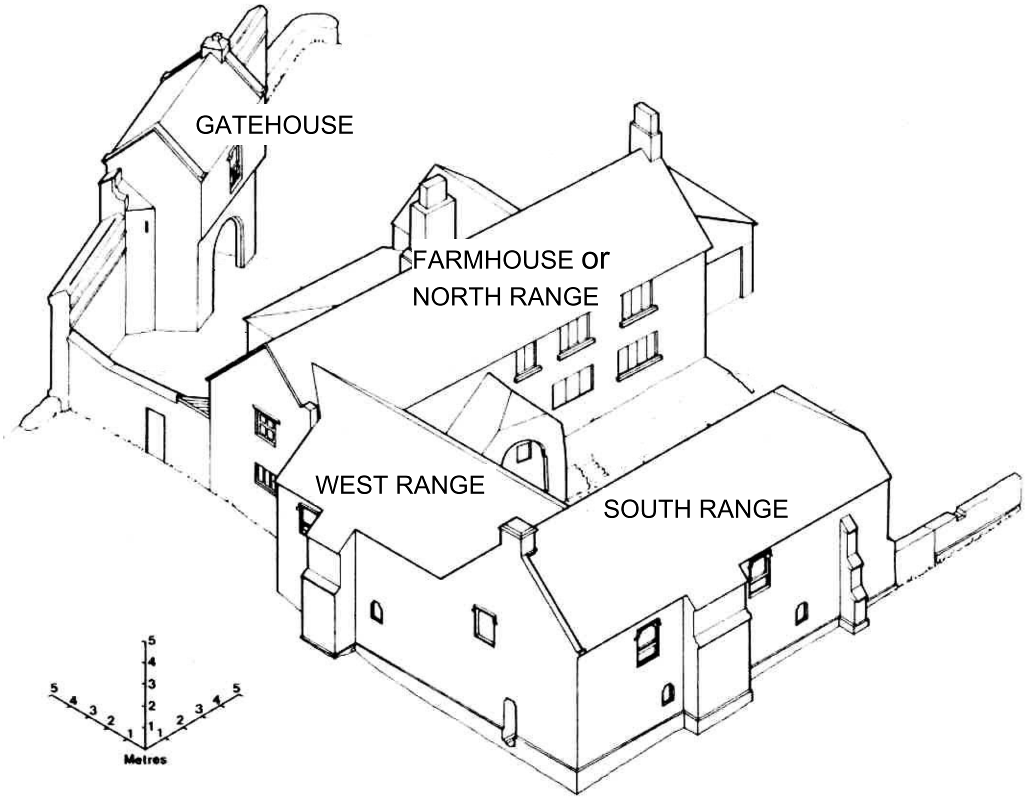


Figure 4 West face of truss T105 in the south range (photograph C Groves)

Figure 5 West face of truss T105 in the south range showing the basic truss type (after English Heritage drawing AS8/006 by Selwood 1995). The timber-framed partition divides the two upper chambers

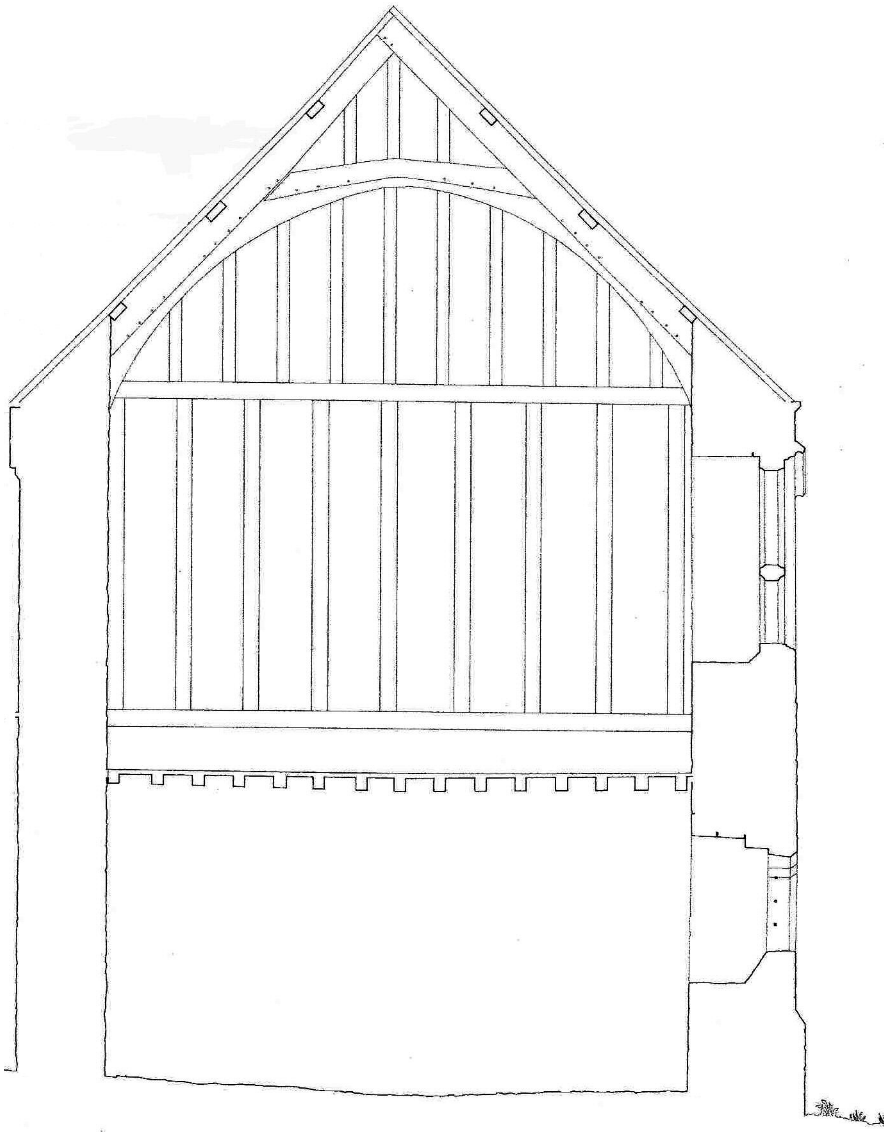


Figure 6 The stone steps and gallery leading to the upper floor of the south and west ranges (photograph reproduced by permission of English Heritage, NMR)

Figure 7 The gallery roof looking to the entrance to the west range (photograph C Groves)

Figure 8 Detail of a shore-type truss in the gallery (photograph C Groves)

Figure 9 Truss T4 in the north range showing the basic truss type associated with the early-seventeenth century roof (Brown 1998, Fig 10)

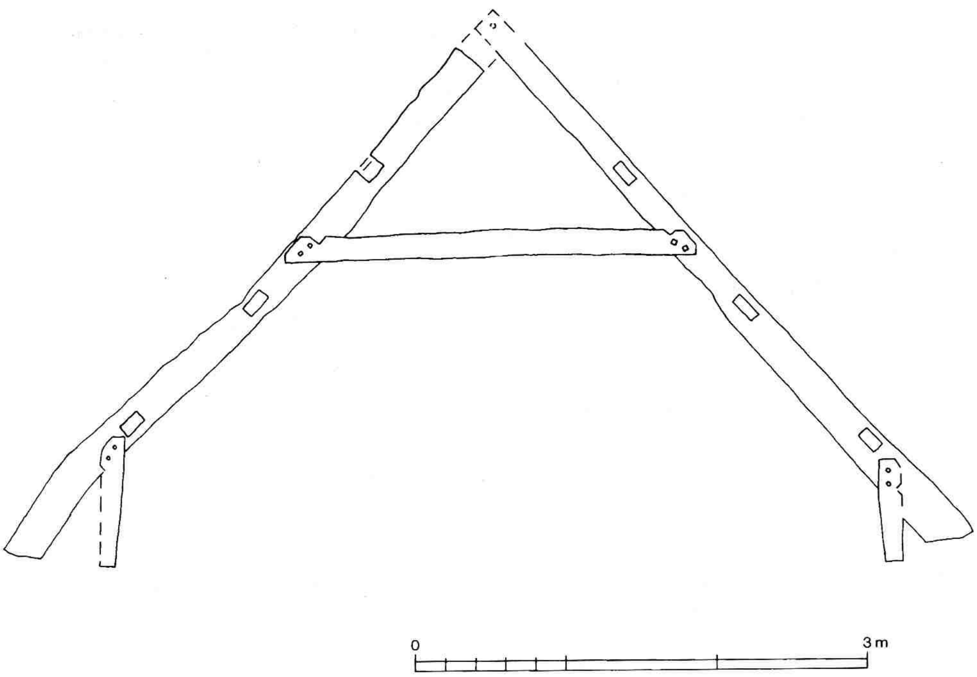


Figure 10 Plan of the first floor showing the truss numbering schemes in both the north and south ranges (after Morley 1983, Fig 4)

