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Church of St John The Baptist Myndtown Shropshire

Tree-ring Analysis of Oak Timbers incorporating a Survey of the Roofs

Alison Arnold, Robert Howard, Bob Meeson, and Cathy Tyers

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MYNDTOWN
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SUMMARY
Analysis was undertaken on samples from timbers representing two phases of roofs within both the nave and the chancel, from the bell-cote and two bell levers, and from three *ex situ* timbers recovered from the nave wall during restoration work. This resulted in the successful dating of 58 samples.

The oldest timbers identified are from the surviving remnants of an earlier nave roof, dated as felled in the range AD 1225–50, and two of the *ex situ* timbers recovered from the nave wall which have a felling date range of AD 1218–43 and hence appear plausibly to be coeval with this roof.

The extant replacement nave roof dates to around a century later being constructed from timber felled in AD 1326–48, as do the remnants of the earlier chancel roof which utilises timber felled in, or around, the winter of AD 1332/33. The third *ex situ* timber and one of the timbers of the bell-cote also belong to the first half of the fourteenth century, having felling date ranges of AD 1301–36 and AD 1314–49 respectively.

The latest timbers are those belonging to a reconstruction of the chancel roof which were felled sometime in the range of AD 1570–95. The majority of the reused beams utilised within the bell-cote have a felling date range of AD 1567–92, and thus appear likely to be coeval with the present chancel roof. In addition, the bell levers also appear likely to be of sixteenth-century date with *termini post quem* dates for felling of AD 1515 and AD 1548.

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INTRODUCTION

Myndtown is located 7km south-west of Church Stretton in south Shropshire, with the church of St John the Baptist situated near the southern end of the Long Mynd at an altitude of *c* 220m on a west-facing slope overlooking the confluence of the rivers East Onny and West Onny (Fig. 1). The church stands near the boundary between enclosed pasture fields which fall away to the south-west, and include earthworks of a medieval settlement earthworks, and open grazing land to the east across Old Churchmoor Hill which rises to just over 460m.

The Grade II*-listed parish church is of twelfth-century or earlier origin and is comprised of a nave with a west belfry and a chancel (Fig. 2). The present, largely nineteenth-century, south porch replaces a fourteenth-century predecessor with curved braces to a cranked tiebeam. The uncoursed rubble masonry is not readily dateable, and all of the windows have been altered or replaced. However, the nave walls are splayed (i.e. they reduce in thickness as they rise), some of the window rear-arches might betray possible Norman origins, and Cranage (1901) noted '*the remains of what looks like a Norman string course at the east end of the nave*'. The south doorway with two-centred arch and plain chamfer may be early fourteenth century. Cranage (1901) attributed the chancel roof to the fifteenth century but did not suggest a date for that over the nave. Fragments of medieval paint noted under the limewash on the nave north wall in 1964 and mentioned in the listed building description (LEN 1054598 here) were verified in 2017.

Following a grant from the Heritage Lottery Fund, preparatory to a programme of repairs and conservation, preliminary investigations in November 2015 directed by architects Arrol and Snell Ltd. included opening up of two small areas around the feet of two coupled-rafter trusses, exposing the remnants of an earlier roof. When the main phase of repairs commenced in February 2017, a part-time watching brief was maintained by Bob Meeson while the roofs were opened up and during the early stages of their repair.

Nave

Earlier roof remnants

During the preliminary investigations of the present roof the remnants of an older roof were discovered (Fig. 3), although this roof is however not proven to be the primary roof. In February/March 2017, the slates and sarking boards were removed and portions of the fabric were opened up by the contractors, Phillips and Curry. All of those timbers that were partially and temporarily exposed to view were recorded (Meeson 2015 unpubl) before they were re-encased in the rebuilt top of the nave walls.

Including those over the end walls, there might have been 15 coupled-rafter trusses in this early, though not necessarily primary, roof. The surviving accessible timbers include the tiebeam referred to by Cranage (1901). At each end, the tiebeam passes over a wall-plate which extends east-west near the outer edge of the wall. Near the north-west corner of the nave this early wall-plate has a scantling of *c*. 0.13m ×

0.14m and it is of simple rectangular section, so unlike some other examples elsewhere, there is no cogging (i.e. there is no raised tongue or fillet on its top face). The south end of the tiebeam is *c*. 0.19m wide and 0.18m deep. Originally, the soffit of this tiebeam extended slightly beyond the outer face of the wall, at which point it is halved, and single-pegged, to receive the corresponding lap joint near the foot of a rafter. Just within the internal wall face a half-dovetail housing on the west face of the tiebeam, again with a single peg-hole, secured the ashlar piece that formerly extended vertically to a corresponding lap joint in the side of the rafter. The south end of the tiebeam is similar. Throughout its span across the nave there are no other halvings, so apparently no struts have ever extended from this tiebeam up to the rafters. Grooves worn by a rope into the sides of the tiebeam suggest that it was retained for its utility in connection with the bell-cote above.

The internal ends of timbers 11, 13, 14, and 27 have been crudely hacked, suggesting that they have been truncated. Moreover, on timbers 13, 14, and 27 part of the end grain has been split off rather than cut. There is more evidence of truncation on timber 5, the inner end of which has been cut through the middle of a drilled hole – possibly a divet or setting-out hole. This evidence can be interpreted in two ways. Firstly, the timbers might be interpreted as the remains of a common tiebeam roof; that is to say, a roof which had a tiebeam under every *sans purlin* single-scantling rafter couple. Secondly, tiebeams might have been spaced at intervals (at 3, 7, and 11 on Fig. 11), the majority of the rafter couples being carried only by internally projecting sole-plates with shaped or moulded terminals that were cut off when the roof was replaced. However, several of the transverse timbers (including 9, 11, and 20) had poor sectional profiles with their top faces left in the round, more suggestive of the limitations imposed by the extremities of long tiebeams than of short sole-plates, making the first interpretation more likely.

Extant roof

Including those over the west wall and the chancel arch, the present roof over the nave has 26 uniform-scantling *sans purlin* coupled-rafter trusses, set over a single wall-plate of rectangular section along the middle of the wall. The sole-plates, which project out beyond the outer faces of the walls, are halved over the wall-plates; these, in turn, support ashlar pieces and the feet of the common rafters, all joints being mortice and tenon. Curved soulaces, extending up to a single collar, have triple-pegged tenons to the rafters and double-pegged tenons to the collars. The rafters are joined at the apex by mortice and tenon joints, the tenons being fully contained within the mortices (Figs 4 and 5). The internal span varies along the length of the nave, the average being approximately 5.3m.

Using rubble masonry packed into clay, the side walls were built up around the sole-plates and ashlar pieces, forming a sloping top in the plane of the roof. Hewett (1980) cited Harlowbury Chapel, Essex, as an example of rafter couples embedded in the primary inclined upper facets of the wall (with no wall-plate, sole-pieces, or ashlars), and attributed these to *c*. AD 1180. Elsewhere the rafters are secured by ashlars and sole-pieces as here at Myndtown. Morley (1985) noted, in his report on St Mary's Church, Kempley, Gloucestershire, that there are few surviving examples of the inner wall face being '*carried up beyond the wall plate level*'; this was subsequently tree-ring dated to AD 1128–32 (Miles *et al* 1999; Miles *et al* 2008).

The sloping top of the wall at St John's Hospital and Chantry, Cirencester, Gloucestershire, may have been built *c.* AD 1202–25 (Arnold and Howard 2007a). Most of these examples employed lap-joint carpentry, whereas in marked contrast in the second roof at the Church of St John the Baptist in Myndtown the use of mortice and tenon joints and curved soulaces both point to a later date.

Another noteworthy characteristic of the second roof here is the survival of two rafter trusses in the thickness of the west gable wall; one overlooking the nave, the other formerly visible externally. For many years the latter has been concealed by roughcast, but it could be seen on a painting of AD 1791 by the Reverend Edward William, and it was exposed to view during the recent conservation work. When first built, the most easterly truss was also open to view where it extended above the chancel roof.

Chancel

No traces of the oldest chancel roof have been observed, but some elements of the second roof have survived (Fig. 6). The latter include in situ sole-plates morticed to receive the feet of rafters and ashlar pieces, and some of the common rafters appear to be re-used from this roof, corresponding with its second-phase counterpart over the nave. Although he was aware of repairs in AD 1859, Cranage (1901) described the present chancel roof as follows: '*The chancel roof has two purlins on each side and excellent ornamental purlin-braces* [i.e. wind-braces]*: one truss has a tie-beam and a collar, and the other a collar only. The date may be fifteenth century.*' With the benefit of closer inspection, it is possible to refine that description and to suggest a later date of construction.

The western tiebeam spans the chancel *c.* 0.35m from the masonry return at the end of the nave; 0.35m × 0.13m in section at its north end, the tiebeam expands to 0.41m × 0.14m at its centre (Fig. 7). The top edge facing west is cut square, but the other three edges have large steep chamfers. The raked struts, which rise directly from the tiebeam to the principals, have a narrow ovolo (quarter-round) moulding on every edge. However, the mouldings on the principals include both a straight chamfer and a quarter-round. The straight, high collar (0.24m × 0.09m) is tenoned into the principals; three edges have very small ovolos, but the fourth has a large single ogee (a device commonly employed *c.* AD 1325–1550), but its position between the top face and the west side of the collar strongly suggests re-use. At the apex the principals are joined by a mortice and tenon joint, and the inner angle is finished with a mason's mitre. Two tiers of side purlins and a ridge purlin are trenched across this truss. Tenoned at both ends, the wind braces to the upper purlins have straight soffits but their top faces are shaped to a pronounced double ogee form. Double-ogees in Old Hall, Claverley, Shropshire, were attributed by Moran (2003) to the late fourteenth/early-fifteenth century, but these were, by convention, on the soffits of the wind-braces. The braces at the Church of St John the Baptist, are more likely to be derivative, and much later in date.

When it was assembled the roof truss adjacent to the east wall of the chancel may have been broadly similar to its western counterpart, but there are some significant differences. Firstly, there are now only pads to support the feet of the principals. The principals retain redundant mortices for the tenons at the heads of raked struts, which could imply that originally there was a tiebeam to support their feet, but equally, it is possible that when this roof was being assembled a decision was taken to omit the tiebeam so as not to cross the east window rear-arch. Secondly, the mouldings on the principals and pads in this east truss are markedly different from those on the west truss. On one side of the soffit there is a narrow bead moulding, and on the other a very narrow double ovolo, with parallels in the mid-seventeenth century. However, on the pads/truncated tiebeam these mouldings are now on the top face, strongly indicating re-use. That re-use might well have been as late as the nineteenth century.

Bell-cote

This structure consists of posts, rails, and braces (Fig. 8), all of which are thought to be reused, possibly from the original fourteenth-century porch. It houses two bells, a twelfth-century tenor bell and a treble bell, thought to be a sixteenth-century recasting of a twelfth-century bell (Elphick 1984 unpubl).

Bell-levers

Both the tenor and treble bells are chimed by unusual club clappers, where the lever itself is used as the headstock (Fig. 9). Similar levers are known from the Church of the Holy Sepulchre in Warminghurst, Sussex, where they were thought to be twelfth-century in date (Elphick 1970). An early attempt by George Elphick to date the bell-levers at the Church of St John the Baptist, by dendrochronology produced two potential dates, the first in the third quarter of the twelfth century and the second in the second quarter of the sixteenth century, however this was in the early pioneering days of the use of dendrochronology as a dating technique when there was very little, if any, reference material available and before the rigorous statistical approach now employed was made feasible by computers.

Ex situ timbers

During restoration work undertaken on the nave wall some timbers were recovered. One of these was obviously originally cut as a lintel as it is stopped and chamfered (Fig. 10), although whether this would have been for a door or a window is unknown.

SAMPLING

Dendrochronological analysis was requested by John Tiernan (Historic England Heritage At Risk Architect) in order to attempt to obtain precise independent dating evidence for the historical development of this church and specifically to understand the chronological relationship of the different roofs over the nave and chancel and whether their construction related to the bell-cote.

Sixty-four core samples were taken from oak (*Quercus* spp) timbers of the nave and chancel roofs, the bell-cote, the two bell levers, and the three ex situ timbers removed from a wall in the nave. Each sample was given the code MYN-T and numbered 01–64. Further details relating to the samples can be found in Table 1. The location of samples has been marked on Figures 9 and 11–25. Sole-plates/tiebeams and trusses have been numbered from east to west, with the exception of the oldest roof timbers of the nave which have been numbered following the unpublished survey by Bob Meeson.

ANALYSIS AND RESULTS

Four of the samples, one from the earlier remnant nave roof, one from the earlier remnant chancel roof, one from the extant chancel roof, and one from the bell-cote had too few rings for secure dating purposes and so were rejected prior to measurement. The remaining 60 samples were prepared by sanding and polishing, and their growth-ring widths measured; the data of these measurements are given at the end of the report. These measurements were then compared with each other by the Litton/Zainodin grouping procedure (see Appendix), resulting in 58 samples cross-matching to form three groups.

Firstly, 37 samples matched each other at a minimum *t*-value of 4.6, and were combined at the relevant offset positions to form MYNTSQ01, a site sequence of 306 rings (Fig. 26). This site sequence was compared against an extensive series of reference chronologies for oak where it was found to match consistently and securely at a first-ring date of AD 1027 and a last-measured ring date of AD 1332. The evidence for this dating is given in Table 2.

Secondly, two samples matched at a *t*-value of 7.5, and were combined at the relevant offset positions to form MYNTSQ02, a site sequence of 61 rings (Fig. 27). This site sequence was also compared against an extensive series of relevant reference chronologies where it was found to span the period AD 1506–66. The evidence for this dating is given in Table 3.

Finally, 19 samples grouped at a minimum *t*-value of 5.6, and were combined to form MYNTSQ03, a site sequence of 149 rings (Fig. 28). This site sequence was again compared against an extensive series of reference chronologies resulting in it being dated to the period AD 1420–1568. The evidence for this date is given in Table 4.

The remaining two ungrouped samples were compared individually against the site chronologies and the reference chronologies but no secure dating was found and these remain undated.

INTERPRETATION

Analysis has resulted in the successful dating of 58 timbers, 22 from the nave roof, 22 from the chancel roof, nine from the bell cote, two from bell-levers, and the three ex situ ones from the nave (Fig. 29). Felling date ranges and *termini post quem* for felling (felled after dates) are generally calculated using the estimate that 95% of mature oak trees from this area have between 15 and 40 sapwood rings. However, given that one of the samples from the earlier chancel roof has 58 sapwood rings, it was thought appropriate to apply the more conservative estimate of 15–50 rings to the timbers of this roof and to those of the broadly coeval extant nave roof which utilises timbers with similar growth characteristics. This wider sapwood estimate has also been applied to the earlier reused timber identified within the bell-cote and the fourteenth-century ex situ timber for the same reasons.

Nave

Earlier roof remnants

Ten of the samples taken from surviving timbers associated with this earlier roof have been successfully dated. Unfortunately, only one of these (MYN-T03) has the heartwood/sapwood boundary ring, the date of which is AD 1210, giving an estimated felling date for the timber represented to within the range AD 1225–50 (using the 15–40 ring sapwood estimate). The other dated samples have last-measured heartwood ring dates ranging from AD 1115 (MYN-T11) to AD 1199 (MYN-T07), which produce *termini post quem* for felling ranging from AD 1130 to AD 1214, making it possible that all of these were also felled in AD 1225–50. This interpretation that at least some of these timbers were felled at the same time in the second quarter of the thirteenth century is supported by the very high t-values noted between MYN-T01, MYN-T07, and MYN-T08, all without any trace of sapwood, and sample MYN-T03, with the heartwood/sapwood boundary ($t = 13.5$, $t = 14.2$, and $t = 14.7$, respectively). This suggests that all four timbers (truncated tiebeams/sole-plates) may have been cut from the same tree and hence felled at the same time, or were at least derived from trees growing in close proximity.

Extant roof

All 12 samples taken from this structure have been dated. Nine of these have the heartwood/sapwood boundary which in all cases is broadly contemporary, varying by only 15 years, and suggestive of a single felling period. The average heartwood/sapwood boundary ring date is AD 1298 which produces a felling date range of AD 1313–48 (using the 15–50 ring sapwood estimate). However, taking into account the outermost measured ring on MYN-T22, which dates to AD 1325, this felling date range can be refined to AD1326–48.

The other three dated samples do not have the heartwood/sapwood boundary ring and so estimated felling dates cannot be calculated for them except to say that with last measured ring dates of AD 1153 (MYN-T14), AD 1287 (MYN-T19), and AD 1233 (MYN-T21), these would be estimated to be after AD 1168, AD 1302, and AD 1248, respectively, making it possible that these timbers were also felled in AD 1326–48. Additionally, sample MYN-T19 matches samples MYN-T13, MYN-T18, and MYN-T21 at $t = 11.7$, 13.9, and 12.7 respectively, levels which suggest all four timbers may have been cut from the same tree and hence felled at the same time, or were again at least derived from trees growing in close proximity. It appears likely that MYN-T14 was heavily trimmed and was derived from the inner part of a larger tree.

Ex situ timbers

All three of these samples taken from timbers removed from a wall in the nave have been dated. Two of these have heartwood/sapwood boundary ring dates somewhat earlier than the third. The average of these two is AD 1203, allowing an estimated felling date range to be calculated for the timber represented of AD 1218–43 (using the 15–40 ring sapwood estimate). The heartwood/sapwood boundary for the third sample (MYN-T25) is AD 1286 giving an estimated felling date of AD 1301–36 (using the 15–50 ring sapwood estimate).