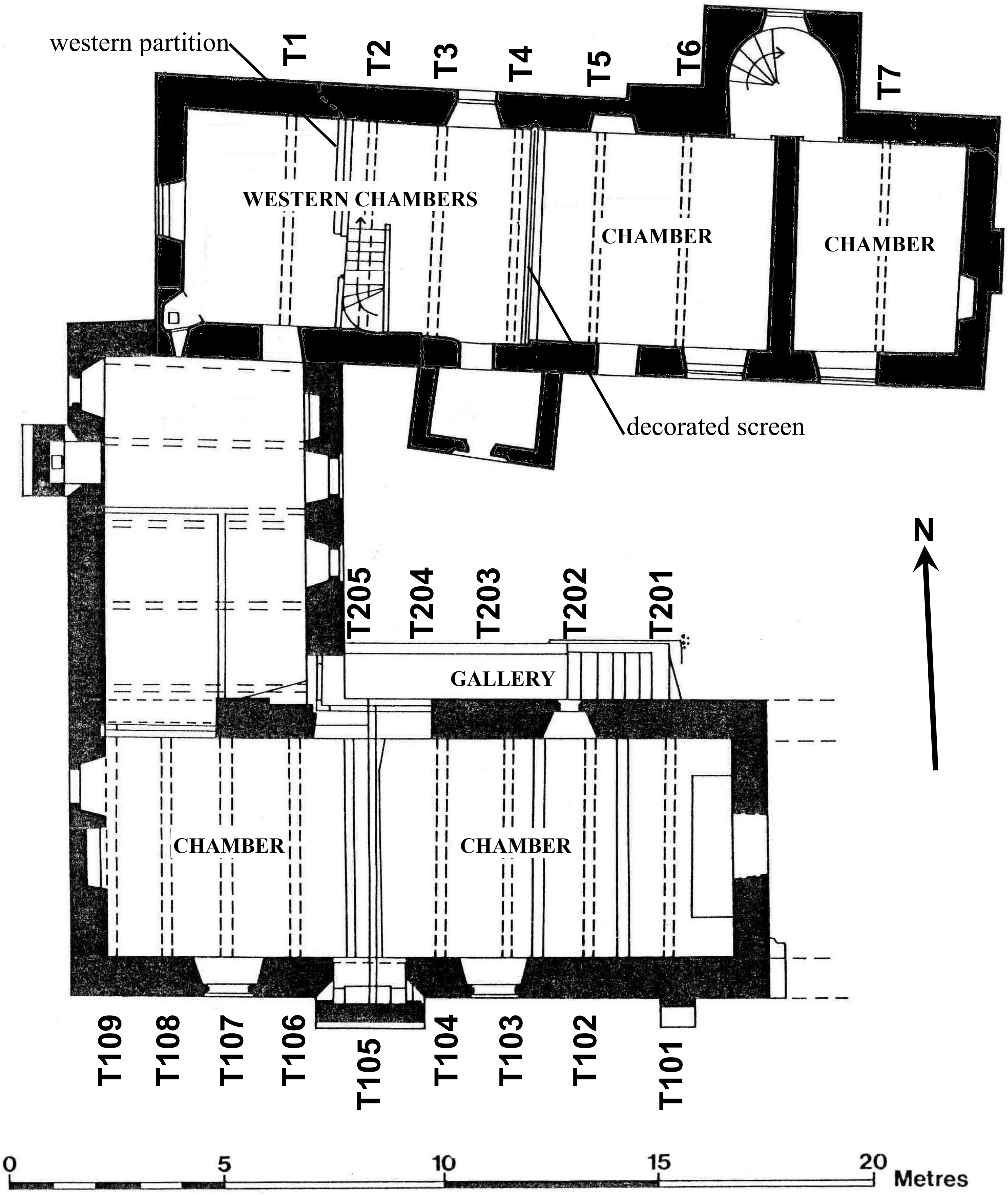


Figure 11 Plan of the ground floor showing the beam numbering schemes in both the north and south ranges (after Morley 1983, Fig 4)

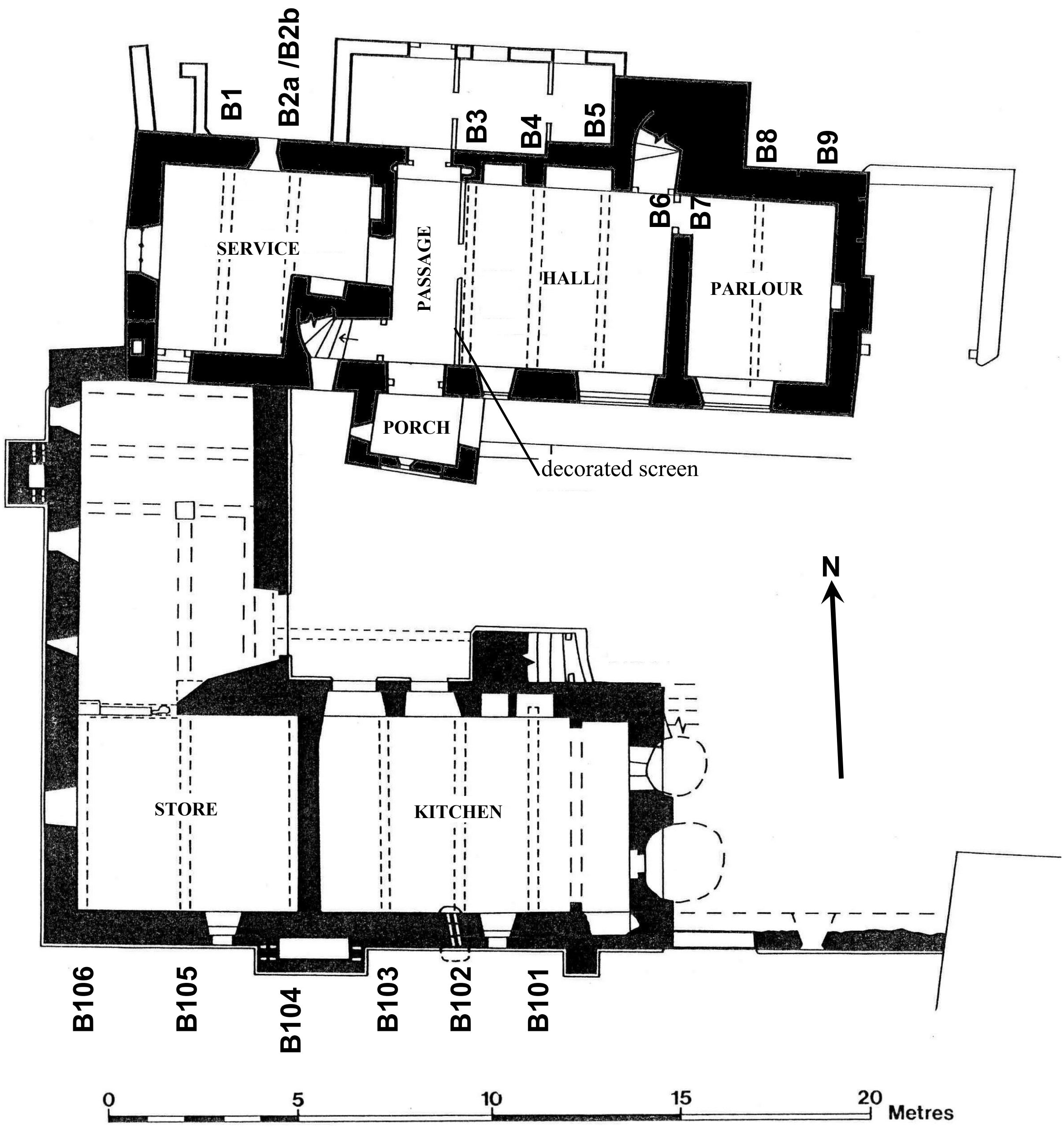


Figure 12 Plan of the first floor showing, where possible, the approximate location of the samples (after Morley 1983, Fig 4)

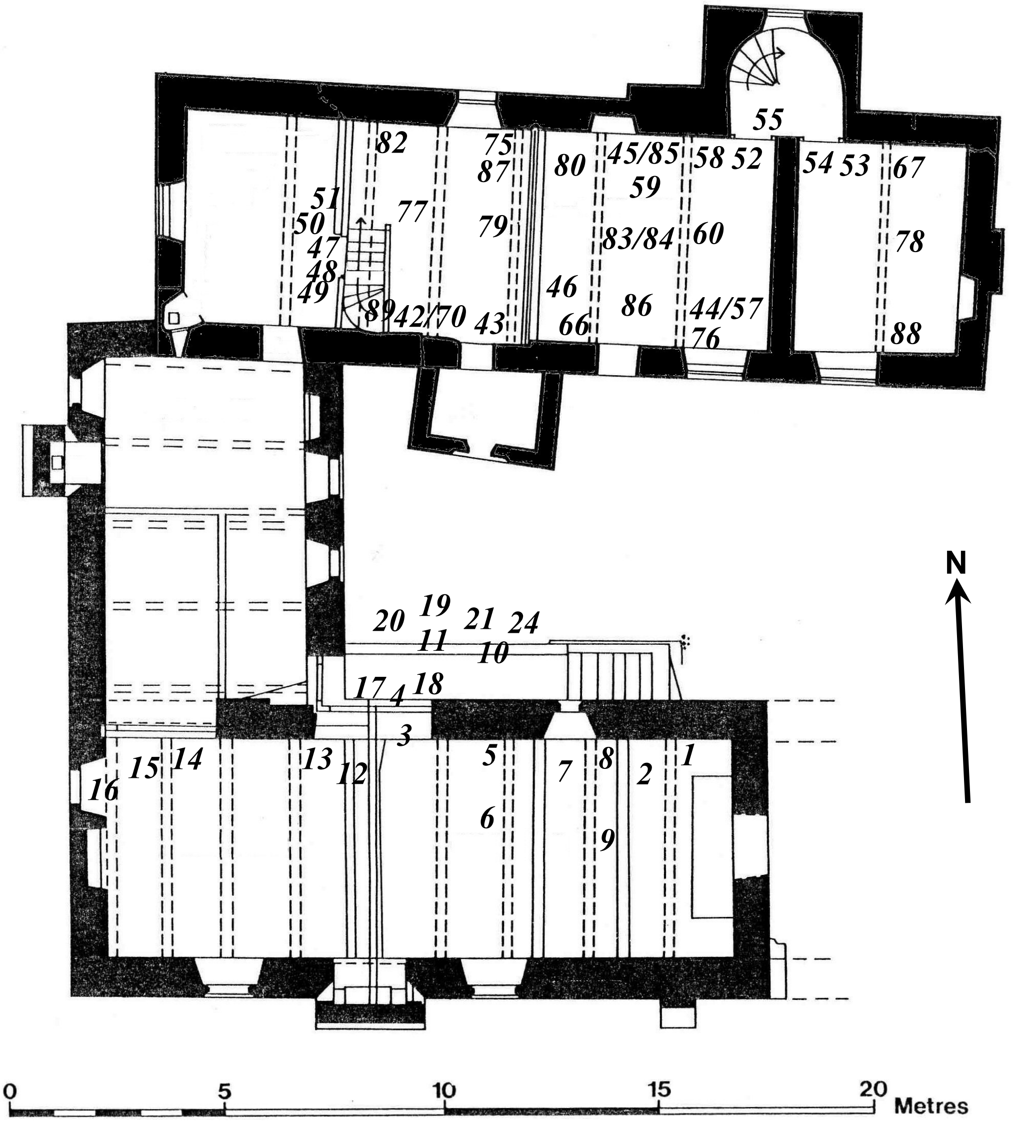


Figure 13 Plan of the ground floor showing, where possible, the approximate location of the samples (after Morley 1983, Fig 4)

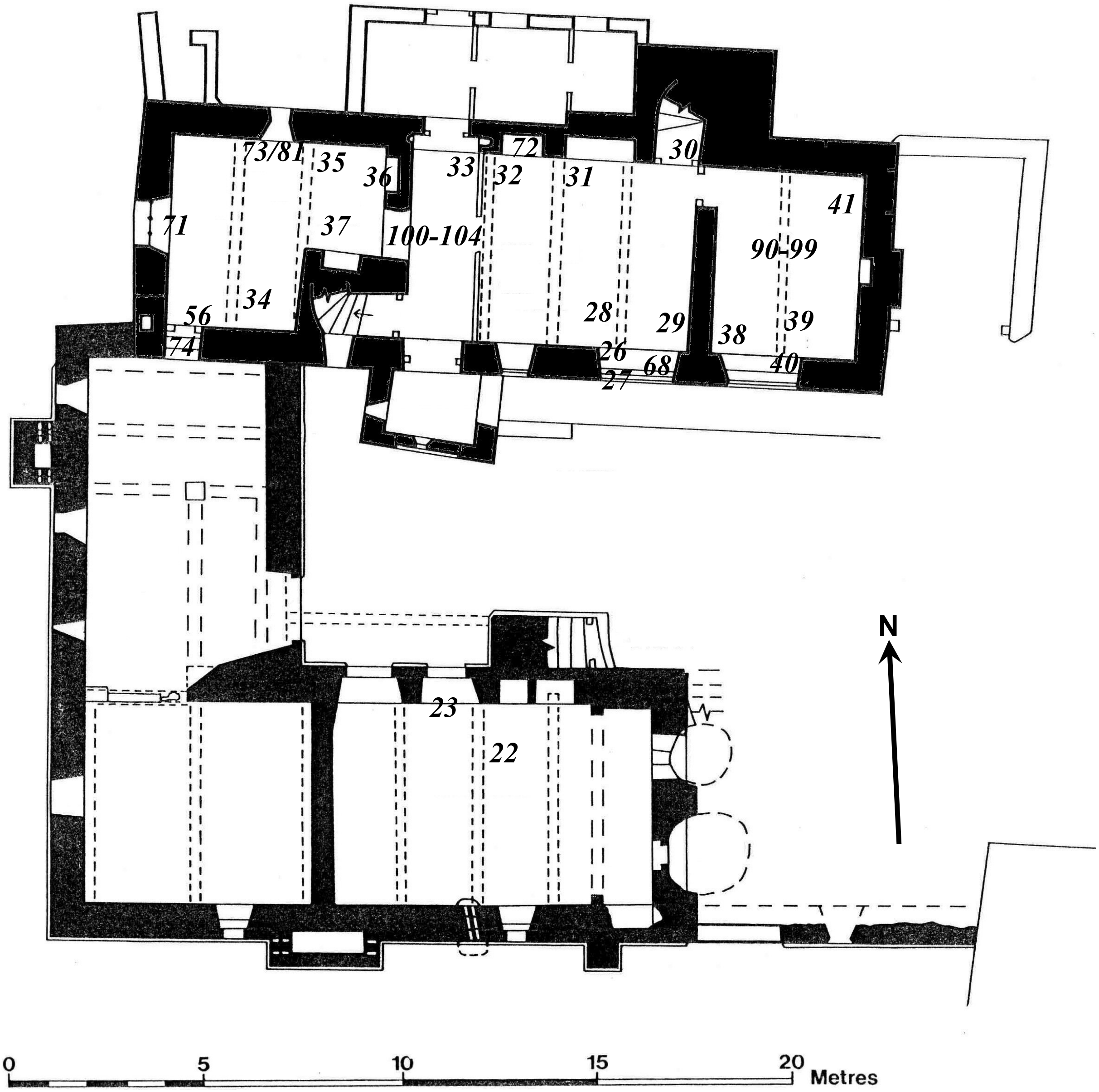


Figure 14 Sketch showing the numbering scheme for the posts of the north wall of the gallery and the approximate location of samples ***19***, ***20***, and ***21***

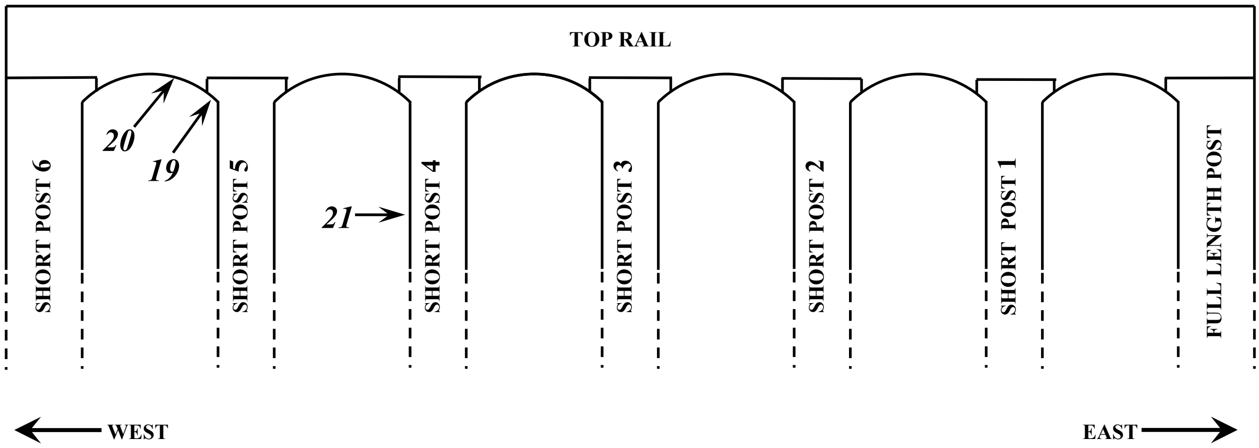


Figure 15 Section through the north range, north face of the south wall, showing the ceiling beam numbering scheme including B2a and B2b (after English Heritage drawing AS8/004 by Selwood 1995)

Figure 16 Sketch showing the numbering scheme for the western partition in the north range and the approximate location of samples *47–51*