Chancel

Earlier roof remnants

Eleven of the samples taken from the remnants of the earlier roof have been dated. One of these, MYN-T32, has complete sapwood and a last-measured ring date of AD 1332. When this sample is examined under the microscope it is possible to see both spring and summer growth cells of the final ring but no spring cells of the following year, giving the timber represented a felling date of winter AD 1332/3. Three other samples have the heartwood/sapwood boundary ring date, the dates of which are broadly contemporary and suggestive of a single felling period. The average heartwood/sapwood boundary ring date is AD 1290, giving an estimated felling date range for the three timbers represented of AD 1305–40 (using the 15–50 sapwood estimate), consistent with these three samples also having been felled in, or around, the winter AD 1332/33. The other dated samples do not have the heartwood/sapwood boundary ring but with last-measured ring dates ranging from AD 1128 (MYN-T28) to AD 1283 (MYN-T40), this would give a series of *termini post quem* for felling dates ranging from AD 1143 to AD 1298. However, one of these samples MYN-T29 (without sapwood) matches MYN-T30 (with heartwood/sapwood boundary) at a level (t = 15.9), high enough to suggest both timbers may have been cut from the same tree and hence felled at the same time. The same can also be said for sample MYN-T40 (without sapwood) which matches MYN-T39 (with heartwood/sapwood boundary) at t = 14.0.

Extant roof

Eleven of the samples have been dated, five of which have the heartwood/sapwood boundary. The average of these is AD 1555, allowing an estimated felling date range to be calculated to AD 1570–95 (using the 15–40 ring sapwood estimate). The rest of the dated samples have last-measured ring dates ranging between, at the earliest, AD 1508 (MYN-T45) and the latest, AD 1537 (MYN-T41) giving *termini post quem* dates for felling ranging from AD 1523 and AD 1552. This, combined with the overall level of cross-matching within this group of timbers, including at least one possible same-tree pair (MYN-T43 / MYN-T50 t=11.0), suggests that these timbers are coeval and also likely to have been felled in the range AD 1570–95.

Bell-cote

Nine of these samples have been dated, six of which have the heartwood/sapwood boundary ring date, but it should be noted that the timbers represented show clear evidence of reuse. The heartwood/sapwood boundary ring date of sample MYN-

T55 at AD 1299 is somewhat earlier than those of the other samples and it has an estimated felling date range of AD 1314–49 (using the 15–50 ring sapwood estimate). The other five samples have broadly contemporary heartwood/sapwood boundary ring dates, varying by only ten years, the average of which is AD 1552 which gives an estimated felling date range for the timbers represented of AD 1567–92 (using the 15–40 ring sapwood estimate).

Bell-levers

Both of these samples have been dated. Unfortunately, neither of these have the heartwood/sapwood boundary and so estimated felling date ranges cannot be calculated except to say that they would be felled after AD 1515 (MYN-T63) and AD 1548 (MYN-T64). Both of these timbers produce good overall cross-matching, including several *t*-values in excess of 6.0, suggesting that they may be of a similar later sixteenth-century date to the extant chancel roof and bell-cote.

DISCUSSION

The oldest phase of building activity identified by the tree-ring analysis is that of the earlier remnant nave roof which is now known to have been constructed with timber felled in AD 1225–50, thus demonstrating a construction date shortly after felling in the first half of the thirteenth century. The high level of cross-matching seen between some of the samples from surviving timbers which opposed each other across the nave is consistent with truncated tiebeams. As noted above, samples MYN-T01 and MYN-T07 (opposing beams 2/17) match at *t*=14.5 and samples MYN-T03 and MYN-T08 (opposing beams 4/19) match at *t*=14.7, with each pair almost certainly representing a single timber. Additionally, due to how well these four samples match each other (grouping at a minimum *t*=value of 14.7), it is suggested that one tree may have been used to produce the two tiebeams.

Also dating to the thirteenth century are two of the ex situ timbers recovered from the nave wall. These are broadly contemporary with the timber of the early nave roof, with both being thought to have been felled in AD 1218–43. It is, therefore, possible that these pieces of wood represent timbers of the oldest nave roof. Indeed, one of these (sample MYN-T27) matches the group of samples MYN-T01/03/07/08 at *t* = 13.0 which raises the possibility that it could be part of the inner portion of one of the putative truncated tiebeams.

It is possible, but not proven, that some of the timber identified as part of an earlier chancel roof also belongs with this thirteenth-century building phase. Three of the samples (MYN-T28, MYN-T37, MYN-T38) taken from this roof, a plate in the north wall and the north and south ends of beam 8, have *termini post quem* for felling dates of AD 1143, AD 1193, and AD 1213 making this a possibility. Alternatively, they may simply represent the inner portions of heavily trimmed, much longer-lived trees and belong with the second phase of activity identified in the fourteenth century. The overall level of cross-matching between the three samples and the other samples in MYNTSQ01 is insufficient to differentiate between these possible interpretations.

The next phase of building activity identified is in the fourteenth century. The extant replacement nave roof utilises timber felled in AD 1326–48, with construction thought likely to have followed shortly after. Broadly coeval with this are the timbers associated with the earlier chancel roof, dated as felled in, or shortly after, the winter of AD 1332/33 and also a single reused timber from the bell-cote felled in AD 1314–49. This latter sample may represent a timber salvaged from the earlier chancel roof when this structure was replaced. The third ex situ beam from the nave wall also belongs to the fourteenth century, with a felling date of AD 1301–36. This timber was clearly a lintel and suggests a window or door being inserted at this time. It is possible that all of these fourteenth-century timbers are coeval and represent a single programme of felling which could have spanned a small number of years.

The latest phase of building activity as evidenced by the dendrochronology is towards the end of the sixteenth century and is represented by the extant chancel roof, the bell-cote, and the two bell-levers. The present chancel roof had previously been dated to the fifteenth century (Cranage 1901) but, as it is now known to be constructed from timber felled in AD 1570–95, its main date of assembly should now be attributed to the second half of the sixteenth century. However, in the east truss 1, both principals retain redundant mortices for former raked struts and the former tiebeam has been truncated, leaving pads, one of which has been reused upside down. Furthermore, the straight wind-braces have tight ogees on their top faces rather than on their soffits by convention, and are likely to be derivative, but they are tenoned into the side purlins and the principals. These anomalies suggest that this sixteenth-century roof may have been subject to limited re-assembly, plausibly as late as the nineteenth century.

The majority of the timber reused within the bell-cote belongs to the second half of the sixteenth century, having been felled in AD 1567–92. However, the heavily cranked timber which now supports the east side of the bell-cote retains pegged soffit mortices for curved braces and mortices for principals, exactly matching those in the south tiebeam of the porch depicted in a watercolour of 1791 (Burt, 2017, 18; Williams watercolour, Shropshire archives X6001/19/372C/39). The former tiebeam can only have been reused under the bell-cote after that date. Braces were inserted into the bell-cote in AD 1939, when it was also re-boarded (Burt, 2017, 42).

Also thought likely to date to the sixteenth century are the two bell levers, with *termini post quem* dates for felling of AD 1515 and AD 1548. One of the bells is thought to be a sixteenth-century recasting, which would potentially compliment the sixteenth-century date for the levers. Alternatively, given that the bell-cote is known to be constructed from reused sixteenth-century timber it may be that these levers also utilise reused timber and were hence fashioned somewhat later. The closest parallel to these levers are at the Church of the Holy Sepulchre in Warminghurst, Sussex, where it has been suggested that they are of twelfth-century date. The examples here are obviously very much later than this and could be taken to indicate that this style of headstock lever was used over a prolonged period of time, but they could also suggest that the date of the Church of the Holy Sepulchre levers should perhaps be re-evaluated. Given that the second bell at the Church of St

John the Baptist, Myndtown, is thought to be twelfth century it may be that these levers are replacement copies of earlier ones.

With respect to the source of the structural timbers associated with each of the three main periods of felling identified in the thirteenth-, fourteenth-, and sixteenth-centuries it appears likely that a single woodland source was used and that the woodland sources for each of these periods of felling were relatively local as evidenced by the highest levels of similarity for the three site sequences generally being found with reference chronologies from the surrounding areas (Tables 2 and 4). The exception to this is the short, less well-replicated site chronology representing the two bell-levers, which shows the highest levels of similarity with a more disparate series of reference chronologies.

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TABLES

Table 1: Details of samples taken from Church of St John the Baptist, Myndtown, Shropshire

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date (AD)	Last heartwood ring date (AD)	Last measured ring date (AD)
Nave						
Remnants of earlier roof						
MYN-T01	Truncated tiebeam/sole-plate 2	146	--	1042	----	1187
MYN-T02	Tiebeam 3	116	--	1066	----	1181
MYN-T03	Truncated tiebeam/sole-plate 4	156	h/s	1055	1210	1210
MYN-T04	Truncated tiebeam/sole-plate 6	52	--	1077	----	1128
MYN-T05	Truncated tiebeam/sole-plate 11	71	--	1055	----	1125
MYN-T06	Truncated tiebeam/sole-plate 12	NM	--	----	----	----
MYN-T07	Truncated tiebeam/sole-plate 17	173	--	1027	----	1199
MYN-T08	Truncated tiebeam/sole-plate 19	132	--	1041	----	1172
MYN-T09	Truncated tiebeam/sole-plate 21	87	--	1048	----	1134
MYN-T10	Truncated tiebeam/sole-plate 22	62	--	----	----	----
MYN-T11	Truncated tiebeam/sole-plate 27	59	--	1057	----	1115
MYN-T12	North wallplate, 8–9	68	--	1067	----	1134
Extant roof						
MYN-T13	South ashlar 2	152	h/s	1140	1291	1291
MYN-T14	North rafter 7	57	--	1097	----	1153
MYN-T15	South ashlar 7	71	h/s	1233	1303	1303
MYN-T16	South ashlar 9	73	h/s	1234	1306	1306
MYN-T17	South archbrace 9	82	h/s	1223	1304	1304
MYN-T18	North ashlar 12	156	28	1164	1291	1319
MYN-T19	South rafter 13	183	--	1105	----	1287
MYN-T20	North archbrace 13	129	h/s	1168	1296	1296
MYN-T21	South rafter 14	113	--	1121	----	1233
MYN-T22	North ashlar 15	143	23	1183	1302	1325

MYN-T23	North rafter 16	111	h/s	1189	1299	1299
MYN-T24	North rafter 20	144	h/s	1150	1293	1293
Ex situ timbers						
MYN-T25	Beam 1 - lintel	76	h/s	1211	1286	1286
MYN-T26	Beam 2	135	h/s	1062	1196	1196
MYN-T27	Beam 3	177	h/s	1033	1209	1209
Chancel						
Remnants of earlier roof						
MYN-T28	North plate	59	--	1070	----	1128
MYN-T29	Truncated tiebeam/sole-plate 1 (north)	162	--	1092	----	1253
MYN-T30	Truncated tiebeam/sole-plate 1 (south)	180	h/s	1098	1277	1277
MYN-T31	South ashlar 3	NM	--	----	----	----
MYN-T32	Truncated tiebeam/sole-plate 4 (north)	207	58C	1126	1274	1332
MYN-T33	South ashlar 4	111	--	1148	----	1258
MYN-T34	Truncated tiebeam/sole-plate 5 (south)	69	--	1177	----	1245
MYN-T35	Truncated tiebeam/sole-plate 6 (south)	78	h/s	1207	1284	1284
MYN-T36	North ashlar 7	55	h/s	----	----	----
MYN-T37	Truncated tiebeam/sole-plate 8 (south)	159	--	1040	----	1198
MYN-T38	Truncated tiebeam/sole-plate 8 (north)	90	--	1089	----	1178
MYN-T39	North brace (chancel arch)	127	h/s	1182	1308	1308
MYN-T40	South brace (chancel arch)	94	--	1190	----	1283
Extant roof						
MYN-T41	North principal, truss 1	83	--	1455	----	1537
MYN-T42	South principal, truss 1	100	h/s	1461	1560	1560
MYN-T43	Tiebeam, truss 1	84	--	1434	----	1517
MYN-T44	North principal rafter, truss 2	NM	--	----	----	----
MYN-T45	South principal rafter, truss 2	49	--	1460	----	1508
MYN-T46	Tiebeam, truss 2	87	h/s	1467	1553	1553
MYN-T47	Collar, truss 2	78	--	1444	----	1521
MYN-T48	North strut, truss 2	70	08	1487	1548	1556
MYN-T49	South strut, truss 2	92	--	1440	----	1531
MYN-T50	Ridge beam	74	--	1449	----	1522

MYN-T51	North upper purlin	88	08	1481	1560	1568
MYN-T52	North common rafter 4, truss 1-2	88	h/s	1466	1553	1553
Bell-cote						
MYN-T53	North-east post	90	--	1420	----	1509
MYN-T54	South-west post	78	h/s	1473	1550	1550
MYN-T55	South cross-beam	81	h/s	1219	1299	1299
MYN-T56	South cill	80	--	1455	----	1534
MYN-T57	South stud	NM	--	----	----	----
MYN-T58	West brace, north	80	h/s	1471	1550	1550
MYN-T59	East brace, south	82	h/s	1468	1549	1549
MYN-T60	East brace, north	55	10	1506	1550	1560
MYN-T61	South brace, east	54	--	1443	----	1496
MYN-T62	West brace, south	48	07	1519	1559	1566
Bell-levers						
MYN-T63	Bell lever, bell 1 (treble)	49	--	1452	----	1500
MYN-T64	Bell lever, bell 2 (tenor)	60	--	1474	----	1533

NM = not measured
h/s = the heartwood/sapwood boundary is the last-measured ring
C = complete sapwood retained on sample, last-measured ring is the felling date

Table 2: Results of the cross-matching of site sequence MYNTSQ01 and relevant reference chronologies when the first-ring date is AD 1027 and the last-measured ring date is AD 1332

Site reference	*t* – value	Span of chronology	Reference
Stokesay Castle, Shropshire	16.8	AD 1046–1289	Miles and Worthington 1997
Wistanstow Church, Dorset	16.4	AD 1069–1199	Miles 1998
Wigmore Abbey, Herefordshire	14.1	AD 1055–1729	Tyers 2002a
Chapter House/Deanery, Brecon Cathedral	11.4	AD 996–1227	Howard *et al* 1994a
Great Oxenbold, Shropshire	10.8	AD 1081–1246	Miles *et al* 1993
Angel Choir, Lincoln Cathedral, Lincolnshire	10.4	AD 904–1257	Laxton and Litton 1988
Hergest Court, Kington, Herefordshire	10.1	AD 1078–1306	Miles 2001
Kenilworth Castle Gatehouse, Warwickshire	10.0	AD 1092–1332	Arnold and Howard 2007b
Blackfriars Priory, Gloucester, Gloucestershire	9.6	AD 1024–1237	Howard *et al* 2002
Kempley Church (nave roof), Gloucestershire	9.4	AD 1036–1114	Miles and Worthington 1999

Table 3: Results of the cross-matching of site sequence MYNTSQ02 and relevant reference chronologies when the first-ring date is AD 1506 and the last-measured ring date is AD 1566

Site reference	*t* – value	Span of chronology	Reference
Ulnaby Hall, High Coniscliffe, Darlington, County Durham	6.7	AD 1493–1608	Hurford *et al* 2009
28–30 The Close, Newcastle-upon-Tyne	6.6	AD 1461–1616	Arnold *et al* 2008a
Hallgarth Manor Cottages, Pittington, County Durham	6.4	AD 1336–1624	Howard *et al* 2001
Manor Farm, Bedstone, Shropshire	6.0	AD 1341–1560	Miles *et al* 1995
The Market House, Ledbury, Herefordshire	6.0	AD 1485–1617	Arnold *et al* 2008b
5 Church Street, Newark, Nottinghamshire	5.9	AD 1403–1655	Arnold *et al* 2002
17/21 Boar Lane, Newark, Nottinghamshire	5.8	AD 1507–1657	Arnold *et al* 2002
The Guildhall, Worcester, Worcestershire	5.7	AD 1420–1582	Arnold *et al* 2006
Bedehouse, Wirksworth, Derbyshire	5.7	AD 1479–1583	Howard *et al* 1994b
Green Farm, Offcote, Derbyshire	5.4	AD 1460–1578	Arnold *et al* 2008c

Table 4: Results of the cross-matching of site sequence MYNTSQ03 and relevant reference chronologies when the first-ring date is AD 1420 and the last-measured ring date is AD 1568

Site reference	*t* – value	Span of chronology	Reference
Croft Castle, Croft, Herefordshire	9.9	AD 1420–1568	Tyers 2002b
Stokesay Castle, Shropshire	9.7	AD 1449–1640	Miles and Worthington 1997
Alcester Town Hall, Alcester, Warwickshire	9.6	AD 1374–1625	Arnold and Howard 2014
Buildwas Abbey, Shropshire	8.7	AD 1374–1547	Miles 2002
Bryn Cambric, Chapel Lawn Shropshire	8.6	AD 1371–1568	Worthington and Miles 2003
26 Westgate Street, Gloucester, Gloucestershire	8.6	AD 1399–1622	Howard *et al* 1998
Court House, Shelsley Walsh,	8.5	AD 1387–1575	Arnold *et al* 2008c
Lower House Farm, Tupsley, Herefordshire	8.4	AD 1425–1613	Tyers 1997
Old House Farm, Bredwardine, Herefordshire	8.1	AD 1408–1595	Arnold *et al* 2013
Mansion House Farm, Eckington, Derbyshire	8.1	AD 1426–1550	Howard *et al* 1994b