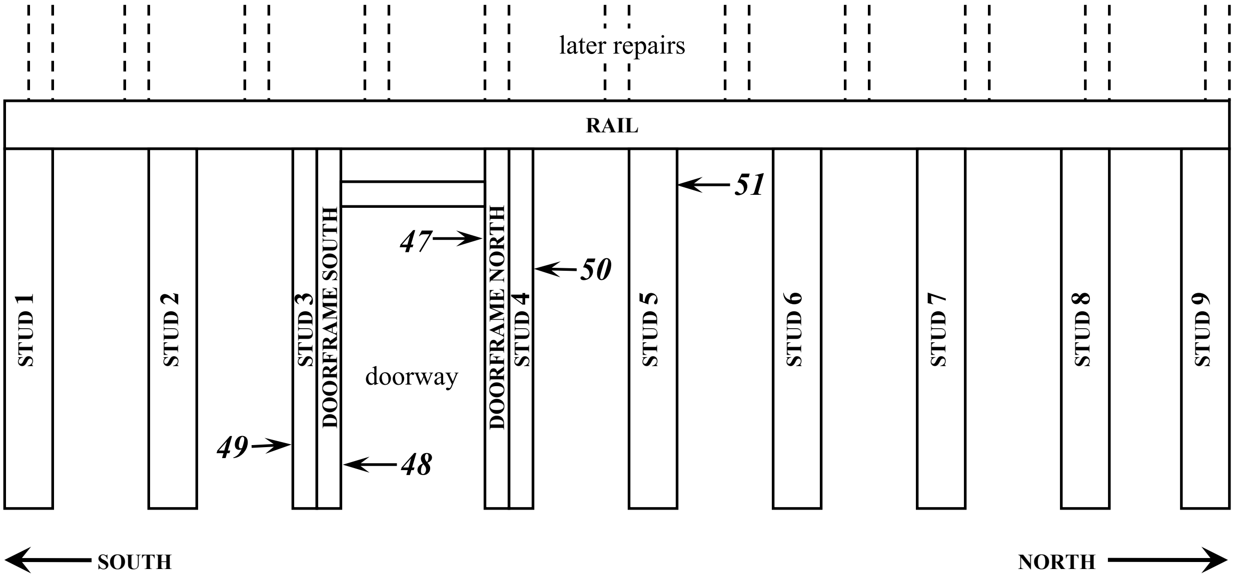


Figure 17 Diagram of the east face of the decorated screen in the north range (after Brown 1998, Fig 8) showing the numbering scheme for the muntins and the approximate location of the samples

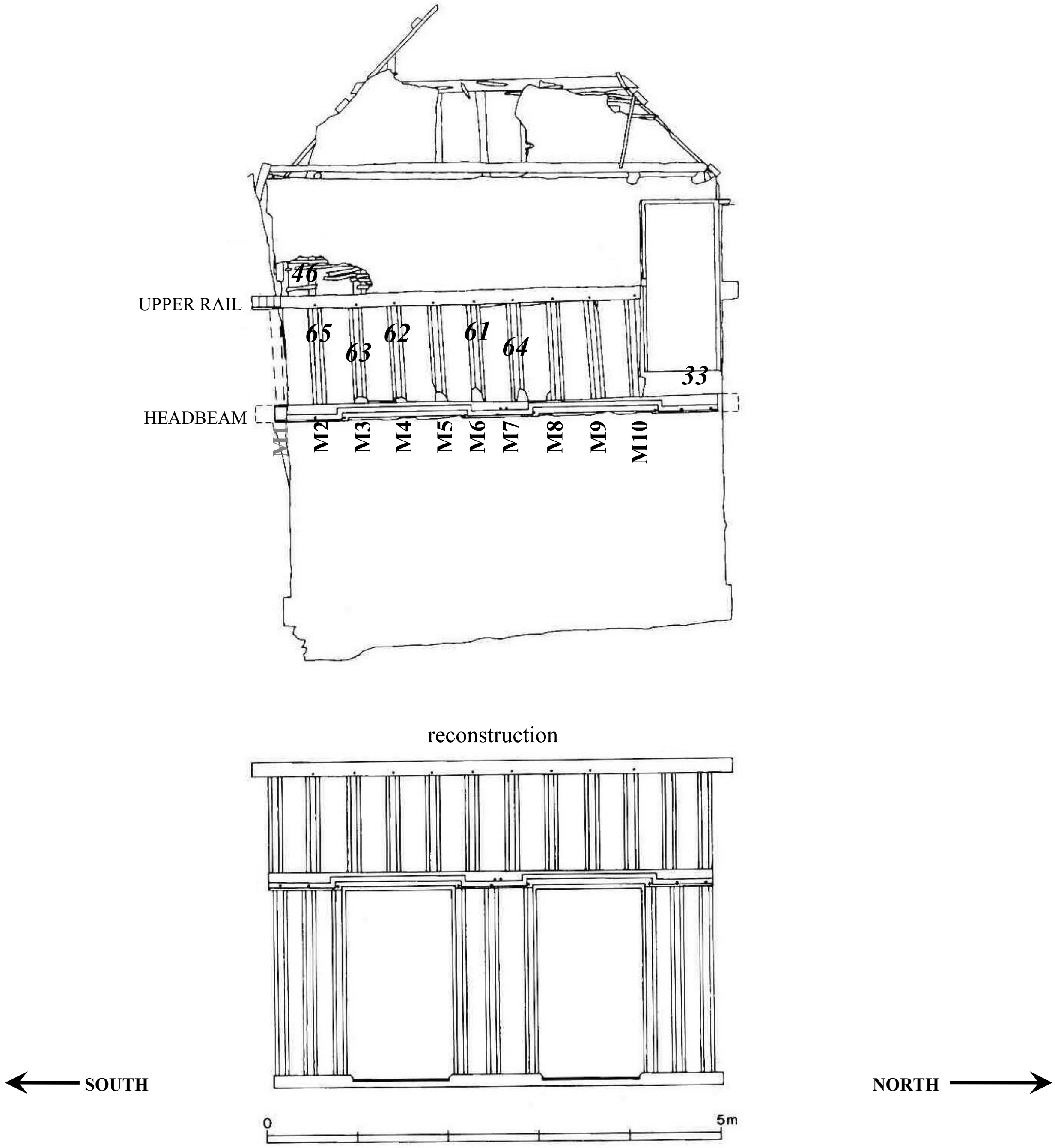


Figure 18 Bar diagram showing the relative positions of the dated ring sequences incorporated into site master chronology ***LBC-A***

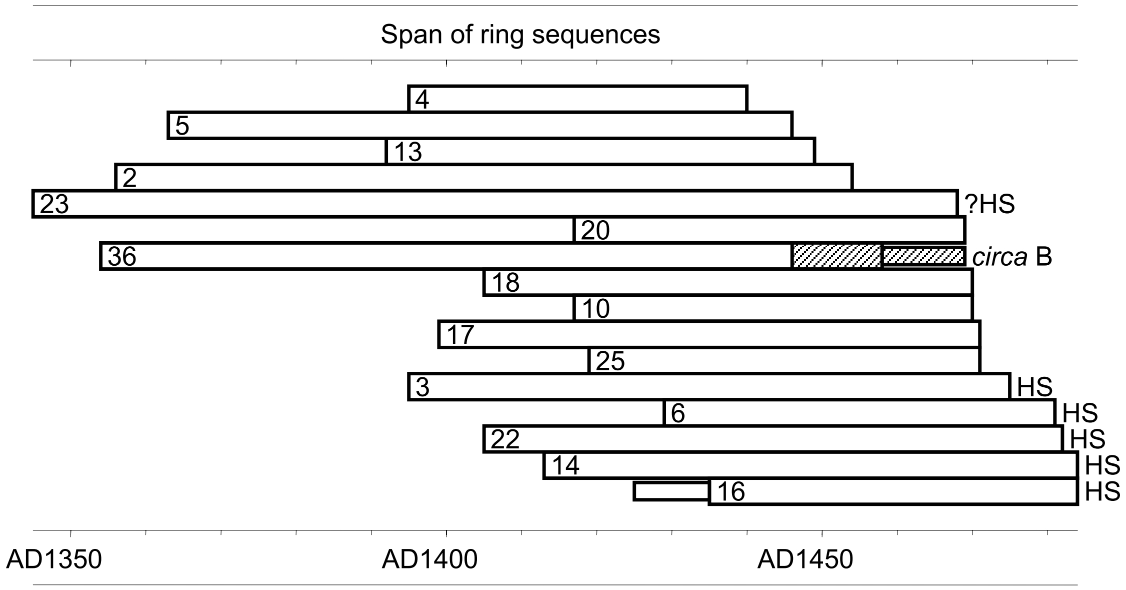
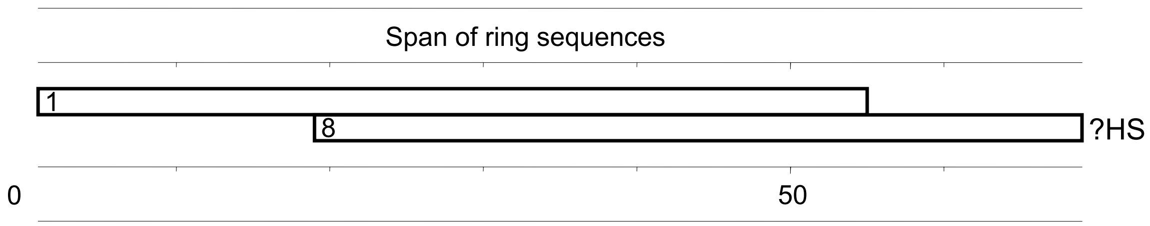
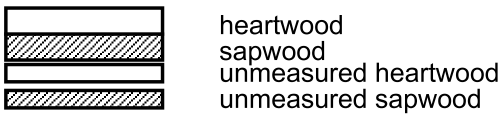