FIGURES

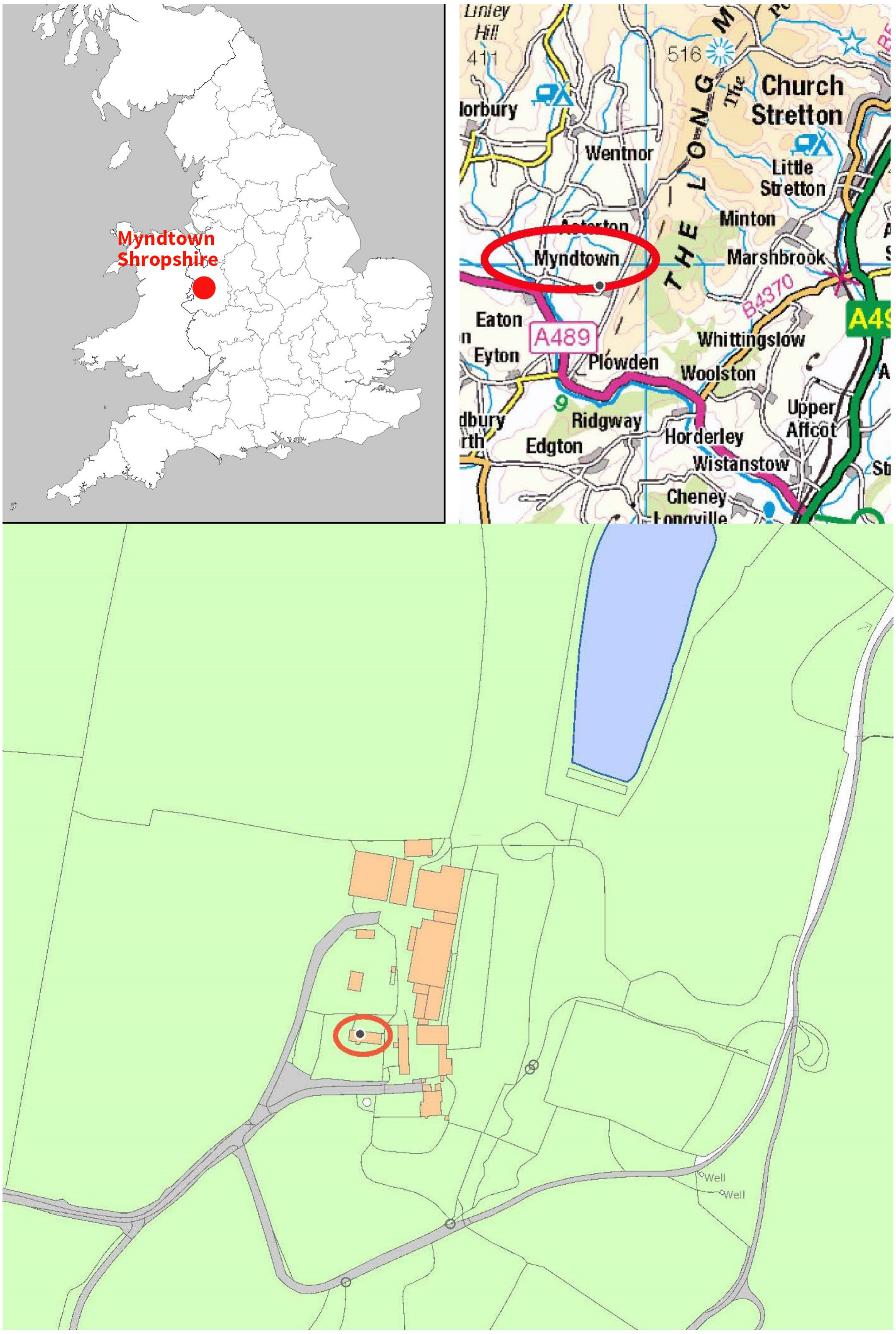


Figure 1: Maps to show the location of Myndtown, Shropshire (marked in red). Scale: top right 1:105,000; bottom 1:3,000. © Crown Copyright and database right 2022. All rights reserved. Ordnance Survey Licence number 100024900

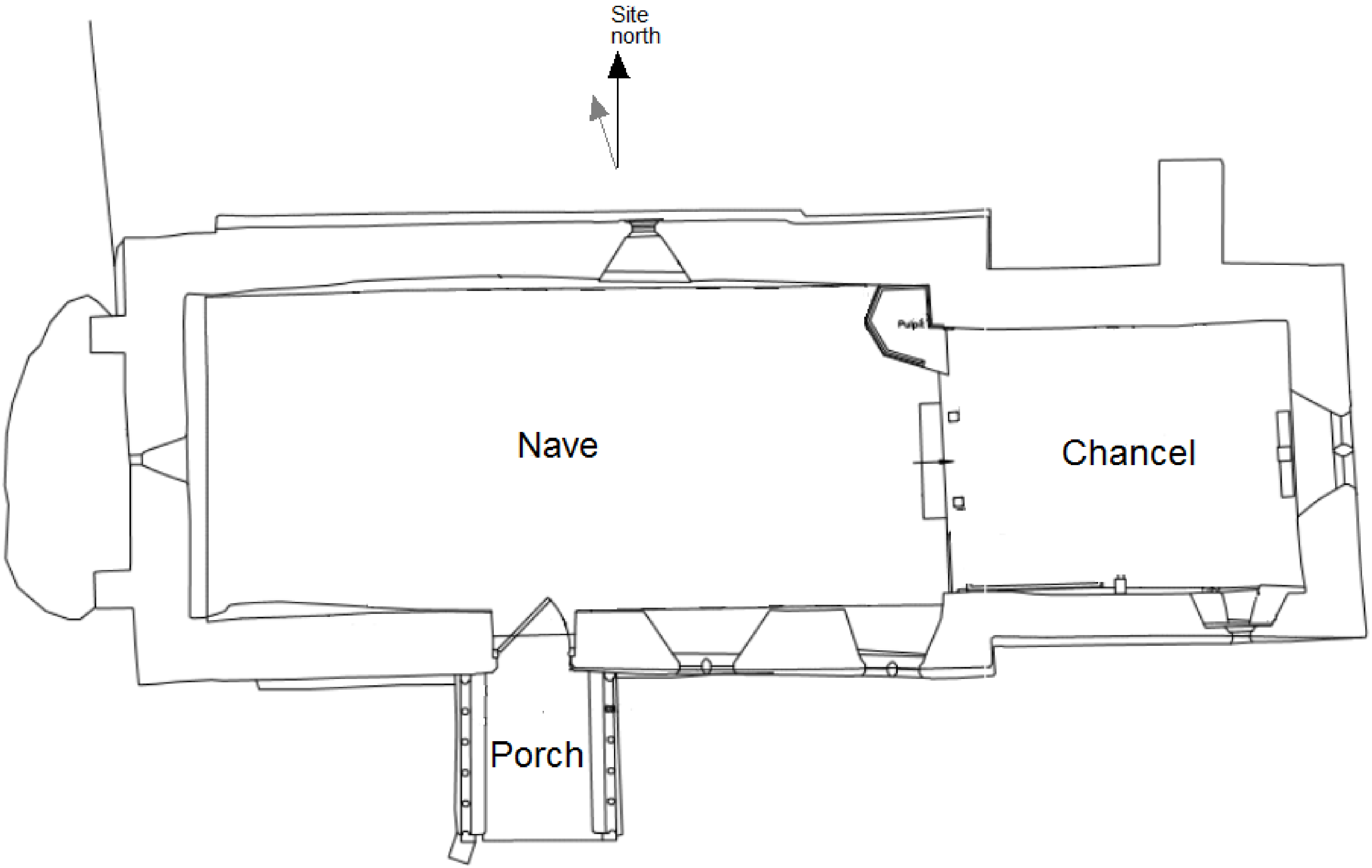


Figure 2: Plan of St John the Baptist Church (Arrol and Snell Limited)

Figure 3: Earlier nave roof from the east, with intact tiebeam in background and the southern end of truncated tiebeams or sole-plates to the left (photograph Alison Arnold)

Figure 4: Extant nave roof, upper, from the west (photograph Robert Howard)

Figure 5: Extant nave roof, lower, from the east (photograph Robert Howard)

Figure 6: Remnants of an earlier chancel roof, from the north-west (photograph Alison Arnold)

Figure 7: Extant chancel roof, truss 2, from the east (photograph Alison Arnold)

Figure 8: Bell-cote, from the north-west (photograph Robert Howard)

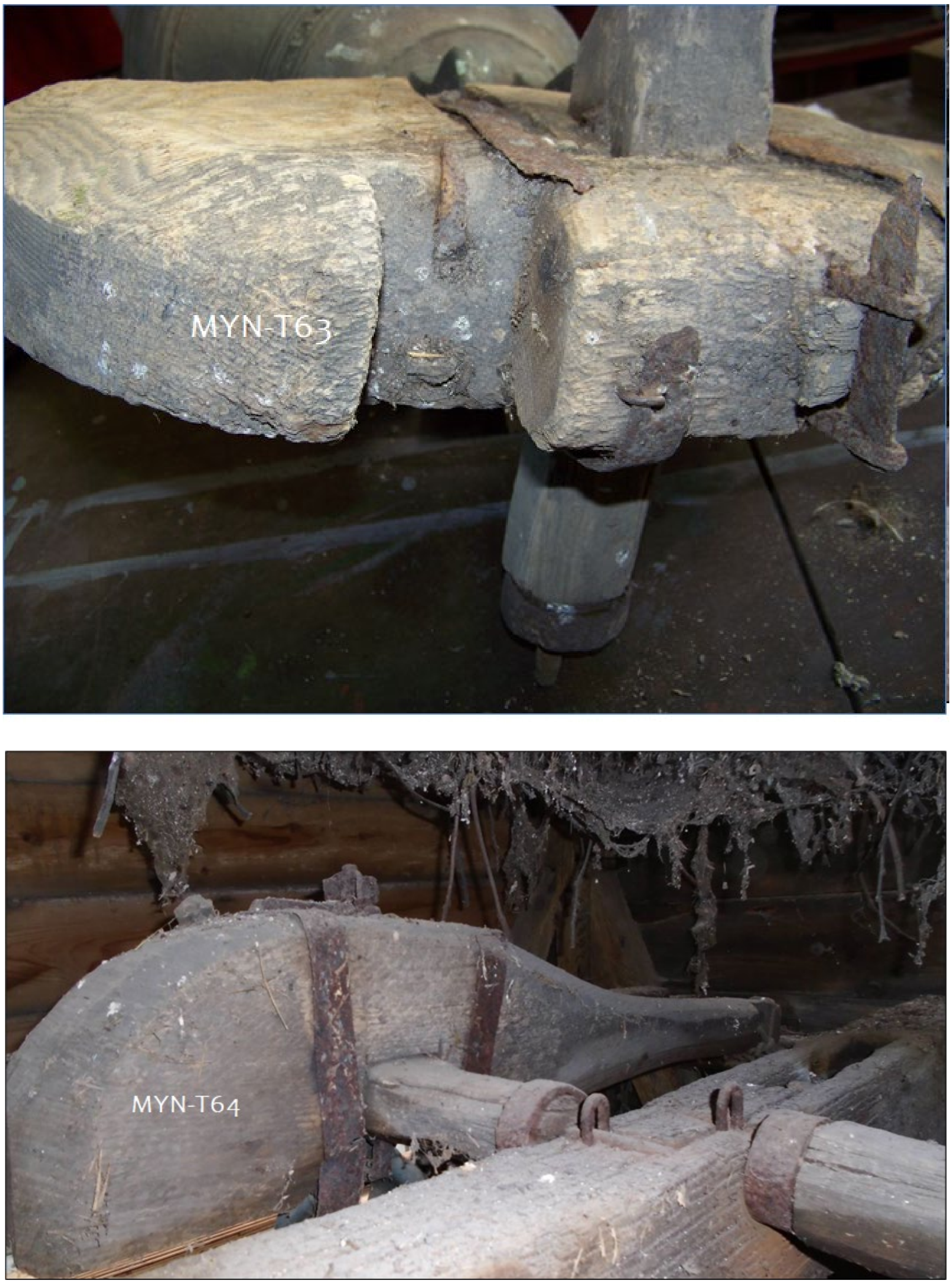


Figure 9: Bell-levers for bell 1 (above; photograph George Dawson) and bell 2 (bottom; photograph Robert Howard)

Figure 10: One of the ex situ beams, sample MYN-T25 (photograph Alison Arnold)

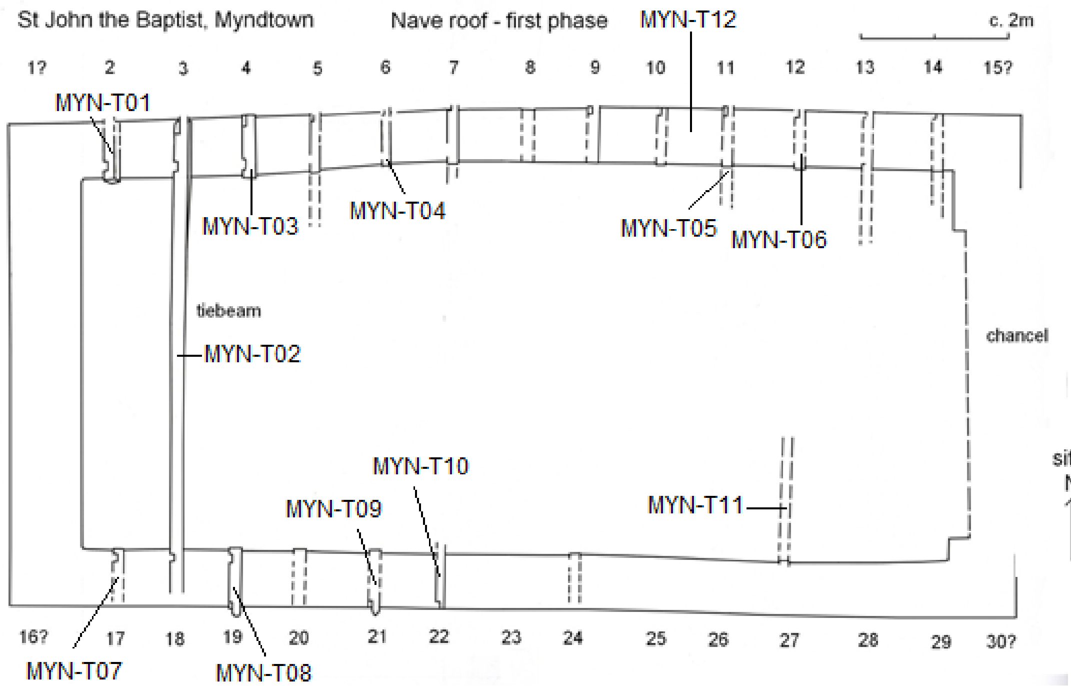


Figure 11: Plan of the nave roof, showing the location of samples MYN-T01–12 (Bob Meeson)

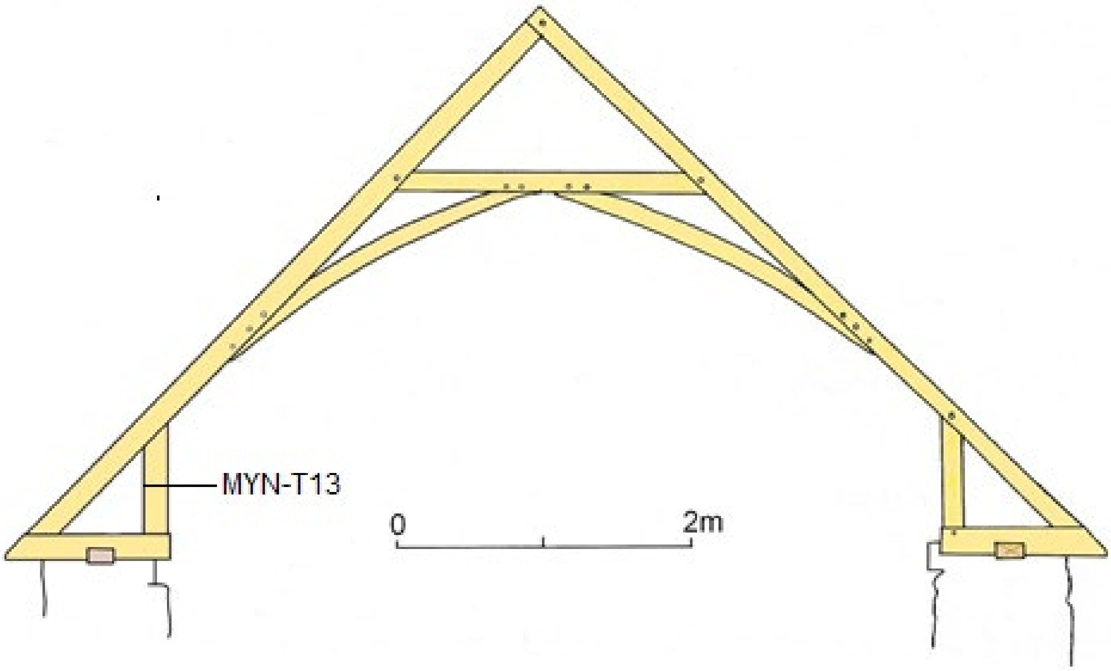


Figure 12: Nave roof, frame 2, showing sampled timber MYN-T13 (Bob Meeson)

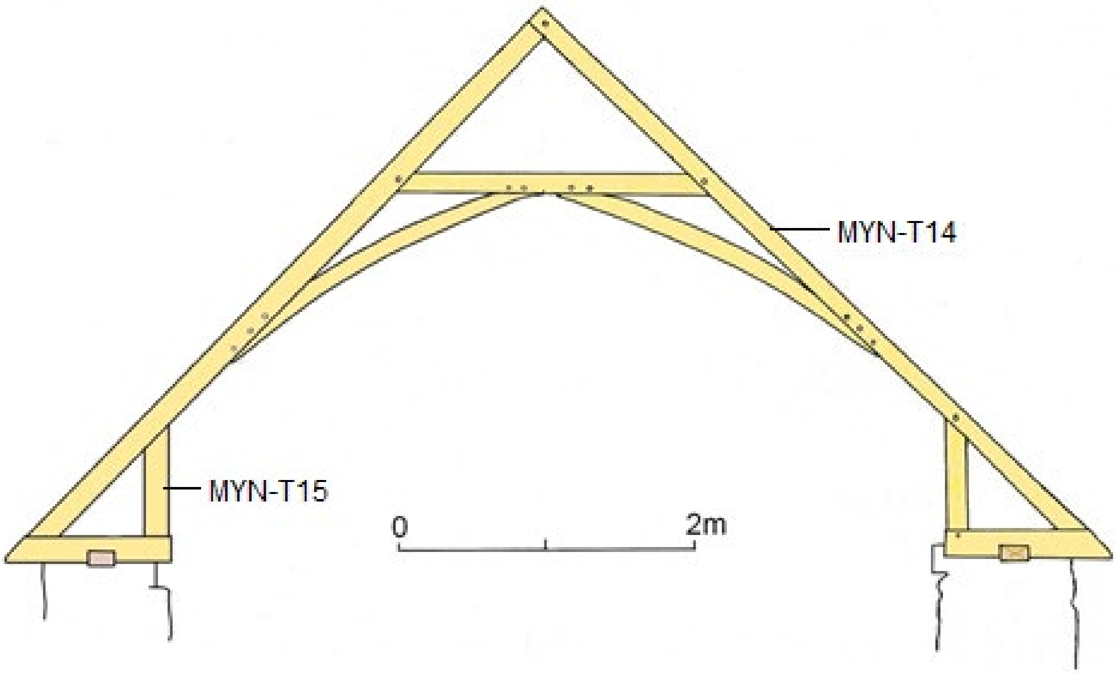


Figure 13: Nave roof, frame 7, showing sampled timbers MYN-T14 and MYN-T15 (Bob Meeson)

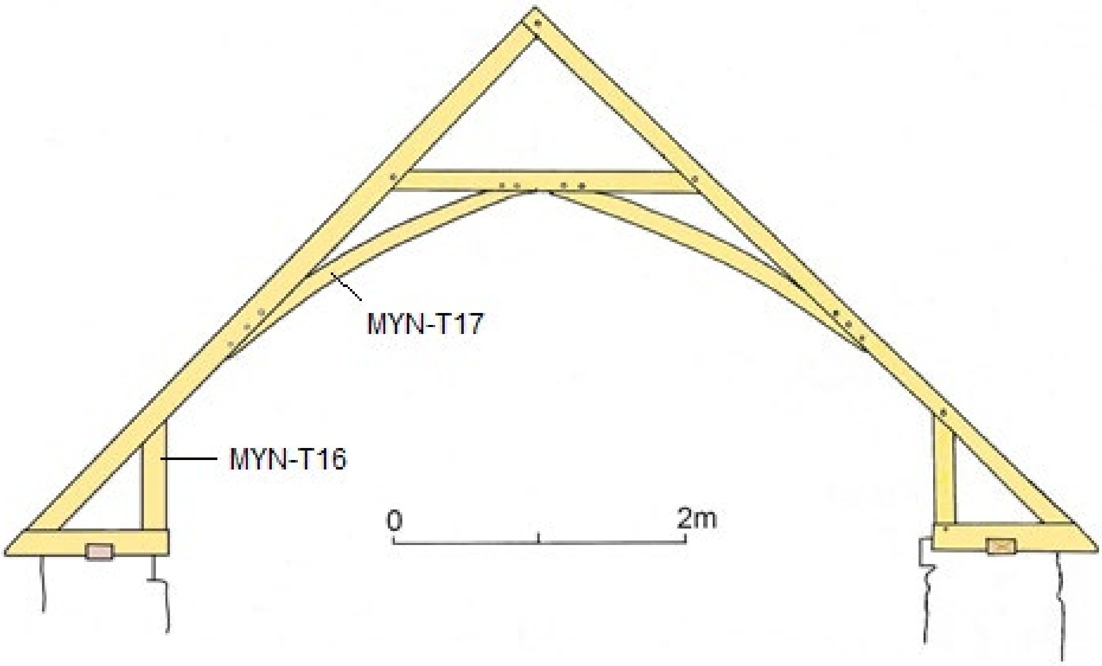


Figure 14: Nave roof, frame 9, showing sampled timbers MYN-T16 and MYN-T17 (Bob Meeson)

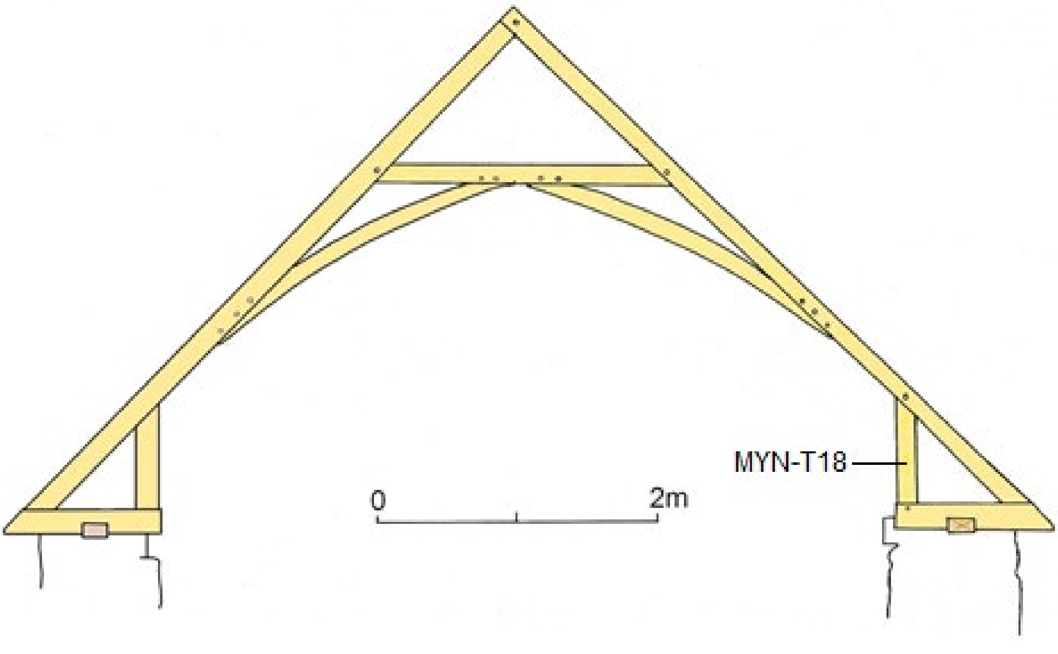


Figure 15: Nave roof, frame 12, showing sampled timber MYN-T18 (Bob Meeson)

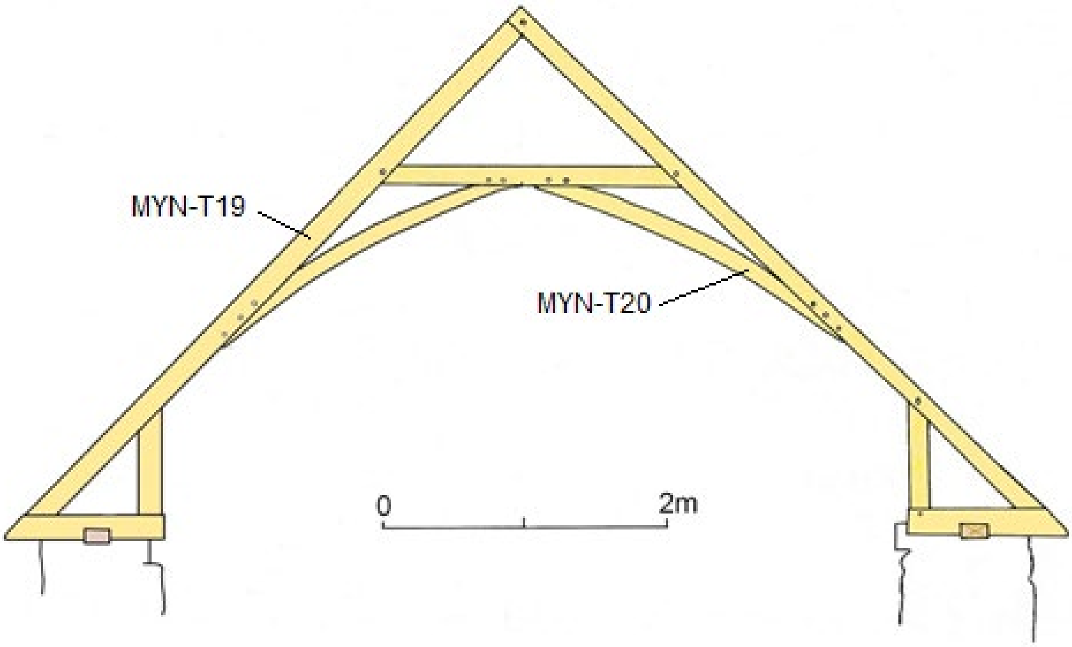


Figure 16: Nave roof, frame 13, showing sampled timbers MYN-T19 and MYN-T20 (Bob Meeson)

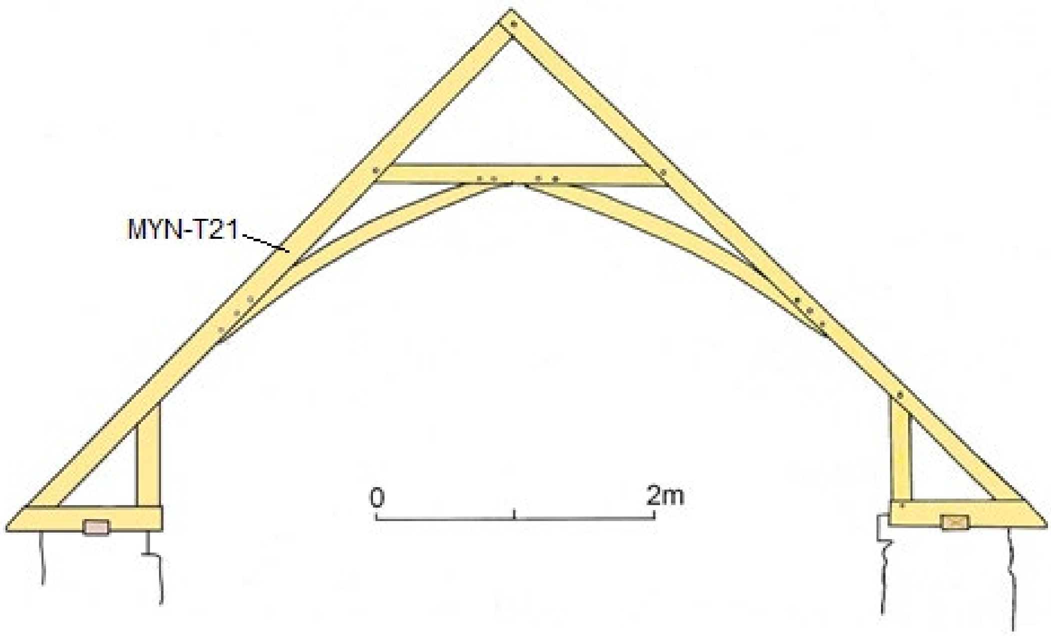


Figure 17: Nave roof, frame 14, showing sampled timber MYN-T21 (Bob Meeson)

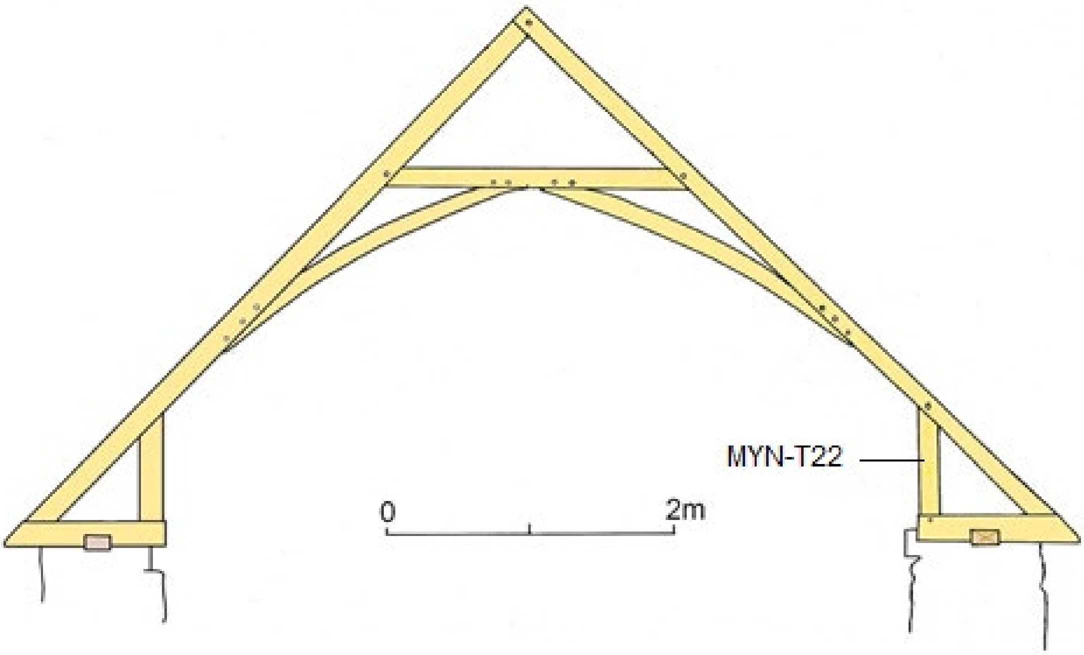


Figure 18: Nave roof, frame 15, showing sampled timber MYN-T22 (Bob Meeson)

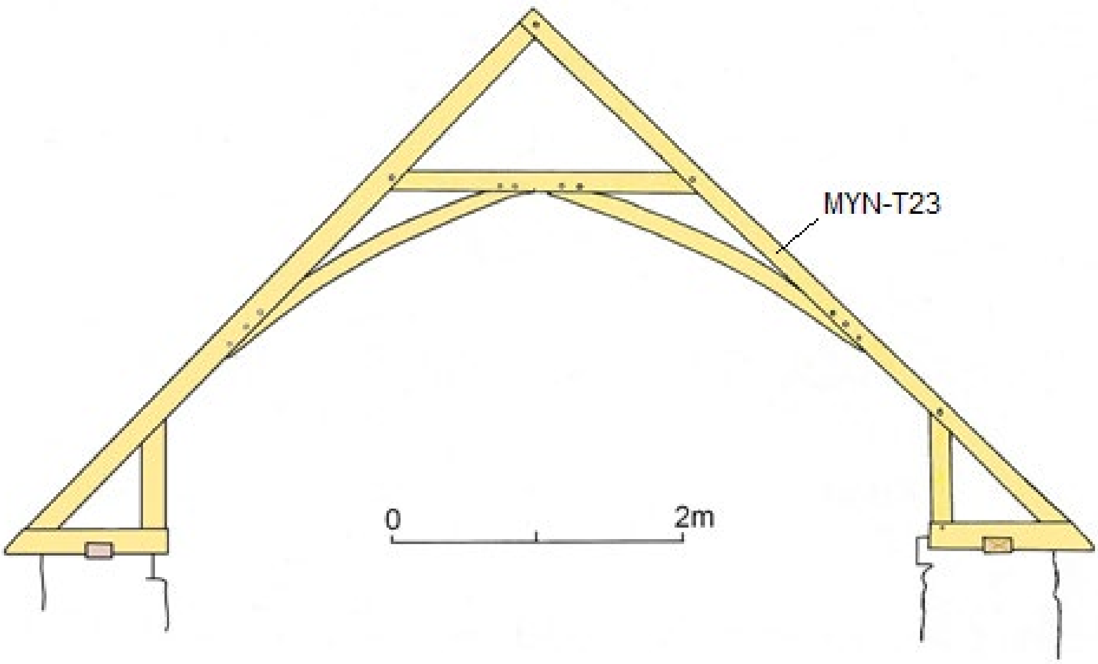


Figure 19: Nave roof, frame 16, showing sampled timber MYN-T23 (Bob Meeson)

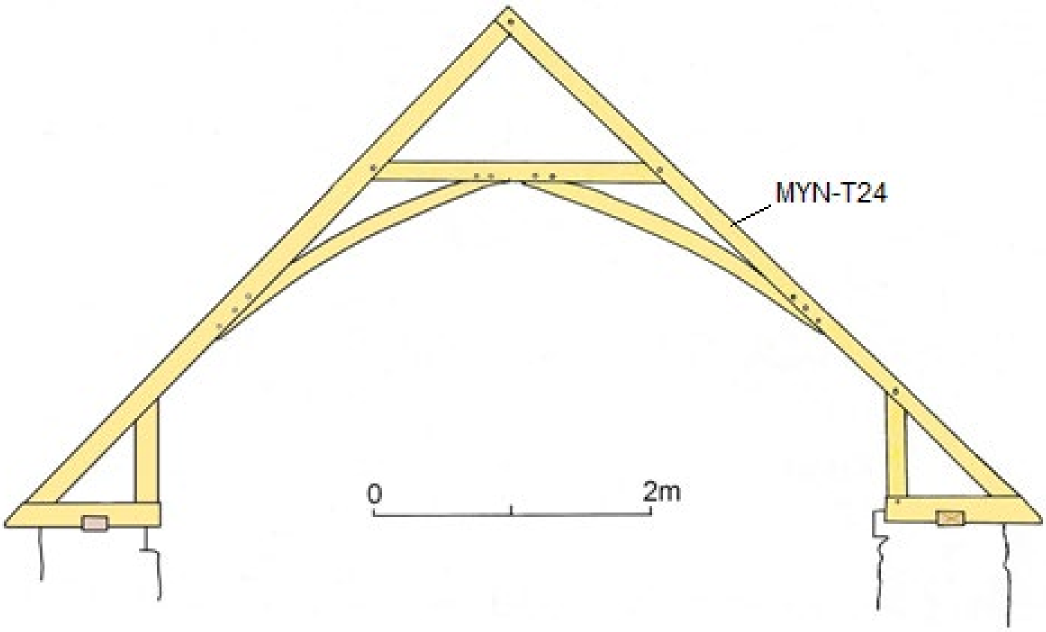


Figure 20: Nave roof, frame 20, showing sampled timber MYN-T24 (Bob Meeson)