Figure 19 Bar diagram showing the relative positions of the matched ring sequences incorporated into site master chronology ***LBC-B***



Key for Figures 18–24:

KEY



HS heartwood/sapwood boundary
?HS possible heartwood/sapwood boundary
B bark boundary
Bw winter bark boundary

Figure 20 Bar diagram showing the relative positions of the dated ring sequences incorporated into site master chronology ***LBC-C***

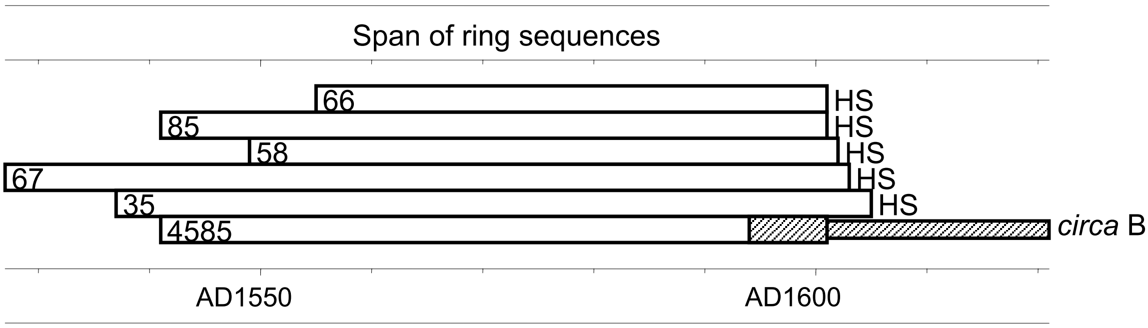


Figure 21 Bar diagram showing the relative positions of the matched ring sequences incorporated into site master chronology ***LBC-D***

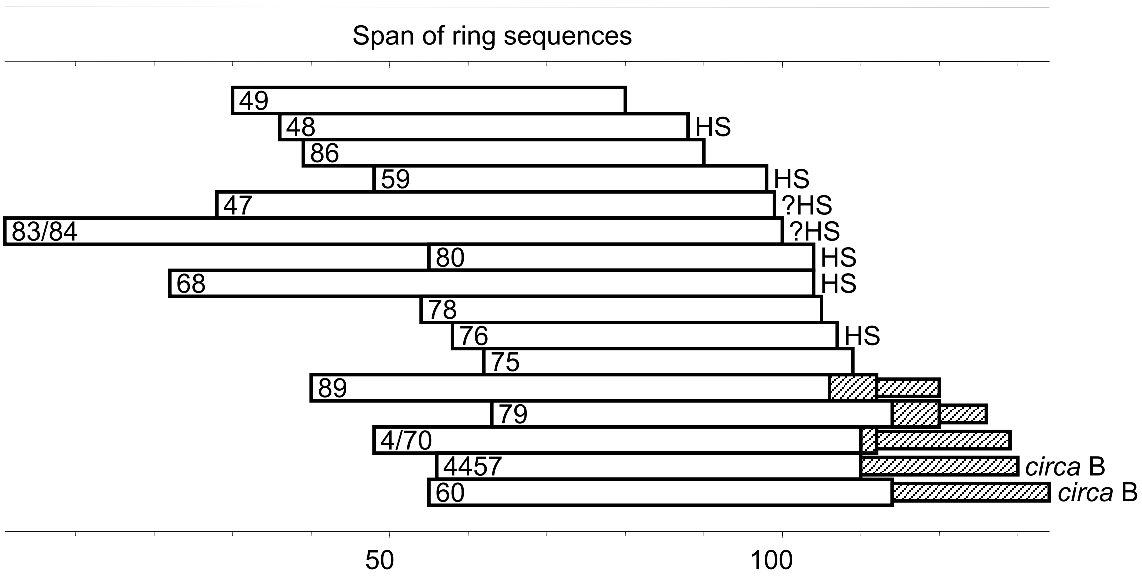


Figure 22 Bar diagram showing the relative positions of the dated ring sequences incorporated into site master chronology ***LBC-E***

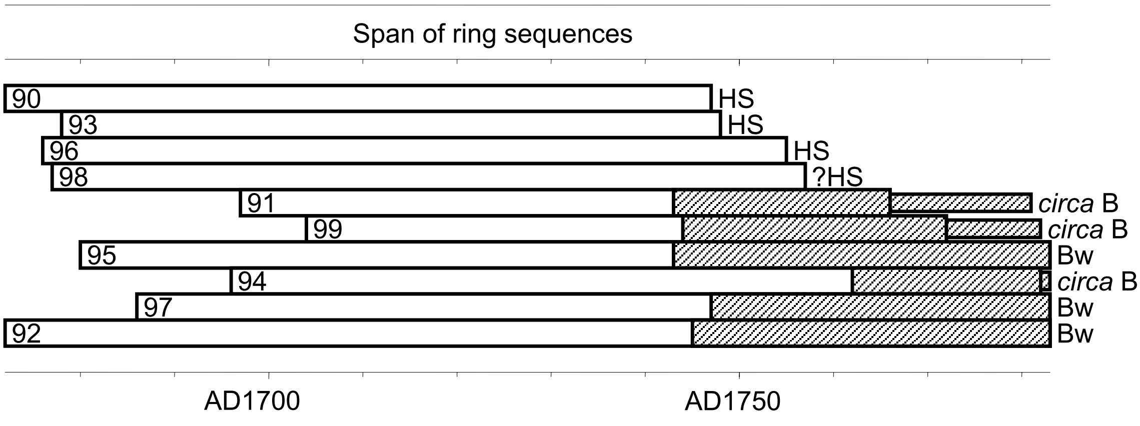


Figure 23 Bar diagram showing the relative positions of the matched ring sequences incorporated into site master chronology ***LBC-F***

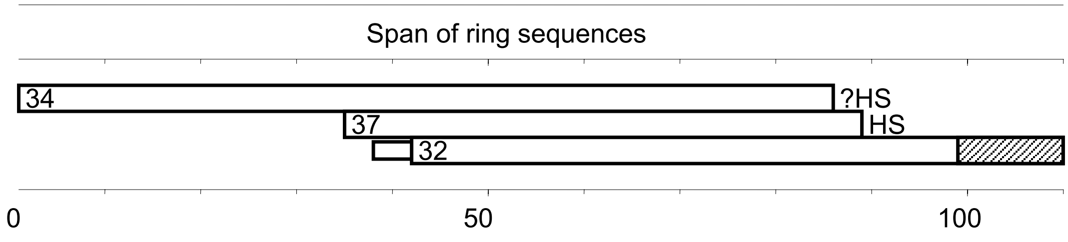


Figure 24 Bar diagram showing the relative positions of the matched ring sequences incorporated into site master chronology ***LBC-G***