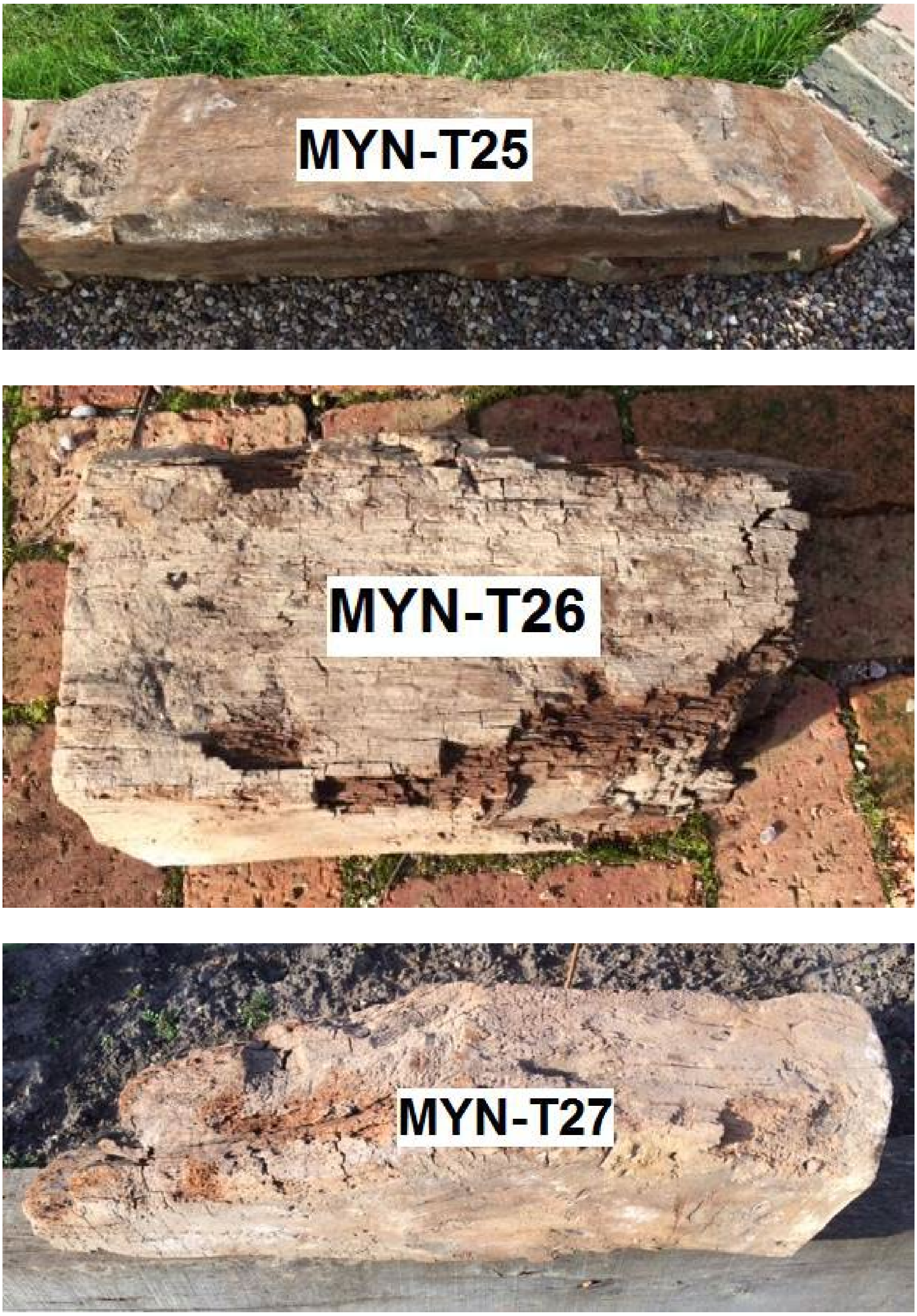


Figure 21: Sampled timbers MYN-T25–7 (photographs Alison Arnold)

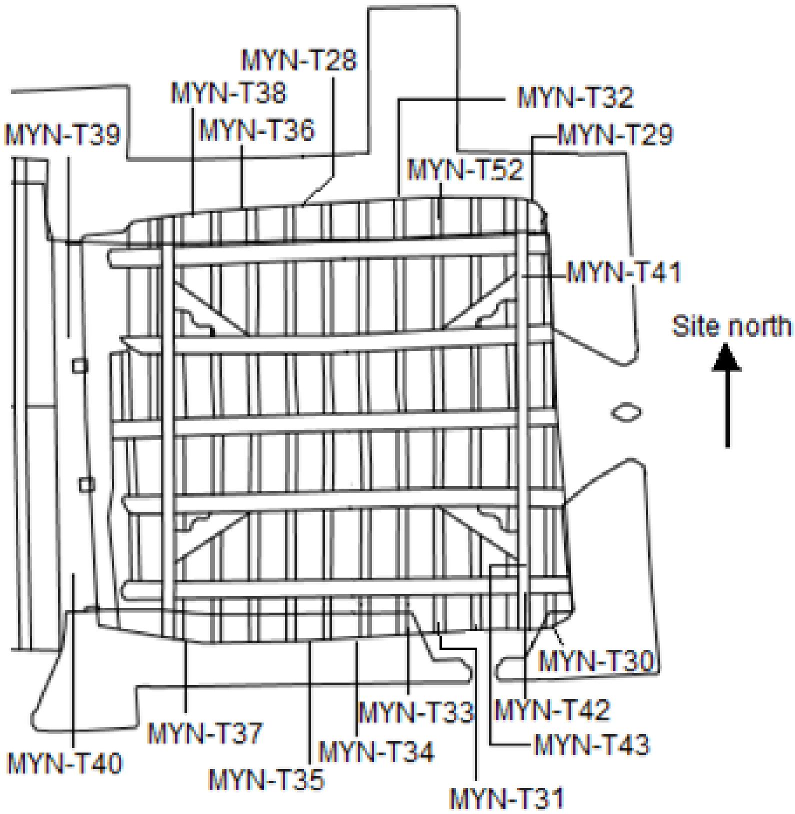


Figure 22: Plan of chancel, showing sampled timbers MYN-T28–43 and MYN-T52 (Arrol and Snell Ltd)

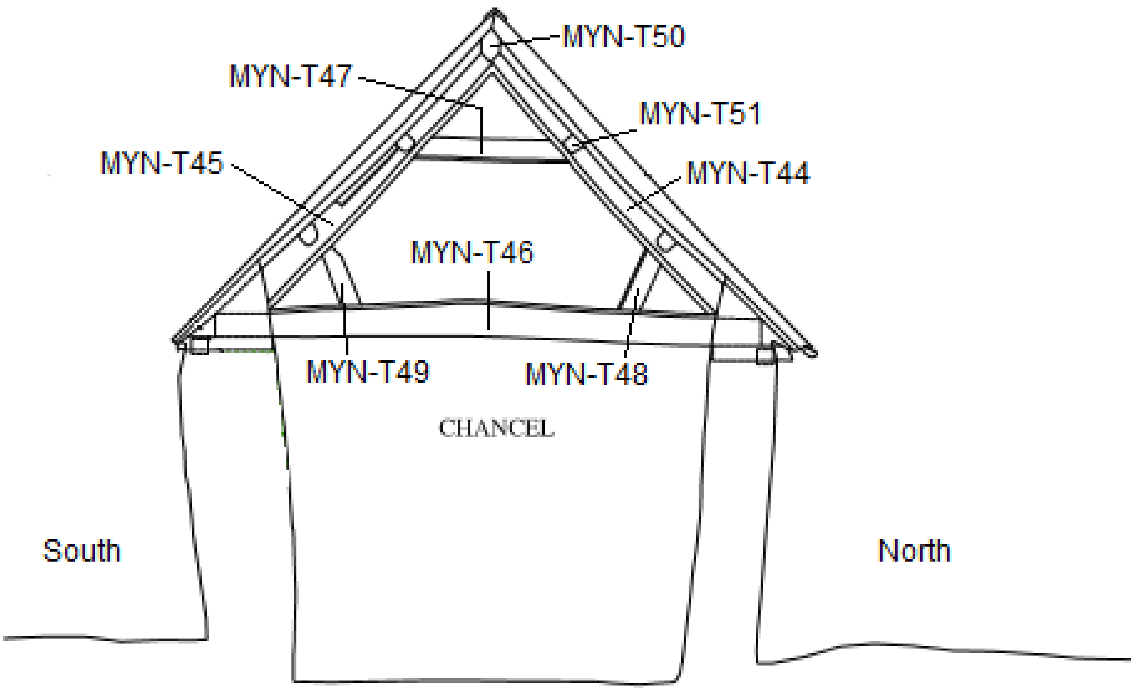


Figure 23: Chancel, truss 2, showing the location of samples MYN-T44–51 (Arrol and Snell Ltd)

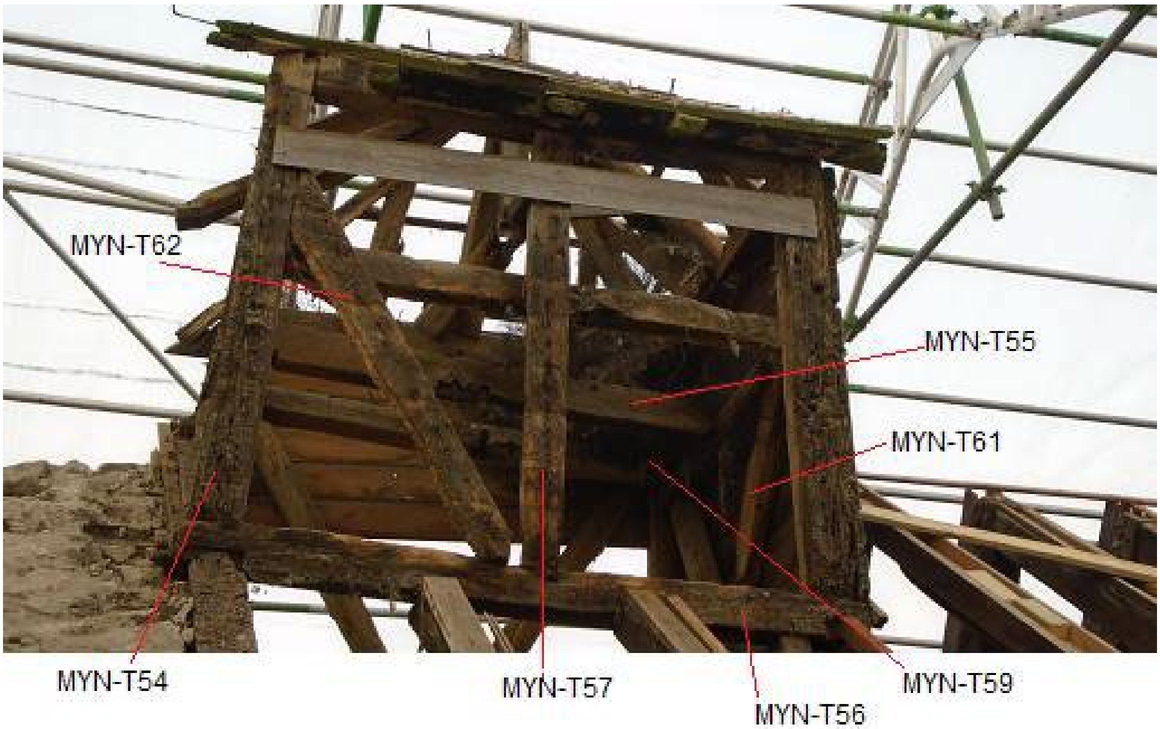


Figure 24: Bell-cote, showing sampled timbers MYN-T54–57, MYN-T59, and MYN-T61–2, from the south (photograph Robert Howard)

Figure 25: Bell-cote, showing sampled timbers MYN-T53, MYN-T58, and MYN-T60, from the north (photograph Robert Howard)

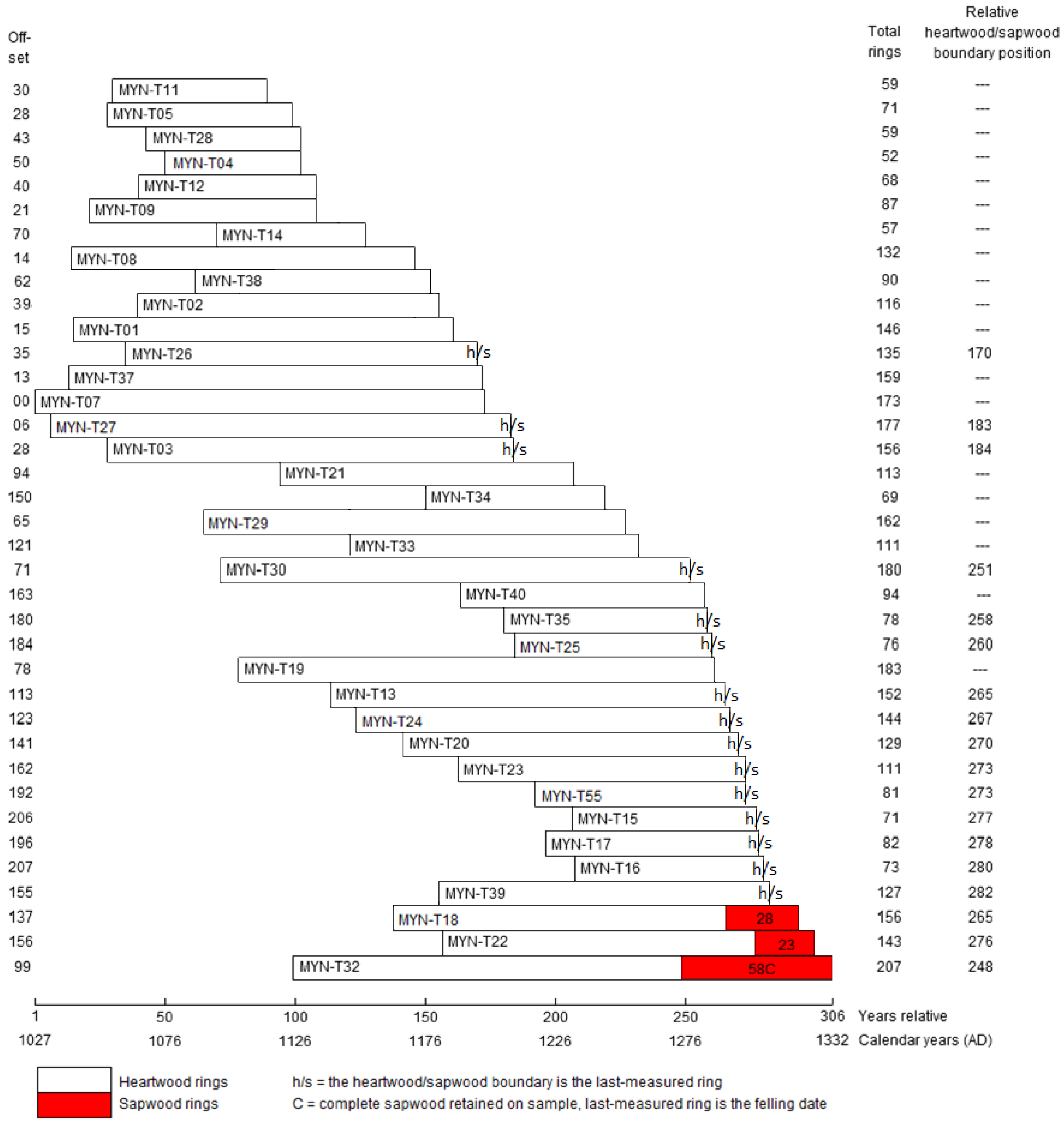


Figure 26: Bar diagram showing the relative position of samples in site sequence MYNTSQ01

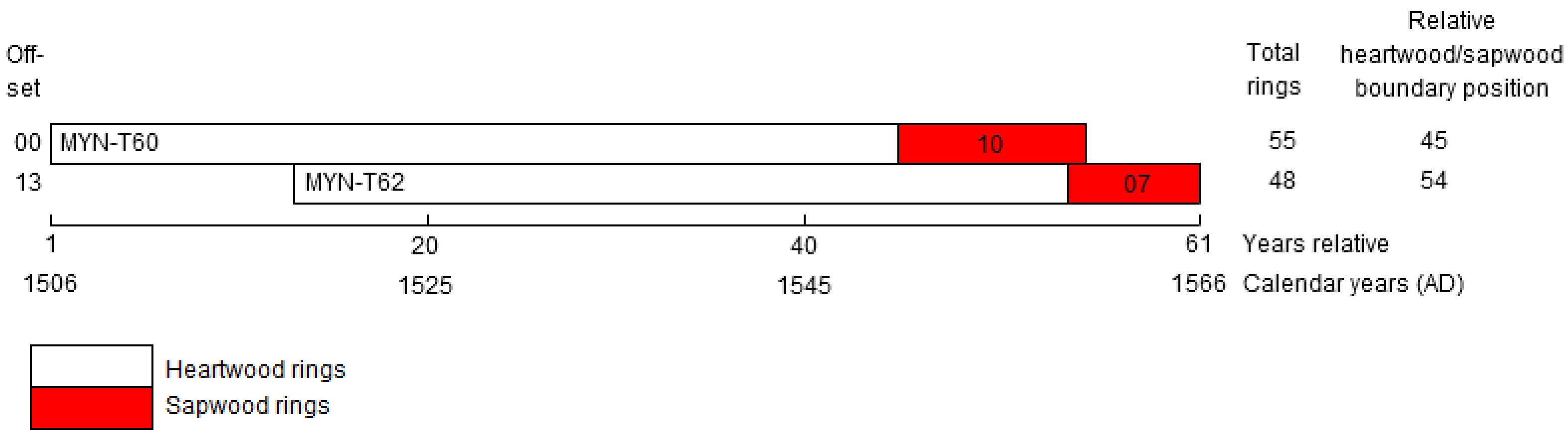


Figure 27: Bar diagram showing the relative position of samples in site sequence MYNTSQ02

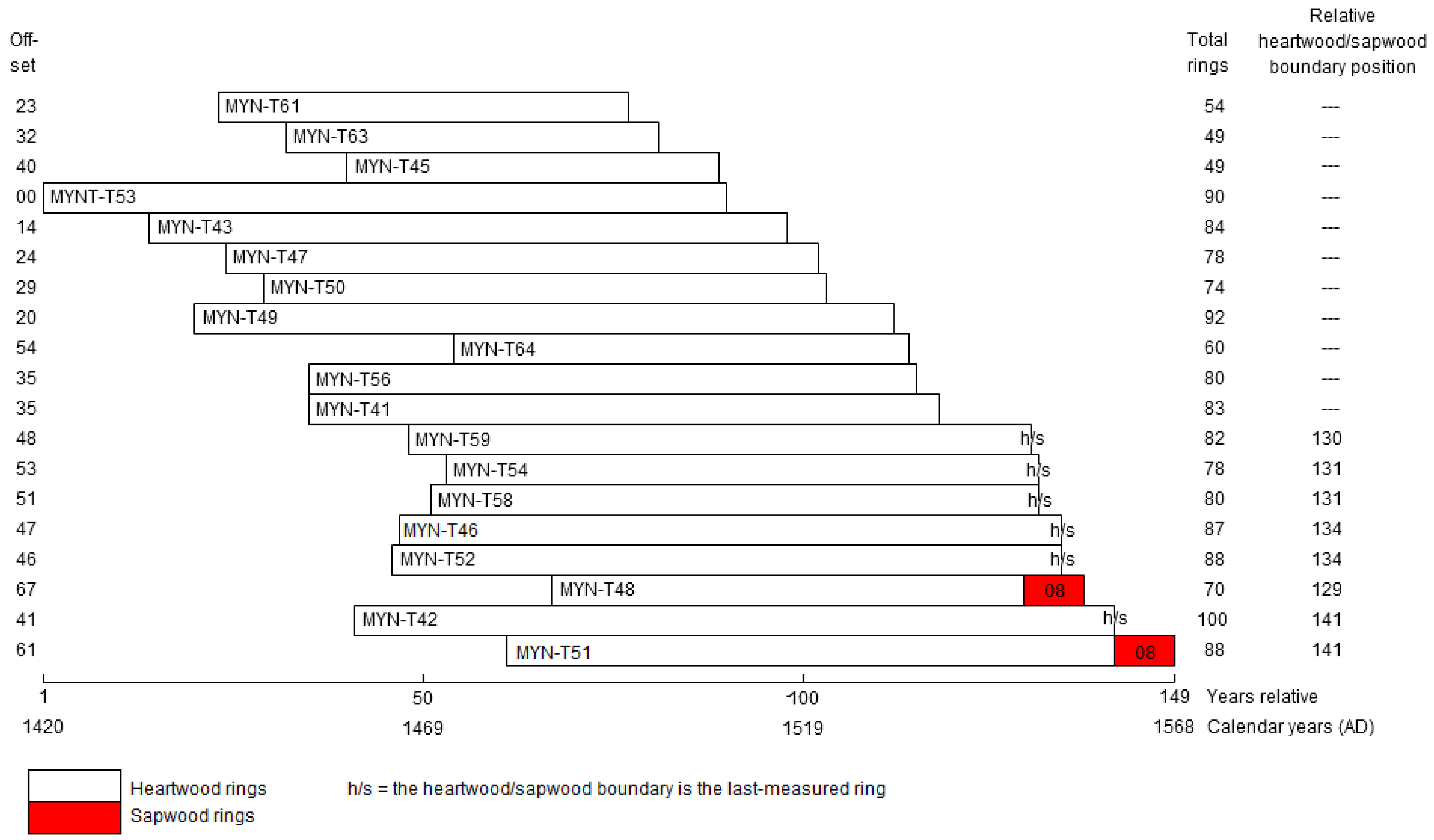


Figure 28: Bar diagram to show the relative position of samples in site sequence MYNTSQ03

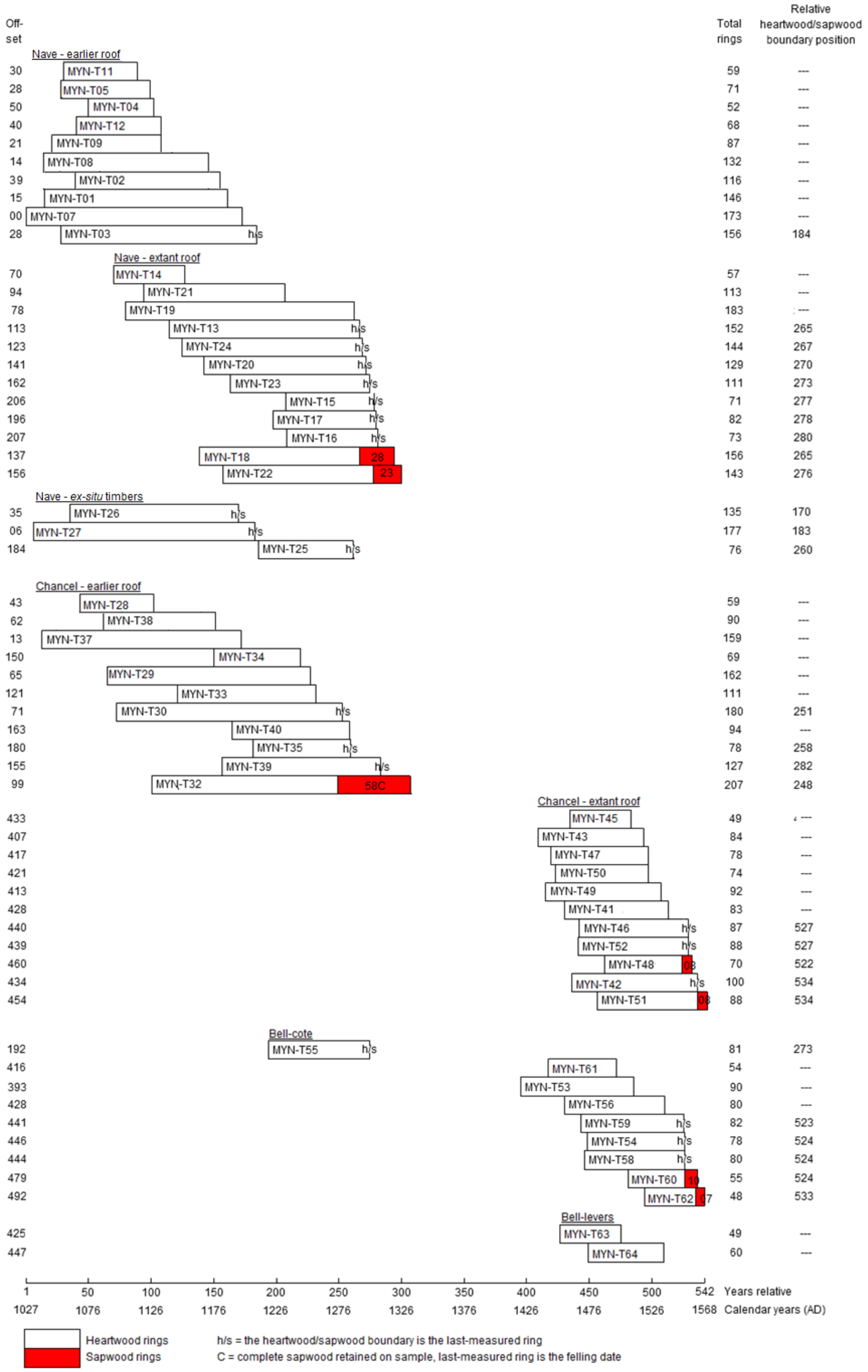


Figure 29: Bar diagram of all dated samples, sorted by phase

DATA OF MEASURED SAMPLES

Measurements in 0.01mm units

MYN-T01A 146
252 264 210 208 169 139 122 140 156 184 164 166 113 144 146 103 89 75 100 99
81 106 119 80 89 106 98 97 95 86 92 105 78 86 120 172 148 131 153 77
92 116 71 105 103 84 134 145 94 129 135 93 75 107 97 85 93 110 127 98
110 134 93 107 83 94 170 146 113 133 111 119 148 158 115 124 139 113 129 174
148 227 202 132 74 97 133 115 101 110 114 108 109 136 102 80 92 92 67 96
93 74 77 93 109 77 92 106 83 96 70 107 100 81 120 104 111 109 116 98
130 115 131 125 134 105 148 211 162 281 266 284 236 105 159 91 151 218 188 197
255 276 139 139 152 183

MYN-T01B 146
252 266 210 213 156 145 122 134 152 184 175 165 116 151 147 110 90 76 87 97
82 113 116 80 85 111 82 96 101 85 96 100 78 87 124 171 130 128 154 72
91 115 66 107 104 86 160 113 102 132 141 92 75 102 102 82 90 111 127 100
112 129 99 105 88 90 168 141 104 125 110 115 155 156 118 124 137 120 127 175
127 189 174 135 86 97 140 97 102 108 120 119 103 130 94 85 85 99 88 98
93 80 72 90 95 88 90 115 75 95 71 110 98 81 123 105 110 105 121 97
134 110 132 122 134 111 145 208 164 276 271 291 231 104 164 86 154 218 186 204
261 279 135 160 131 211

MYN-T02A 116
121 112 153 141 152 166 143 176 127 169 164 111 144 166 91 98 161 86 154 93
79 125 120 97 115 97 83 86 93 110 94 115 99 121 139 109 112 96 77 143
100 124 153 114 110 143 106 155 186 135 123 161 147 109 188 186 148 206 174 165
123 176 215 118 129 124 140 126 121 132 117 84 122 108 106 169 129 109 110 118
128 96 98 135 111 102 105 130 81 89 97 78 84 99 89 83 107 82 85 78
92 75 66 99 101 146 119 127 96 78 88 63 85 97 83 94

MYN-T02B 116
123 116 153 140 156 158 122 154 132 189 161 112 143 166 101 94 160 89 143 88
74 127 111 99 103 98 83 91 94 110 88 114 108 113 135 121 111 113 87 136
96 115 160 122 121 145 111 155 179 150 125 165 138 111 170 193 144 215 175 160
116 180 203 117 132 119 147 122 121 129 107 77 111 99 112 173 116 98 114 119
126 100 96 127 105 105 98 140 81 81 110 65 84 95 98 82 103 81 86 77
87 61 73 94 96 150 114 132 96 73 97 65 88 97 86 84

MYN-T03A 156
278 296 209 251 172 232 207 153 235 177 145 223 166 171 184 199 244 223 179 158
160 188 190 148 169 193 81 109 147 68 140 86 99 100 128 102 153 97 77 83
116 99 115 71 81 92 101 95 102 86 115 83 89 141 114 96 116 84 110 125
101 72 113 107 94 139 144 127 193 170 128 71 119 180 87 103 76 111 99 92
98 94 67 108 80 82 114 99 72 79 102 107 88 95 117 87 70 62 90 64
61 68 62 64 70 78 69 95 70 98 98 90 85 104 139 86 170 135 180 116
60 115 66 106 168 117 110 126 133 77 88 80 104 60 86 102 104 93 116 184
152 160 180 209 256 191 272 203 240 148 234 229 106 194 147 225

MYN-T03B 156
275 286 217 254 172 230 213 151 226 163 133 224 174 169 179 192 245 224 177 162

159 188 185 147 165 191 83 106 145 67 140 98 87 108 115 91 145 90 82 89
110 98 102 81 84 102 87 110 110 87 116 86 96 130 109 95 115 91 109 117
90 82 116 105 96 127 156 127 193 172 130 74 111 175 87 97 73 103 98 96
93 93 72 110 79 81 107 92 76 78 97 99 96 85 128 92 66 66 91 57
64 63 71 64 74 70 72 87 78 97 100 90 87 94 145 86 162 133 178 116
63 116 67 104 168 112 111 124 139 74 92 82 105 73 70 99 108 94 121 177
148 180 175 231 263 190 274 195 229 165 222 219 110 194 172 208

MYN-T04A 52
85 69 114 123 48 114 136 95 120 142 109 89 117 104 100 188 134 70 138 151
198 172 178 190 187 203 220 192 210 244 218 412 354 282 208 162 201 236 184 173
213 182 122 164 147 172 212 173 190 156 193 155

MYN-T04B 52
90 67 113 115 50 115 144 91 120 147 109 87 119 102 104 178 132 80 133 153
171 178 178 183 188 209 213 189 213 239 218 391 340 276 205 146 200 227 203 178
215 207 129 160 159 164 217 173 190 164 188 181

MYN-T05A 71
213 179 101 180 191 244 232 201 69 55 55 87 137 140 144 277 241 140 199 183
151 224 198 152 218 238 116 181 181 125 249 241 168 295 603 404 311 371 270 168
163 176 208 194 187 222 182 192 161 171 233 176 192 241 204 178 189 129 136 157
131 143 157 147 103 174 198 223 233 281 212

MYN-T05B 71
200 174 110 158 191 240 235 198 62 51 51 80 144 142 137 278 237 137 193 188
148 217 206 150 225 237 122 182 184 126 233 241 168 301 599 438 318 364 267 175
171 174 207 191 177 221 181 187 175 172 233 182 191 240 208 177 192 140 134 161
125 148 153 152 94 181 199 227 229 286 209

MYN-T07A 173
174 239 210 275 258 182 141 183 120 121 217 173 96 156 199 221 224 181 137 107
108 101 162 150 171 137 121 100 131 152 104 143 125 146 172 133 212 136 122 124
124 130 131 136 132 140 135 110 108 143 181 130 130 133 75 108 112 73 105 98
93 133 122 116 127 93 76 66 99 88 82 52 74 99 78 90 104 76 111 78
70 80 72 67 80 63 81 101 95 88 97 74 104 97 127 91 98 105 78 53
74 91 90 78 64 99 79 104 85 87 65 67 79 79 77 83 72 68 84 71
59 64 65 68 61 44 76 60 71 86 85 75 103 91 73 115 81 103 110 111
101 113 124 117 199 198 184 179 93 136 88 113 149 120 119 146 142 89 82 70
131 74 89 97 91 71 86 92 98 99 118 127 160

MYN-T07B 173
197 253 210 262 252 183 146 195 116 112 224 171 90 140 187 243 223 183 135 111
119 92 165 155 170 133 124 87 135 154 109 138 123 149 175 134 209 137 122 123
126 127 131 139 136 135 133 114 110 143 181 131 128 136 67 109 110 70 102 97
92 141 127 107 127 95 75 65 96 95 76 62 78 93 75 97 110 81 114 83
73 80 76 62 79 69 83 90 97 82 89 74 96 98 125 82 104 101 75 61
71 98 82 69 72 91 96 85 98 77 62 75 67 80 75 81 68 70 81 56
64 59 68 62 56 41 86 59 72 88 82 87 105 87 71 111 80 101 102 119
98 109 130 122 195 195 181 164 96 141 80 107 147 109 140 142 143 79 81 75
133 66 88 98 90 69 86 114 105 99 118 125 165

MYN-T08A 132

191 226 249 244 230 218 189 115 225 219 202 195 256 163 304 305 229 319 191 241
186 142 215 167 113 198 177 133 174 214 194 206 168 214 143 188 228 134 141 179
90 125 170 89 129 93 101 150 176 147 156 124 93 91 160 120 121 90 121 120
93 109 113 91 142 103 110 142 145 96 122 108 134 167 104 110 126 76 78 130
156 88 129 113 92 73 107 130 74 106 103 126 123 114 123 96 83 107 88 80
120 106 86 94 126 139 89 126 131 107 89 82 140 84 95 85 76 93 125 136
82 101 106 127 138 138 112 115 151 124 176 190

MYN-T08B 132
192 228 254 248 236 228 191 119 223 214 199 194 261 163 302 308 228 322 190 239
195 136 216 159 129 191 182 138 170 212 196 205 171 212 145 189 229 125 142 179
84 122 170 89 121 100 99 148 178 140 160 122 94 94 156 120 124 84 122 120
93 108 112 86 143 105 108 144 151 99 114 103 135 163 105 108 134 80 91 129
162 78 130 113 105 58 112 129 76 100 110 124 117 114 124 101 78 106 93 84
120 106 88 93 125 144 87 117 128 110 87 85 135 92 84 95 73 100 127 133
79 101 86 137 142 128 111 110 159 108 193 199

MYN-T09A 87
50 69 40 47 42 25 30 54 24 23 61 41 44 70 67 63 65 57 93 82
74 38 73 88 74 55 59 84 110 109 90 81 147 93 112 143 116 184 128 156
180 160 139 145 172 154 95 137 130 166 134 112 164 128 115 155 137 176 179 161
218 210 134 94 66 111 131 114 132 190 144 84 124 148 138 161 152 201 175 243
251 181 243 236 331 315 286

MYN-T09B 87
51 64 41 37 50 21 35 55 23 23 47 32 51 48 45 52 44 45 96 107
90 34 78 86 73 48 63 73 100 117 79 92 142 81 111 154 108 183 139 145
192 172 151 145 172 154 108 141 119 162 140 120 179 115 112 148 134 183 180 165
214 191 127 87 63 114 130 111 125 199 133 94 100 147 137 165 148 199 183 220
250 177 238 230 333 303 274

MYN-T10A 61
186 71 172 117 185 65 115 29 43 113 369 130 149 180 176 137 222 231 140 303
220 170 295 271 178 190 167 196 207 293 145 157 157 139 119 130 126 164 151 159
188 147 154 197 183 303 216 205 231 222 225 202 152 142 175 169 185 260 277 155
138

MYN-T10B 62
224 79 141 121 196 114 133 30 45 112 364 127 154 180 170 137 226 232 136 306
223 169 285 288 176 192 167 196 202 295 142 158 156 152 129 129 135 163 151 139
190 144 154 202 186 300 217 205 233 210 177 252 157 147 170 157 189 256 270 155
103 111

MYN-T11A 59
276 305 270 300 242 193 210 203 184 239 259 228 226 226 225 197 148 152 184 238
291 190 235 230 150 226 226 164 281 248 193 294 281 212 174 215 241 187 210 150
168 214 140 196 153 200 163 158 217 158 156 168 151 130 131 98 105 111 94