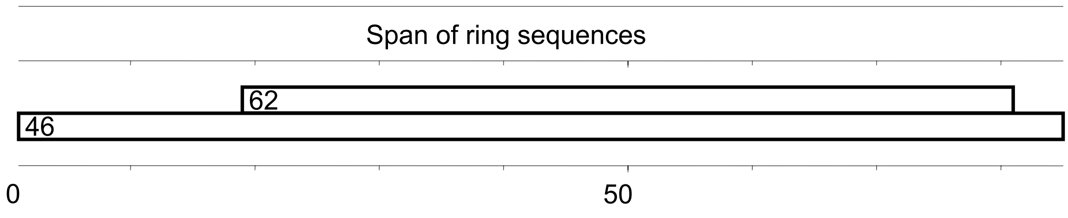
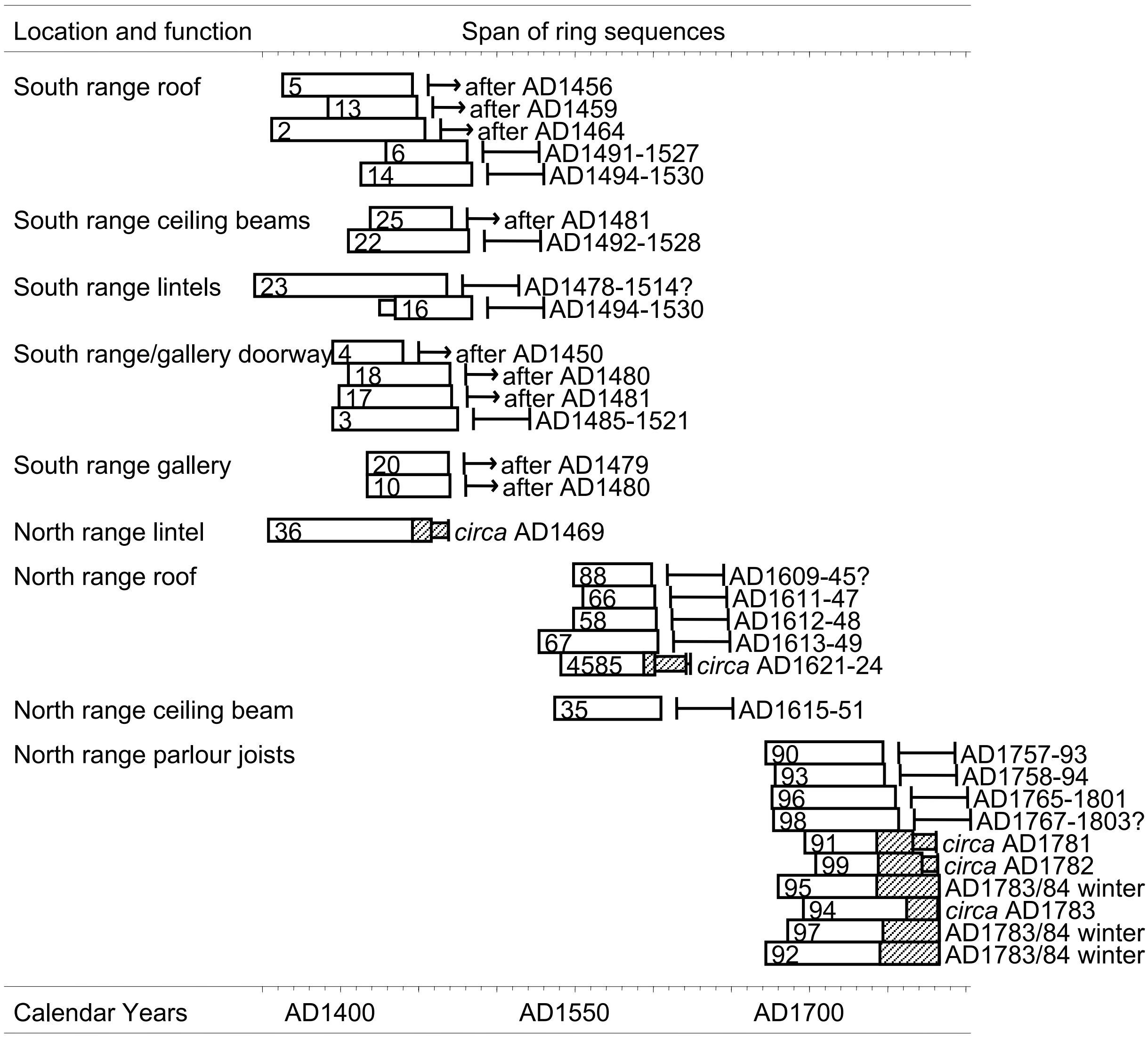


Figure 25 Bar diagram showing the relative positions of the dated ring sequences and their felling dates from the north and south ranges arranged by location and function



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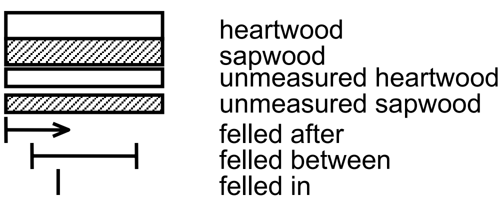
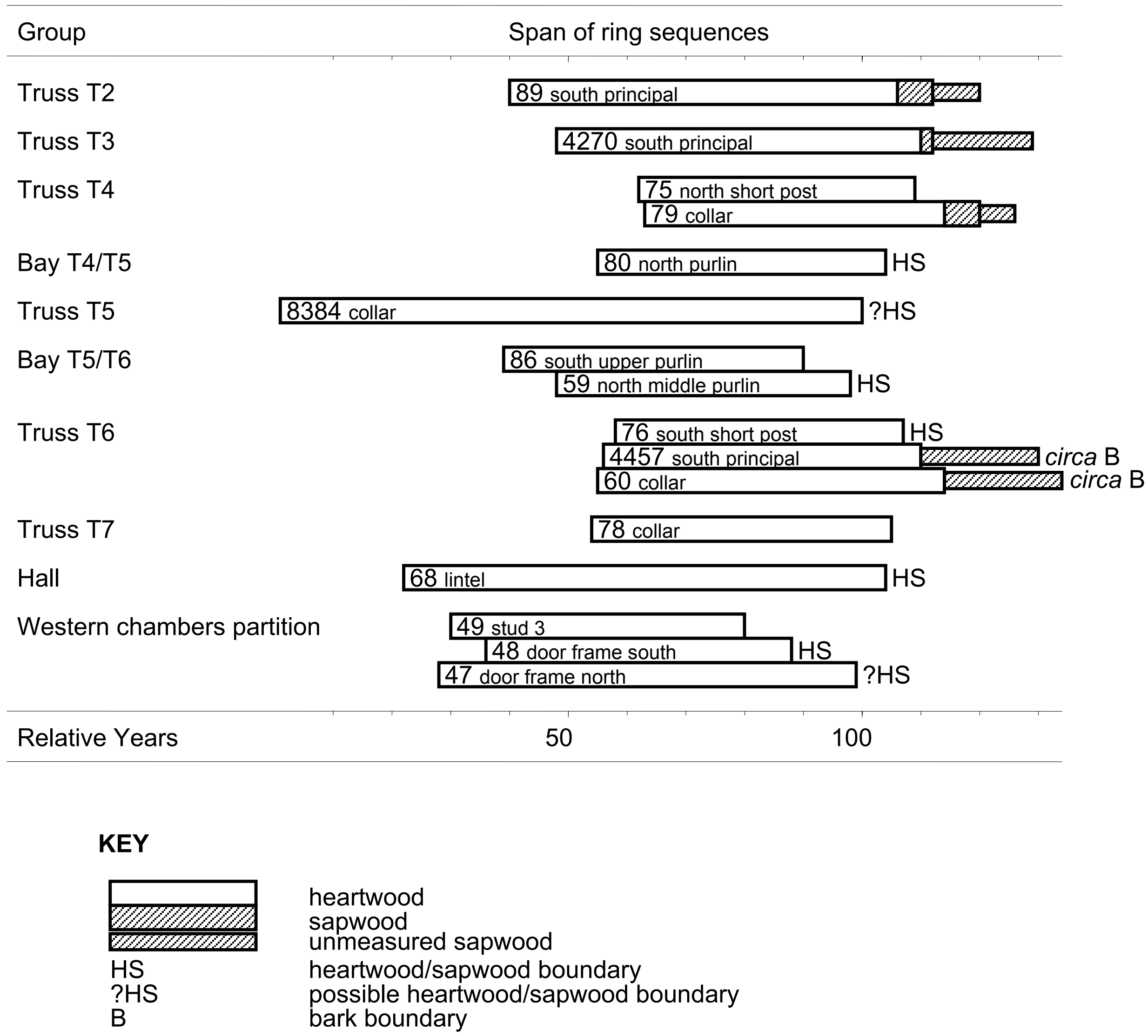


<u>Figure 26</u> Bar diagram showing the relative positions of the matched ring sequences incorporated into site master chronology ***LBC-D***, all from the north range, arranged by location and function



<u>Table 1</u> Details of the samples

Number of rings – total number of measured rings including both heartwood and sapwood; + - indicates the presence of unmeasured heartwood rings
Sapwood rings – number of measured sapwood rings only; + - indicates the presence of unmeasured sapwood rings; hs – heartwood/sapwood boundary present; ?hs – possible heartwood/sapwood boundary present; bw – bark edge present with an apparently complete outermost ring
ARW – average ring width in millimetres