MYN-T11B 59
301 314 251 277 233 201 204 194 192 256 255 218 207 232 222 201 142 140 177 250
288 192 225 232 148 214 220 168 277 252 181 297 278 210 171 206 245 180 214 153
164 216 135 188 155 188 165 160 212 159 155 155 163 133 117 110 98 106 125

MYN-T12A 68
239 245 277 151 318 184 137 111 143 192 243 146 245 195 112 192 177 117 202 143
136 163 135 111 111 101 95 69 103 109 110 90 92 102 83 98 85 75 103 83
64 82 102 78 71 41 74 88 69 102 102 59 59 73 112 120 153 122 122 115
130 94 71 129 122 156 143 164

MYN-T12B 65
283 244 184 150 224 147 103 104 128 170 231 163 223 227 146 225 188 191 258 205
202 230 203 140 144 142 115 119 142 123 142 106 140 138 120 163 160 134 181 152
135 179 199 172 156 76 82 112 129 165 187 107 99 104 106 107 145 140 156 126
133 117 86 175 142

MYN-T13A 152
178 158 134 149 148 143 120 119 106 134 107 145 124 161 146 114 130 161 136 137
115 153 178 127 144 99 160 132 143 156 124 104 124 112 95 89 99 106 142 142
118 109 148 99 67 67 75 81 59 80 65 57 63 73 96 77 109 90 95 107
108 133 99 98 80 83 80 72 88 83 96 103 73 45 71 75 82 101 94 77
66 78 67 73 72 88 102 94 96 95 104 75 79 62 63 58 66 81 66 68
64 57 47 73 57 73 74 81 83 75 68 91 69 63 81 105 87 101 108 91
90 113 66 82 88 122 103 106 119 116 85 85 107 103 92 66 81 81 76 81
102 109 103 107 87 95 106 85 89 99 117 122

MYN-T13B 152
178 167 132 148 150 143 119 120 102 132 109 153 122 161 139 119 134 164 131 134
117 160 172 122 140 103 160 131 142 154 114 124 125 125 79 84 102 100 133 152
112 110 141 103 68 69 67 85 60 79 62 59 61 72 91 82 111 87 97 103
105 138 102 105 74 80 80 76 89 83 98 99 71 44 75 76 78 107 91 78
61 75 72 71 72 88 104 88 106 91 102 79 83 51 61 64 62 80 73 60
73 50 52 75 61 72 69 86 86 71 75 80 71 71 82 102 87 103 107 89
92 106 70 76 99 124 103 108 120 112 77 93 104 109 95 60 82 81 75 87
99 112 104 96 95 92 110 87 93 99 126 109

MYN-T14A 57
203 193 162 145 135 204 208 208 273 269 181 256 248 276 254 220 187 219 198 191
182 138 79 103 139 135 166 165 209 160 147 161 125 107 100 108 127 128 148 161
122 171 125 213 167 159 151 156 144 142 151 136 170 142 214 187 148

MYN-T14B 57
209 194 160 160 130 192 202 195 262 259 176 234 298 265 240 212 184 229 198 187
186 139 80 107 140 133 169 164 212 151 150 151 130 112 103 111 129 123 156 155
125 148 148 214 163 161 142 155 152 142 129 133 165 152 210 178 152

MYN-T15A 71
127 153 156 131 175 148 128 268 139 171 210 175 165 150 179 213 233 176 237 168
275 201 198 200 255 226 208 176 204 261 179 170 163 145 120 234 242 160 124 132
152 165 159 148 153 139 121 132 139 139 161 204 189 197 145 149 160 158 151 201
206 241 192 175 168 150 136 142 167 172 141

MYN-T15B 71
120 151 159 132 180 149 124 268 137 175 202 164 155 159 184 214 230 185 233 165
268 211 203 212 254 232 230 175 203 253 182 164 168 145 117 235 241 162 119 126
147 172 154 145 160 143 124 133 142 137 164 205 193 197 150 147 154 151 156 201
204 251 186 181 163 152 145 135 164 162 141

MYN-T16A 73
179 201 138 185 179 187 180 131 125 146 144 146 138 139 138 164 171 163 153 220
201 225 247 265 207 217 188 202 218 151 130 151 143 129 205 179 186 155 219 182
218 187 157 142 126 145 137 163 153 150 257 146 134 124 144 177 136 169 173 212
193 148 147 143 130 129 134 173 139 133 135 155 156

MYN-T16B 73
179 200 132 192 175 204 170 126 122 149 141 147 131 143 135 156 173 156 158 232
201 206 245 250 186 242 181 198 215 156 132 152 137 131 201 181 184 164 208 172
217 195 158 145 120 141 139 167 161 157 232 147 147 122 134 182 142 149 161 209
182 156 140 149 135 131 140 172 136 136 137 150 127

MYN-T17A 82
148 162 167 174 189 190 199 160 143 183 179 174 145 142 170 178 180 188 163 169
210 183 154 156 158 171 213 159 143 118 123 169 168 144 171 158 185 155 169 204
159 152 162 164 136 181 168 170 134 162 166 181 141 133 120 116 131 127 115 120
170 166 145 142 161 150 134 142 133 129 186 155 163 188 174 163 162 142 138 148
165 190

MYN-T17B 82
144 155 174 185 192 193 188 169 136 169 183 175 146 147 170 179 177 181 166 165
215 186 162 157 166 166 211 167 145 120 121 162 172 153 169 154 175 156 172 214
147 148 153 158 141 177 174 168 139 163 159 176 150 135 128 119 129 118 121 119
165 166 142 151 155 150 135 148 131 132 180 171 158 193 171 169 157 153 131 156
158 185

MYN-T18A 156
148 127 187 162 193 224 161 169 176 169 126 105 116 119 154 167 156 128 151 141
110 95 95 118 86 117 123 87 84 103 99 110 121 103 118 117 123 156 123 147
109 102 114 90 119 115 118 102 54 57 62 79 77 96 90 87 75 91 90 72
65 80 95 93 81 80 82 76 69 56 71 80 59 108 67 79 100 78 79 76
74 84 95 95 89 87 73 78 59 59 79 84 89 92 80 74 82 78 54 62
92 88 77 89 117 137 86 74 95 95 80 67 68 87 66 60 69 88 95 93
85 89 100 91 87 83 72 82 105 104 91 105 88 84 82 66 52 61 64 71
70 76 86 91 82 78 97 81 81 101 77 78 80 64 64 88

MYN-T18B 156
151 121 180 162 189 231 150 169 180 163 126 108 115 116 154 167 161 136 156 144
110 96 92 133 84 116 129 82 86 93 106 110 130 99 122 114 118 151 114 145
114 109 116 94 111 114 112 112 57 45 65 74 80 91 93 86 75 87 91 74
68 79 90 90 78 76 88 69 73 61 68 81 68 101 77 80 95 80 78 78
76 77 95 103 93 87 71 72 65 55 88 95 89 87 79 66 86 76 62 67
88 88 81 78 105 131 81 92 79 86 74 74 60 82 75 63 65 91 85 106
97 90 93 82 81 76 85 59 111 103 112 86 92 99 74 74 51 67 65 64
65 75 76 84 76 81 89 85 74 55 45 51 56 58 63 71

MYN-T19A 183
204 195 145 212 194 167 174 129 141 155 143 152 141 114 61 125 169 118 108 88
82 90 69 85 66 76 64 68 82 88 104 84 72 87 79 104 79 57 78 88
70 58 66 66 88 60 133 84 130 81 82 91 104 130 95 78 90 120 85 87
65 108 99 91 115 84 83 87 72 56 50 64 53 84 70 71 66 82 64 54
39 56 87 55 91 85 64 59 81 78 60 63 55 65 57 65 77 61 78 50

58 59 56 74 58 69 54 38 42 48 45 59 61 64 50 50 50 51 51 52
57 58 58 61 55 49 43 49 40 51 58 41 75 54 47 70 46 49 51 50
61 60 66 69 67 64 78 62 68 87 88 74 90 79 77 74 79 68 60 85
79 79 70 98 102 65 68 78 74 64 52 40 67 62 53 66 69 79 81 76
63 106 98

MYN-T19B 183
197 198 145 216 193 169 184 132 148 154 142 153 141 113 63 121 171 122 112 87
92 82 72 86 65 77 61 75 79 91 99 86 70 84 82 106 74 58 79 88
77 53 65 69 87 64 127 87 131 75 83 88 108 133 93 79 90 117 94 81
66 110 95 99 104 84 73 88 77 57 45 61 57 78 81 60 59 96 57 49
45 54 90 59 79 89 65 55 93 75 54 71 58 72 59 59 84 53 84 53
58 60 59 64 59 68 55 46 38 41 57 51 58 65 57 45 53 55 53 43
55 61 58 61 55 49 44 49 39 56 51 53 66 55 48 69 42 50 54 48
60 63 68 63 68 67 73 64 67 88 90 78 87 79 78 72 80 70 58 86
76 78 73 94 106 64 64 79 76 59 48 45 64 59 45 66 67 77 78 74
77 102 92

MYN-T20A 129
151 219 123 156 163 159 155 139 177 105 163 212 162 180 191 183 96 103 116 137
93 114 128 136 153 170 149 124 139 116 131 120 125 147 133 139 101 96 98 70
79 86 108 112 87 95 82 84 91 123 110 119 124 90 72 73 91 94 105 92
81 105 120 125 124 97 101 117 66 107 100 94 85 59 78 107 93 91 96 107
134 126 99 113 70 85 84 109 105 147 133 172 106 89 98 70 86 105 118 100
193 210 145 92 72 89 89 85 70 88 89 106 115 131 121 149 147 131 128 103
91 79 81 75 96 119 142 136 129

MYN-T20B 129
168 225 116 158 154 170 158 136 163 92 150 215 155 184 196 185 98 111 108 142
92 117 129 138 138 176 148 127 126 125 129 116 130 155 118 145 101 92 100 69
87 83 107 113 82 99 88 77 98 116 111 115 128 82 76 74 94 90 106 93
87 103 119 120 120 104 105 98 66 100 99 94 90 59 80 102 96 83 101 113
129 131 101 101 69 88 80 104 111 146 133 164 115 99 96 71 88 104 122 99
175 207 150 94 79 81 94 75 82 94 82 99 119 140 99 150 137 133 116 91
77 79 77 88 98 145 144 131 112

MYN-T21A 113
212 163 179 196 258 202 196 180 146 146 116 126 145 158 177 168 123 146 148 149
113 109 104 142 149 140 160 142 164 118 185 165 188 118 125 113 165 185 143 142
142 199 122 137 124 177 143 155 163 146 168 154 152 140 117 131 112 148 159 127
114 169 136 101 82 96 174 99 127 147 112 104 148 120 98 113 99 118 105 103
114 83 120 101 89 114 103 110 109 112 113 85 83 79 80 113 117 113 134 124
117 112 105 97 106 120 108 102 103 106 75 75 68

MYN-T21B 113
232 169 178 204 255 209 193 172 147 148 120 130 146 161 178 155 132 145 140 159
110 113 103 141 153 142 155 135 157 118 182 150 188 107 123 120 163 184 146 147
141 194 136 121 118 173 143 157 165 162 162 154 152 138 116 134 111 147 158 130
114 170 133 102 80 100 172 88 120 141 113 103 149 120 94 116 100 116 109 99
113 85 117 102 88 114 109 104 109 111 113 87 81 78 84 114 118 114 130 129
114 112 102 98 114 118 114 97 104 105 84 78 82

MYN-T22A 143

109 63 86 97 116 62 76 103 94 94 108 125 96 109 84 99 113 82 117 91
124 94 113 123 62 134 111 138 142 113 118 126 96 107 142 120 180 148 131 79
78 131 156 132 113 82 106 113 95 94 73 93 88 58 82 90 86 71 57 62
122 93 90 122 119 124 140 89 98 61 108 101 146 96 115 78 102 69 85 97
61 74 101 66 37 76 93 95 80 86 99 107 115 95 109 86 100 108 127 90
104 94 93 92 93 86 83 108 98 123 123 107 82 85 74 62 94 78 77 57
75 108 154 145 180 135 107 138 94 117 67 79 125 93 85 73 98 110 129 92
119 124 89

MYN-T22B 143
109 61 95 96 114 56 82 102 98 97 113 122 94 111 81 101 110 78 114 90
127 92 119 127 69 136 106 142 135 109 125 119 93 100 144 123 167 146 128 80
79 126 154 127 111 85 103 124 94 81 78 90 91 53 90 95 89 71 49 63
124 90 86 117 108 117 126 91 91 66 113 93 143 100 115 76 99 57 78 98
52 83 91 61 41 75 96 91 69 90 91 113 118 105 105 89 100 103 118 93
101 107 83 91 89 84 85 100 97 115 118 98 91 74 83 59 98 76 80 58
86 117 128 172 164 105 108 128 102 105 69 73 126 85 92 73 88 105 125 114
100 134 114

MYN-T23A 111
126 143 151 150 167 188 196 193 169 195 196 172 198 188 213 172 127 168 115 163
121 133 123 76 62 90 76 81 81 86 109 99 119 86 80 97 143 165 157 153
119 128 91 105 56 70 90 68 95 92 85 104 87 81 117 93 109 129 122 99
105 105 118 90 91 95 124 116 138 126 133 139 150 99 87 95 101 94 91 123
91 82 87 98 99 96 69 91 92 72 82 94 91 102 109 96 97 118 73 78
83 108 106 151 160 134 113 103 89 88 77

MYN-T23B 111
124 147 150 148 165 192 193 191 163 201 204 162 194 192 227 170 134 165 121 160
111 130 116 67 79 68 79 77 93 97 122 108 121 103 68 101 134 172 142 135
119 129 91 108 53 70 88 70 94 89 87 109 95 92 112 94 115 127 119 102
114 104 116 91 84 90 126 110 133 116 148 120 147 106 87 88 101 87 90 120
99 90 87 89 88 103 78 78 89 87 79 94 97 103 106 98 104 117 77 80
77 113 103 164 156 120 125 91 103 102 81

MYN-T24A 144
104 130 99 128 107 102 112 125 138 149 156 121 155 94 127 122 123 137 139 140
118 151 156 133 93 84 90 75 115 114 93 98 150 154 83 69 66 105 56 100
86 84 76 113 102 86 107 77 123 94 104 105 103 93 66 71 96 85 98 98
104 84 67 59 53 66 73 87 68 68 72 64 69 60 77 81 85 72 85 85
91 70 73 52 63 66 64 79 70 83 81 70 67 92 73 96 101 90 94 92
85 91 68 68 118 107 92 87 85 93 86 58 63 68 92 114 71 70 103 91
64 69 66 80 89 60 60 62 67 63 70 78 83 74 72 59 90 85 63 70
64 54 69 85

MYN-T24B 144
96 127 106 122 106 110 112 132 136 159 143 129 149 103 136 117 122 138 139 132
126 154 155 143 93 99 94 82 104 128 107 82 160 145 88 62 77 101 61 92
91 85 82 104 99 89 105 88 112 94 111 104 105 96 70 71 98 88 92 98
98 91 66 56 55 64 72 86 68 72 68 63 73 63 78 77 84 79 88 83
92 68 71 54 63 65 63 79 74 86 89 61 62 99 77 86 94 93 101 99
81 91 72 75 115 108 90 92 84 88 79 64 60 63 95 107 61 67 109 90
77 71 73 73 87 53 62 65 60 69 69 77 83 75 70 60 94 84 64 68

61 57 70 74

MYN-T25A 76
421 264 266 270 268 243 298 206 176 235 316 212 190 214 301 244 274 345 299 285
247 196 110 220 296 161 258 266 296 328 238 202 285 350 253 195 224 184 192 145
160 89 151 171 218 218 238 163 212 145 143 151 165 123 117 79 82 102 70 126
129 145 145 155 103 101 141 106 134 105 115 139 149 172 133 101

MYN-T25B 76
415 256 259 295 259 242 292 208 177 238 310 216 179 216 297 241 276 343 294 287
239 193 108 219 293 158 256 262 290 321 247 204 291 344 253 182 237 177 212 160
163 84 153 170 221 218 236 159 214 143 138 154 162 127 115 74 85 103 126 127
124 146 146 149 97 102 144 109 104 121 125 122 147 164 133 118

MYN-T26A 135
98 124 161 109 155 163 130 133 172 105 105 131 113 99 206 92 83 140 172 80
116 140 86 156 133 86 100 100 78 98 94 122 114 131 114 110 125 118 139 105
163 211 199 377 242 301 252 307 80 119 57 137 153 137 175 178 125 204 359 261
175 448 325 307 157 236 284 106 100 93 110 88 134 70 140 59 45 58 54 90
125 132 183 275 220 222 195 192 93 114 118 185 112 84 85 119 132 139 131 67
76 81 79 100 108 144 102 92 62 118 79 89 47 37 70 42 55 55 40 32
37 46 30 26 26 60 44 207 231 94 117 132 104 77 89

MYN-T26B 135
99 122 155 109 158 164 118 135 174 110 98 134 115 98 200 98 72 140 179 85
103 144 89 158 126 94 94 102 73 101 96 115 119 133 112 115 125 115 141 104
164 220 196 365 243 318 273 263 83 97 48 137 162 142 190 184 125 204 345 281
180 430 340 307 154 234 295 110 90 90 109 101 130 66 118 65 48 61 61 135
132 145 168 250 194 206 184 176 99 104 126 223 140 100 90 103 100 172 169 62
76 73 84 102 119 136 99 99 57 117 78 93 45 35 71 49 48 54 38 28
38 40 31 26 30 60 41 209 192 79 126 161 117 111 77

MYN-T27A 177
389 376 237 204 459 341 144 230 227 241 316 177 186 143 157 108 145 197 175 113
122 86 118 119 101 201 127 205 174 132 154 211 112 153 186 117 159 235 181 122
162 106 82 176 124 97 165 152 101 174 209 98 180 185 125 163 144 123 104 113
118 129 139 101 103 117 117 129 85 133 119 98 165 115 121 135 134 65 78 53
50 69 75 73 75 54 59 82 89 65 94 105 103 70 94 95 68 68 78 84
78 84 80 78 61 76 66 88 89 74 79 78 109 77 79 79 102 90 93 66
80 65 68 78 80 113 84 84 80 84 68 87 80 73 77 86 111 86 103 90
92 67 49 51 53 90 114 77 86 85 84 51 67 87 72 48 61 100 78 72
102 84 88 73 68 74 80 66 76 57 80 49 76 71 41 25 50