Sample	Provenance	Function	Type	Number of rings	Sapwood rings	ARW	Date of measured sequence	Comments
SOUTH RANGE								
1	truss T101	north principal	oak	55	-	1.98		
2	bay T101/T102	north lower purlin	oak	99	-	1.37	AD 1356–1454	
3	east chamber	north wall inner door lintel	oak	81	hs	1.44	AD 1395–1475	
4	east chamber	north wall door arch	oak	46	-	1.58	AD 1395–1440	
5	truss T103	north principal	oak	84	-	1.61	AD 1363–1446	
6	truss T103	collar	oak	53	hs	1.44	AD 1429–1481	
7	bay T102/T103	north lower purlin	oak	98	hs	1.23		
8	truss T102	north principal	oak	51	?hs	1.93		
9	truss T102	collar	oak	46	hs	1.59		
10	gallery truss T203	north principal	oak	54	-	2.11	AD 1417–1470	
11	gallery truss T204	north principal	oak	-	-	-		rejected
12	truss T105	north upper archbrace	oak	-	-	-		rejected
13	bay T105/T106	north lower purlin	oak	58	-	1.26	AD 1392–1449	
14	truss T108	north principal	oak	72	hs	2.06	AD 1413–1484	
15	truss T108	north lower archbrace	oak	-	-	-		rejected
16	west chamber	west wall inner lintel	oak	+50	hs	2.17	AD 1435–1484	+10 inner heartwood rings
17	east/west chamber	north wall central door post	oak	73	-	2.29	AD 1399–1471	
18	east chamber	north wall outer door lintel	oak	66	-	2.10	AD 1405–1470	
19	gallery	jowled short post 5	oak	-	-	-		rejected
20	gallery	top rail	oak	53	-	2.52	AD 1417–1469	
21	gallery	jowled short post 4	oak	-	-	-		rejected
22	kitchen	ceiling beam 102	oak	78	hs	1.92	AD 1405–1482	
23	kitchen	north wall inner lintel	oak	124	?hs	1.08	AD 1345–1468	
24	gallery?	mid rail?	oak	48	-	2.43		
25	south/west range?	celing beam?	oak	53	-	1.33	AD 1419–1471	
NORTH RANGE								
26	hall	south wall inner lower lintel	oak	-	-	-		rejected
27	hall	south wall outer lintel	oak	-	-	-		rejected
28	hall	ceiling beam B5	oak	74	-	1.99		
29	hall	ceiling beam B6	oak	50	hs	2.96		
30	hall	north wall door jamb stairs entrance	oak	-	-	-		rejected
31	hall	ceiling beam B4	oak	61	hs	2.28		
32	hall	ceiling beam B3	oak	+69	11	2.53		+4 inner heartwood rings
33	decorated screen	head beam	oak	55	-	1.73		
34	service room	ceiling beam B1	oak	86	?hs	1.23		
35	service room	ceiling beam B2a	oak	69	hs	2.04	AD 1537–1605	
36	service room	east wall outer lintel above wall recess	oak	105	12+	0.96	AD 1354–1458	+*c* 10mm sapwood to bark edge
37	service room	ceiling beam B2b	oak	55	hs	2.24		
38	parlour	ceiling beam B7	oak	50	-	1.85		
39	parlour	ceiling beam B8	oak	59	-	2.44		
40	parlour	south wall inner lintel	oak	56	?hs	1.43		
41	parlour	ceiling beam B9	oak	-	-	-		rejected
42	truss T3	south principal	oak	61	hs	2.62		duplicate of 70; +*c* 35mm sapwood
43	truss T4	south principal	oak	47	-	2.90		
44	truss T6	south principal	oak	54	hs+	2.47		duplicate of 57; +*c* 35mm sapwood
45	truss T5	north principal	oak	45	hs+	2.03	AD 1551–1595	duplicate of 85; +*c* 35–40mm sapwood to bark edge
46	decorated screen	upper rail	oak	85	hs	1.31		
47	western chambers partition	door frame north side	oak	72	?hs	1.47		
48	western chambers partition	door frame south side	oak	53	hs	1.03		
49	western chambers partition	stud 3	oak	51	-	2.00		
50	western chambers partition	stud 4	oak	-	-	-		rejected
51	western chambers partition	stud 5	oak	-	-	-		rejected
52	central chamber	north wall door frame west side	oak	-	-	-		rejected
53	east chamber	north wall door frame east side	oak	46	-	1.80		
54	east chamber	north wall door frame west side	oak	-	-	-		rejected
55	central chamber	north wall door frame east side	oak	-	-	-		rejected
56	service room	south wall door frame east side	oak	-	-	-		rejected
57	truss T6	south principal	oak	53	hs+	2.31		duplicate of 44; +*circa* 35mm sapwood to bark edge
58	truss T6	north principal	oak	54	hs	2.64	AD 1549–1602	
59	bay T5/T6	north middle purlin	oak	51	hs	1.47		
60	truss T6	collar	oak	60	hs+	1.86		+*circa* 20–25 sapwood rings to bark edge
61	decorated screen	muntin 6	oak	70	-	1.76		
62	decorated screen	muntin 4	oak	63	-	1.40		
63	decorated screen	muntin 3	oak	51	hs	1.40		
64	decorated screen	muntin 7	oak	89	-	1.67		
65	decorated screen	muntin 2	oak	-	-	-		rejected

Table 1 Details of the samples (cont)

Sample	Provenance	Function	Type	Number of rings	Sapwood rings	ARW	Date of measured sequence	Comments
66	truss T5	south principal	oak	47	hs	2.64	AD 1555–1601	
67	truss T7	north principal	oak	77	hs	2.80	AD 1527–1603	
68	hall	lintel	oak	83	hs	1.04		description on label: “curved top lintel looking south”
69	central chamber	panel head	oak	-	-	-		rejected; description on label:“south face panel head”
70	truss T3	south principal	oak	65	?hs	2.74		duplicate of 42
71	service room	west wall inner lintel	ash	-	-	-		rejected
72	hall	north wall lintel to west of main fireplace	oak	59	19 bw	1.03		
73	service room	north wall inner lintel	oak	-	-	-		duplicate of 81; rejected
74	service room	south wall inner lintel	ash	-	-	-		rejected
75	truss T4	north short post	oak	48	-	2.74		
76	truss T6	south short post	oak	50	hs	1.95		
77	truss T3	collar	oak	112+	-	1.31		+15 outer heartwood rings
78	truss T7	collar	oak	52	-	2.49		
79	truss T4	collar	oak	58	6+	2.58		+6 sapwood rings
80	bay T4/T5	north purlin	oak	50	hs	1.87		upper, middle or lower purlin not known
81	service room	north wall inner lintel	oak	54	-	2.57		duplicate of 73
82	truss T2	north short post	oak	48	hs	1.84		
83	truss T5	collar	oak	96	?hs	1.09		duplicate of 84
84	truss T5	collar	oak	99	?hs	1.10		duplicate of 83
85	truss T5	north principal	oak	61	hs	2.26	AD 1541–1601	duplicate of 45
86	bay T5/T6	south top purlin	oak	52	-	2.06		
87	truss T4	north principal	oak	-	-	-		rejected
88	truss T7	south principal	oak	51	?hs	3.21	AD 1549–1599	
89	truss T2	south principal	oak	73	6+	2.42		+8 sapwood rings
90	parlour	joist 9W	oak	76	hs	1.04	AD 1672–1747	
91	parlour	joist 10E	oak	70	23+	1.30	AD 1697–1766	+*c* 15 sapwood rings to bark edge
92	parlour	joist 7W	oak	112	38 bw	0.90	AD 1672–1783	
93	parlour	joist 6E	oak	71	hs	1.40	AD 1678–1748	
94	parlour	joist 1E	oak	87	20+	1.36	AD 1696–1782	+1–2 sapwood rings to bark edge
95	parlour	joist 7E	oak	104	40 bw	0.95	AD 1680–1783	
96	parlour	joist 1W	oak	80	hs	1.06	AD 1676–1755	
97	parlour	joist 8E	oak	98	36 bw	0.92	AD 1686–1783	
98	parlour	joist 8W	oak	81	?hs	1.23	AD 1677–1757	
99	parlour	joist 2W	oak	69	28+	1.24	AD 1704–1772	+*c* 10 sapwood rings to bark edge
100	passage	joist	oak	51	-	2.07		
101	passage	joist	oak	53	-	2.21		
102	passage	joist	oak	-	-	-		rejected
103	passage	joist	oak	53	-	1.39		duplicate of 104
104	passage	joist	oak	53	-	1.34		duplicate of 103

Table 2 Matrix showing the *t*-values obtained between the matching ring sequences included in the site master chronology ***LBC-A***.
– indicates *t*-values less than 3.00; \ indicates overlap of less than 30 years

Sample	**3**	**4**	**5**	**6**	**10**	**13**	**14**	**16**	**17**	**18**	**20**	**22**	**23**	**25**	**36**
2	5.15	3.63	3.97	\	3.64	14.08	3.38	\	3.51	7.78	4.21	3.71	5.60	6.76	6.44
3		3.89	–	3.54	5.17	4.04	4.89	3.61	4.54	5.65	5.66	5.24	5.48	5.01	3.21
4			3.21	\	\	–	\	\	–	–	\	3.27	4.19	\	3.13
5				\	3.96	–	6.12	\	3.15	4.20	3.88	–	–	\	3.67
6					–	\	6.30	3.16	–	–	–	4.49	–	–	–
10						3.21	–	3.22	–	4.26	5.13	3.03	3.44	3.16	–
13							3.75	\	–	5.54	4.58	4.11	4.79	6.51	6.41
14								–	–	3.92	–	5.77	3.35	–	–
16									–	4.36	3.27	–	–	–	\
17										3.69	–	4.12	3.53	6.53	–
18											4.61	3.65	5.13	5.26	4.58
20												4.36	3.85	3.04	4.83
22													3.94	4.40	–
23														5.54	3.69
25															4.07

Table 3 Dating the site master chronology ***LBC-A***, dated AD 1345–1484 inclusive. Example *t*-values with some relevant regional and site reference chronologies

Area	**Reference chronology**	**Date span**	***t*-values**
Cornwall	Goldophin House, Godolphin Cross (Groves unpubl)	AD1376–1620	5.88
Cornwall	Pendennis Castle, nr Falmouth (Tyers 2004c)	AD1358–1541	6.50
Devon	21 The Mint, Exeter (Nayling 2001)	AD1398–1575	5.49
Devon	Broomham, Kings Nympton (Groves 2005)	AD1370–1464	4.78
Devon	Crediton Holy Cross church (Tyers 2004b)	AD1317–1536	6.24
Devon	Lower Chilverton, Coldridge (Groves 2005)	AD1351–1488	6.34
Devon	Prowse Farm barn, Sandford (Groves 2005)	AD1380–1473	6.32
Devon	Townsend Farmhouse barn, Stockland (Tyers and Groves 2003)	AD1387–1478	6.16
Herefordshire	White House, Vowchurch (Nayling 1999)	AD1364–1602	4.78
Welsh Border	(Siebenlist-Kerner 1978)	AD1341–1636	5.00

Table 4 Ring width data from the site master chronology ***LBC-A***, dated AD 1345–1484 inclusive

Date	**Ring widths (units of 0.01mm)**									
AD1345					166	123	118	70	73	36
AD1351	41	72	70	67	68	60	80	81	98	66
	51	39	143	156	123	117	87	51	86	105
	106	126	140	125	107	72	106	102	142	187
	149	150	148	149	79	90	111	98	112	94
	95	88	119	128	111	116	109	81	136	112
AD1401	116	152	198	208	191	253	169	215	143	140
	157	181	215	226	253	183	229	224	134	218
	170	117	222	218	219	200	130	179	167	188
	200	236	207	183	261	222	192	132	103	149
	135	128	187	165	185	207	210	183	173	126
AD1451	147	146	138	224	159	187	183	210	176	180
	143	130	156	140	153	172	203	179	138	140
	100	142	169	148	229	193	143	148	100	120
	162	162	158	156						

Table 5 Matrix showing the *t*-values obtained between the matching ring sequences included in the site master chronology ***LBC-B***

Sample	8
1	4.58

Table 6 Matrix showing the *t*-values obtained between the matching ring sequences included in the site master chronology ***LBC-C***

Sample	4585	58	66	67	88
35	4.06	3.80	3.13	5.86	4.50
4585		5.18	4.42	6.48	6.32
58			5.01	8.23	6.41
66				3.65	5.89
67					7.29

<u>Table 7</u> Matrix showing the *t*-values obtained between the matching ring sequences included in the site master chronology ***LBC-D***. – indicates *t*-values less than 3.00; \ indicates overlap of less than 30 years

Sample	4457	47	48	49	59	60	68	75	76	78	79	80	83/84	86	89
4270	11.33	5.56	3.78	3.67	4.80	6.21	3.47	3.46	7.14	5.47	–	4.30	4.56	3.25	3.23
4457		7.87	5.18	\	5.71	6.40	4.43	5.04	9.65	5.23	4.28	5.63	6.44	4.04	3.65
47			9.29	4.35	4.71	3.19	4.70	3.99	5.90	3.19	3.82	–	6.53	3.07	5.12
48				5.10	3.83	–	6.14	\	3.76	–	\	–	5.96	5.32	3.94
49					–	\	4.25	\	\	\	\	\	–	–	–
59						–	4.58	–	3.27	–	–	–	5.08	4.85	3.88
60							–	–	6.68	6.76	5.57	–	3.14	–	–
68								–	–	–	–	–	4.40	4.83	4.04
75									3.78	3.78	4.97	–	–	\	–
76										4.59	6.20	3.74	4.90	3.88	3.44
78											6.34	–	3.15	3.06	–
79												–	–	\	–
80													3.88	–	–
8384														4.07	4.42
86															–

Table 8 Matrix showing the *t*-values obtained between the matching ring sequences included in the site master chronology ***LBC-E***. – indicates *t*-values less than 3.00

Sample	91	92	93	94	95	96	97	98	99
90	3.99	7.06	3.57	3.72	7.02	4.01	6.32	8.34	–
91		3.83	6.55	4.08	–	3.82	6.24	5.11	5.65
92			3.14	4.69	5.68	4.85	4.98	5.81	–
93				3.40	–	5.82	4.50	4.27	3.49
94					4.76	7.54	7.28	11.03	6.67
95						–	6.54	4.50	–
96							3.58	10.82	3.92
97								7.14	4.43
98									4.17

Table 9 Matrix showing the *t*-values obtained between the matching ring sequences included in the site master chronology ***LBC-F***

Sample	34	37
32	4.78	4.40
34		6.94

Table 10 Matrix showing the *t*-values obtained between the matching ring sequences included in the site master chronology ***LBC-G***

Sample	62
46	10.91

Table 11 Dating the site master chronology ***LBC-C***, dated AD 1527–1605 inclusive and its individual components. Example *t*-values with some relevant regional and site reference chronologies; – indicates *t*-values less than 3.00

Area	**Reference chronology**	**Date span**	***t*-values**						
			LBC-C	**35**	**45/85**	**58**	**66**	**67**	**88**
Ireland	Belfast (Baillie 1977)	AD1001–1970	3.75	4.22	4.31	4.35	3.72	–	5.36
Cambridgeshire	Sutton-in-the-Isle bellframe (Tyers 1995)	AD1508–1615	4.34	3.64	4.08	4.45	–	3.45	3.57
Derbyshire	Bolsover Castle Riding School (Howard *et al* 2005)	AD1494–1744	3.64	3.31	4.34	3.05	–	–	3.02
Derbyshire	Bretby Hall, Bretby T30 (Howard *et al* 1999)	AD1494–1805	4.10	3.99	4.76	3.49	4.50	–	4.28
Herefordshire	Pembridge bell tower (Tyers 1999a)	AD1559–1668	4.31	4.27	3.27	3.67	–	–	3.67
Oxfordshire	Rose Farm House, Mapledurham (Haddon-Reece *et al* 1989)	AD1543–1613	5.58	5.54	3.77	3.40	4.14	3.32	4.00
Oxfordshire	Manor Farm, Stanton St John (Miles and Worthington 1998)	AD1533–1637	4.18	4.66	3.92	3.79	–	3.61	–
Berkshire	Windsor Castle St Georges (Hillam pers comm)	AD1551–1667	4.90	3.83	4.02	3.84	3.50	3.22	3.43
Wiltshire	Queen Manor Farm Granary, Clarendon (Tyers 1999b)	AD1337–1602	3.46	3.08	7.47	3.90	–	3.15	3.23
Cornwall	Goldophin House, Godolphin Cross (Groves unpubl)	AD1376–1620	4.20	5.98	3.26	3.65	3.90	–	4.32

Table 12 Dating the site master chronology ***LBC-E***, dated AD 1672–1783 inclusive. Example *t*-values with some relevant regional and site reference chronologies

Area	Reference chronology	Date span	*t*-values
London	Royal Arsenal Woolwich (Tyers 2000)	AD1617–1782	5.22
Worcestershire	Worcester Cathedral (Howard *et al* 2000; Arnold *et al* 2003b; Arnold *et al* 2004)	AD1443–1772	5.80
Berkshire	Skeleton Barn, Hampstead Norreys (Miles 2001)	AD1722–1811	4.70
Kent	Chatham Dockyard (Bridge 1998)	AD1615–1780	5.45
Kent	Manor Barn, Great Newstead (Arnold *et al* 2003a)	AD1670–1780	6.92
Wiltshire	St John the Baptist Church, Bishopstone (Bridge 1999)	AD1705–1798	4.37
Wiltshire	Clarendon House Granary (Tyers 2001)	AD1675–1764	4.39
Cornwall	South Coombeshead barn, Stoke Climsland (Tyers and Groves 1999)	AD1714–1833	4.59
Devon	Buckland, Yelverton (Morgan pers comm)	AD1677–1799	6.11
Devon	Exeter Cathedral (Mills 1988)	AD1659–1787	6.90

Table 13 Ring width data from the site master chronology ***LBC-C***, dated AD 1527–1605 inclusive

Date	Ring widths (units of 0.01mm)								
AD1527							138	221	210	238
	218	251	147	161	183	101	215	271	410	348
	263	294	235	232	292	156	159	163	378	408
AD1551	411	301	293	304	422	277	327	468	441	435
	351	407	263	318	319	316	353	273	287	332
	281	226	233	286	213	185	214	144	175	244
	199	228	212	235	244	210	204	163	176	135
	191	230	212	194	203	163	162	133	104	118
AD1601	136	199	245	236	272					

Table 14 Ring width data from the site master chronology ***LBC-E***, dated AD 1672–1783 inclusive

Date	**Ring widths (units of 0.01mm)**								
AD1672		271	351	198	225	176	204	133	126	174
	104	246	170	145	137	156	86	97	99	127
	162	133	143	145	141	201	187	163	127	160
AD1701	154	135	150	161	80	100	87	136	146	130
	112	140	134	128	166	177	204	176	150	160
	129	124	139	136	96	120	145	109	101	84
	86	90	79	99	87	93	66	91	76	74
	65	43	66	88	59	79	63	49	40	37
AD1751	51	65	54	74	73	71	45	53	90	64
	45	39	56	62	59	73	69	87	75	69
	47	46	47	65	74	94	86	83	71	116
	119	132	109							