MYN-T27B 177
372 394 232 201 457 333 138 238 206 236 234 191 166 139 154 99 145 186 163 111
112 78 126 116 90 193 122 205 180 122 164 200 125 147 192 115 160 250 169 125
158 111 83 170 121 106 170 163 102 176 209 104 181 163 147 143 140 117 109 111
118 129 138 101 110 113 114 129 90 115 128 103 169 112 123 142 122 74 62 55
54 70 86 74 69 59 55 81 78 71 91 104 102 77 83 97 69 72 75 84
82 84 85 75 68 68 72 86 80 83 72 93 89 82 81 87 93 91 95 66
78 68 65 84 80 100 71 88 83 82 65 86 83 77 77 81 114 91 102 86
108 59 45 56 55 90 110 83 74 87 77 58 73 71 76 51 58 91 71 72
102 96 67 90 60 67 77 60 69 60 52 50 73 67 54 46 36

MYN-T28A 59
181 203 145 178 141 108 165 178 89 148 162 80 156 165 99 133 127 76 147 130
100 94 123 126 105 96 78 96 96 91 100 75 74 84 67 118 110 127 139 130
98 107 65 80 86 63 91 123 70 83 100 112 92 125 102 109 78 87 102

MYN-T28B 59
184 178 144 162 106 90 187 191 120 149 156 80 163 145 103 146 137 94 169 128
102 96 132 127 96 98 76 98 103 94 102 71 73 87 67 119 119 114 139 142
99 106 68 76 88 70 93 127 75 77 99 104 102 118 112 112 73 85 100

MYN-T29A 162
70 99 106 139 102 121 142 135 77 90 81 116 83 110 108 97 122 71 63 85
84 123 100 97 100 72 67 62 85 93 93 82 80 73 71 50 67 66 51 47
66 71 60 70 52 51 81 68 68 58 70 83 71 91 91 88 91 102 81 88
46 115 79 102 98 79 91 88 79 73 72 50 48 32 46 50 70 59 70 75
84 76 58 27 35 40 42 49 51 60 61 57 41 39 50 46 36 70 77 64
51 77 72 87 44 50 41 59 62 52 40 55 46 49 53 43 62 73 78 102
53 67 48 44 65 62 71 53 40 55 68 69 62 71 93 76 74 92 86 64
76 62 80 83 36 88 64 65 76 54 57 62 53 72 74 86 59 82 70 63
57 50

MYN-T29B 162
80 102 103 130 115 119 151 137 76 80 81 124 87 100 110 101 124 75 69 75
80 122 102 109 100 89 66 77 80 87 99 83 73 87 67 54 66 49 56 46
61 70 65 70 56 53 69 61 64 57 80 80 75 89 91 94 83 112 76 91
49 121 84 104 102 80 93 80 87 74 70 56 52 36 35 51 59 64 72 72
83 74 62 32 30 38 45 48 49 63 58 52 40 47 46 49 38 68 79 64
68 74 67 70 56 56 48 56 60 67 45 56 41 50 45 46 72 67 83 100
58 68 43 53 60 63 77 57 34 56 72 70 66 65 92 72 72 92 92 64
74 61 74 70 54 77 69 66 68 59 57 62 55 74 66 78 62 79 76 63
47 56

MYN-T30A 180
106 124 86 75 76 115 92 98 96 86 91 51 53 62 46 68 74 63 79 56
42 42 52 58 70 60 69 70 74 46 53 48 41 48 49 54 58 71 63 43
86 81 77 70 86 80 74 97 96 99 84 106 77 73 52 100 69 93 85 72
78 72 74 63 60 56 43 44 38 57 50 63 58 62 64 58 43 36 30 31
53 56 57 53 72 66 46 51 57 55 39 77 101 57 70 76 71 72 53 59
51 50 56 63 48 56 50 52 41 45 71 89 84 114 62 71 48 50 63 66
72 52 45 57 68 73 73 70 93 72 79 93 85 69 73 62 79 78 52 83
69 70 84 61 66 60 66 86 70 68 70 68 68 56 47 63 49 59 62 70
58 49 45 56 43 48 53 60 33 49 67 67 43 46 48 51 47 60 42 50

MYN-T30B 180
107 125 85 80 69 122 87 101 93 84 89 56 51 53 57 68 70 69 84 57
46 46 59 59 58 62 64 67 67 62 55 59 48 39 44 52 50 56 67 64
52 82 79 66 83 83 82 90 106 100 87 112 74 77 51 96 79 91 90 76
77 68 72 75 56 46 44 40 43 53 56 61 55 67 66 58 49 38 31 29
50 60 56 55 70 66 50 51 58 55 42 74 103 64 67 74 76 69 63 59
47 59 53 57 46 58 52 51 51 52 67 86 96 113 63 72 48 50 65 68
74 46 51 55 71 73 74 73 95 87 82 105 91 65 77 57 84 86 54 78
71 74 86 56 64 67 72 84 63 69 60 65 71 52 50 64 46 56 67 71

55 47 51 48 44 48 59 54 32 48 68 71 42 47 43 57 48 41 51 69

MYN-T32A 207
88 114 107 80 82 66 120 85 78 95 78 71 81 72 91 92 92 79 81 77
95 101 65 90 91 88 110 120 72 97 144 108 129 131 125 89 86 63 61 59
98 65 87 102 93 108 87 72 68 77 79 70 100 115 85 55 90 80 58 53
60 76 68 76 67 78 73 97 72 68 77 86 68 80 72 85 63 50 47 50
55 58 65 54 63 54 34 30 33 39 36 35 35 42 50 47 42 38 36 46
50 36 44 42 44 31 36 38 35 32 34 36 39 29 39 36 35 31 34 33
34 29 27 33 35 31 31 30 39 34 35 34 39 45 28 36 39 37 33 40
38 34 39 38 30 28 37 34 32 35 28 28 32 27 30 42 30 32 47 32
41 34 26 37 28 32 43 33 40 39 38 30 33 38 27 30 31 34 30 33
45 30 35 31 34 40 31 35 27 34 24 40 37 27 30 38 30 25 32 26
23 33 35 28 34 20 34

MYN-T32B 207
74 125 96 86 74 76 115 85 76 100 74 78 73 78 80 98 87 85 69 90
88 102 76 114 89 100 99 112 84 88 138 122 125 142 117 87 86 62 61 60
85 75 88 103 93 101 89 77 69 77 75 74 106 112 89 52 82 75 53 60
57 70 66 82 67 75 63 99 73 64 78 87 69 80 78 77 61 52 57 41
54 57 64 61 61 52 39 35 32 36 31 38 37 40 46 42 44 39 37 48
48 40 42 43 42 32 35 34 34 33 38 36 37 24 43 38 35 30 31 35
34 30 27 33 35 34 33 32 31 36 36 37 36 40 32 39 35 38 33 47
33 34 38 37 33 34 35 31 33 38 29 23 32 23 27 42 33 36 34 31
39 35 30 29 32 42 36 33 40 37 42 33 29 29 28 35 29 36 40 34
33 34 35 27 35 34 35 37 25 30 24 44 33 33 36 24 32 32 26 24
26 30 34 36 32 41 21

MYN-T33A 111
135 143 127 161 110 250 144 151 191 236 253 277 250 222 262 161 198 137 150 141
171 200 140 169 133 101 75 57 84 62 120 130 117 130 153 152 67 102 85 112
69 116 102 99 81 117 99 102 121 95 105 87 86 136 108 119 78 81 88 53
96 64 74 99 79 80 73 83 83 103 96 115 119 88 83 95 88 112 134 129
115 114 92 82 94 95 80 84 62 111 83 81 92 68 80 89 82 90 95 97
90 86 82 77 54 60 63 62 66 65 50

MYN-T33B 111
155 145 126 162 111 251 145 152 192 228 256 252 278 225 258 160 193 132 153 153
158 199 142 164 120 95 78 56 84 68 111 129 119 137 161 160 68 94 93 106
66 118 101 103 81 118 119 118 123 96 116 97 85 135 112 110 72 78 87 52
102 67 79 103 76 92 75 82 80 102 96 115 112 96 90 86 91 119 133 124
113 114 101 80 85 91 72 78 61 100 79 72 92 65 79 85 75 88 85 89
80 81 84 86 52 67 61 62 51 63 54

MYN-T34A 69
206 320 325 285 249 288 299 145 129 193 262 134 98 104 105 122 156 170 216 241
167 191 225 164 115 130 139 99 94 116 95 117 134 139 178 149 134 144 165 158
162 179 168 168 178 172 177 194 184 106 90 76 86 100 73 88 94 138 164 122
231 200 204 299 168 114 176 188 183

MYN-T34B 69
201 278 368 289 261 298 302 150 129 186 274 141 97 97 100 122 156 178 206 249
161 189 230 153 122 136 131 101 101 115 96 120 126 139 189 150 128 156 156 151

161 173 164 165 174 165 182 195 192 106 86 84 90 103 80 87 102 138 159 125
213 205 182 285 186 101 184 189 173

MYN-T35A 78
118 187 140 118 141 132 110 121 144 163 139 124 157 206 140 104 91 105 143 171
132 124 113 108 84 86 56 55 87 54 95 71 102 108 121 78 89 100 92 123
144 197 191 129 143 93 102 79 90 92 106 101 138 134 165 205 145 171 150 122
105 157 176 148 82 97 78 92 78 73 124 95 77 81 86 106 111 94

MYN-T35B 78
115 187 140 119 145 123 115 117 143 150 150 134 157 195 142 97 92 111 137 170
137 124 110 106 82 93 55 69 87 45 95 75 107 117 120 83 92 105 97 115
146 193 201 116 151 91 97 81 94 106 113 107 157 135 182 219 143 167 155 126
106 152 167 159 92 95 81 84 89 77 118 92 72 81 90 94 99 87

MYN-T36A 55
339 331 345 223 92 80 71 91 122 127 163 167 150 131 137 148 120 117 224 179
170 296 167 201 361 335 277 437 434 486 368 424 536 701 742 649 548 668 636 348
252 315 294 282 225 316 231 349 284 198 232 199 287 419 283

MYN-T36B 55
335 337 343 223 94 76 75 90 119 128 158 165 153 129 137 145 125 120 231 177
166 300 172 195 365 318 286 438 443 488 366 426 548 702 733 647 549 668 638 346
255 306 300 282 228 316 223 346 287 198 231 201 288 412 284

MYN-T37A 159
110 147 64 124 103 119 141 128 75 119 97 68 59 43 45 74 120 108 160 117
142 117 107 145 122 142 194 184 140 91 121 91 84 58 69 70 117 131 97 82
120 74 86 123 80 108 94 76 77 89 61 72 55 52 47 71 72 67 84 73
80 58 63 72 55 87 75 65 94 101 63 65 49 70 73 64 61 65 66 38
66 82 87 108 116 80 77 73 69 58 51 59 89 68 56 62 52 52 61 64
63 92 73 67 61 58 73 98 62 61 60 59 78 88 62 65 98 79 133 87
77 74 107 68 47 52 76 69 76 82 87 80 82 68 60 75 64 53 83 83
60 45 90 76 50 51 69 63 52 58 52 62 60 71 69 55 46 43 40

MYN-T37B 159
111 145 68 116 106 117 147 122 74 121 91 75 55 46 42 81 132 119 154 127
154 116 103 140 120 142 187 178 124 103 114 88 82 64 59 70 107 137 92 79
105 70 82 122 89 106 96 76 74 89 64 76 55 51 45 73 70 74 84 76
72 61 67 71 45 91 81 60 95 102 64 65 47 68 74 66 64 65 66 40
59 84 88 111 102 95 68 68 78 58 52 58 92 64 58 61 52 57 52 68
66 92 66 62 67 61 64 101 49 63 60 52 78 86 60 63 105 68 128 100
83 58 105 65 47 62 71 67 77 83 79 87 80 72 62 70 64 59 83 85
58 49 86 74 49 53 62 61 55 57 60 57 59 72 67 52 47 47 36

MYN-T38A 90
188 124 110 84 143 135 130 124 141 154 125 121 118 112 135 134 185 144 117 144
133 132 155 85 116 158 141 131 144 167 83 171 213 153 229 191 150 165 179 162
93 115 121 165 157 125 146 116 111 95 95 115 118 116 99 77 95 117 108 96
109 80 113 96 149 128 108 120 153 125 138 134 95 114 85 100 108 171 145 95
111 96 138 133 126 155 100 119 85 123

MYN-T38B 90

179 125 102 92 126 132 133 129 133 149 127 132 93 130 146 118 189 147 119 150
131 132 142 89 117 160 141 121 157 166 82 174 209 157 227 191 134 155 171 152
97 111 105 170 140 120 141 119 108 93 100 118 121 106 105 69 114 118 110 96
109 82 103 92 155 135 111 119 134 135 141 127 97 118 90 98 109 171 143 100
113 93 142 132 141 144 93 122 84 126

MYN-T39A 127
121 107 55 61 128 142 45 69 188 166 205 276 344 215 399 78 39 40 57 118
85 113 117 65 99 47 77 70 111 173 97 134 79 79 70 169 138 171 143 95
86 104 132 243 340 198 179 148 153 100 88 43 160 170 95 270 353 189 356 165
99 247 356 221 299 229 233 201 99 150 84 59 140 158 132 167 134 156 104 120
185 130 159 178 183 105 215 227 142 130 231 252 173 183 104 156 114 95 157 171
173 254 235 205 179 121 81 67 47 71 81 123 128 93 108 84 96 100 91 124
159 150 121 83 125 155 124

MYN-T39B 127
126 111 51 62 127 142 43 74 192 163 204 275 335 212 389 77 40 41 56 115
90 112 113 62 103 36 84 73 106 174 94 141 71 82 67 171 146 164 145 93
88 106 130 238 340 199 181 152 163 111 81 52 160 168 98 272 341 193 374 167
103 249 363 215 305 234 235 207 112 156 93 39 146 171 128 166 150 169 97 131
171 132 159 182 182 105 220 228 142 135 230 246 175 183 104 162 116 92 159 165
175 248 233 202 182 118 83 64 54 60 86 127 141 93 128 64 94 105 94 121
156 155 125 88 112 156 114

MYN-T40A 94
168 192 205 234 286 220 296 160 111 128 120 120 68 70 72 62 88 46 88 73
118 155 110 122 63 68 74 141 165 234 181 101 75 131 142 206 201 163 99 129
129 89 79 57 128 147 93 191 259 193 236 147 113 182 245 201 288 208 195 239
156 206 115 102 226 259 230 325 210 263 171 224 336 270 293 258 360 192 413 468
266 258 452 401 306 275 185 298 219 215 270 250 245 393

MYN-T40B 94
175 194 203 225 291 213 310 142 103 143 129 112 80 60 78 54 87 47 100 76
110 155 111 119 67 63 76 140 169 237 186 91 82 131 143 203 202 160 98 133
130 83 82 57 129 145 91 195 267 212 209 144 120 177 245 197 292 211 166 239
154 202 126 102 218 263 225 358 189 266 179 222 330 274 290 260 359 201 409 472
275 245 445 406 318 285 191 291 212 228 267 245 257 396

MYN-T41A 83
179 279 163 127 145 178 151 192 238 132 155 188 288 259 331 283 208 202 160 272
261 229 275 195 296 245 284 292 322 239 348 192 282 154 229 244 128 118 161 321
218 358 209 186 276 257 272 306 273 350 364 407 183 260 173 133 216 207 261 241
222 205 183 182 215 177 257 271 170 189 154 198 165 191 172 160 200 155 201 192
244 239 229

MYN-T41B 83
212 284 159 129 148 183 147 193 246 127 157 181 290 252 343 301 209 212 147 289
256 231 278 176 327 237 315 289 336 235 339 181 285 154 225 259 106 116 151 325
211 364 194 185 271 254 273 297 297 353 363 408 207 249 183 148 236 194 243 255
228 186 115 162 243 176 243 267 183 193 165 186 166 209 185 161 201 157 205 188
242 251 220

MYN-T42A 100

158 227 330 129 159 134 209 169 276 281 210 180 142 212 208 207 178 168 194 187
211 193 246 244 254 163 220 158 200 206 173 161 166 192 148 266 156 151 213 229
165 180 92 89 86 104 95 126 134 148 161 152 165 193 147 132 128 127 161 111
154 240 178 202 169 199 228 288 197 159 264 133 194 164 186 222 160 167 156 174
162 103 92 98 78 91 105 125 148 154 183 153 143 134 92 93 108 119 112 127

MYN-T42B 100
181 226 326 142 153 136 217 175 216 283 219 172 138 219 207 200 182 169 224 164
221 197 243 260 260 155 235 148 199 204 175 164 163 202 145 261 160 151 210 227
166 175 84 88 97 98 94 131 126 148 160 146 162 174 162 120 132 132 170 107
154 231 177 201 160 201 231 280 179 156 255 129 182 158 213 223 175 157 151 168
173 117 89 94 62 102 111 139 144 147 182 148 147 130 95 93 118 115 117 143

MYN-T43A 84
393 327 248 274 225 300 252 174 263 246 217 179 154 237 84 144 151 308 178 178
322 207 247 183 155 208 378 254 288 377 145 173 140 324 283 385 404 299 270 152
353 458 271 282 234 366 264 246 206 242 255 356 212 394 220 302 290 173 183 233
402 335 461 304 205 270 325 265 291 332 293 387 261 208 232 221 207 238 248 243
164 210 179 138

MYN-T43B 84
370 328 247 271 220 299 259 172 239 269 219 180 150 239 98 173 153 285 179 174
325 210 243 173 164 200 373 251 291 392 140 171 145 328 278 383 393 299 272 170
347 446 277 302 224 349 260 242 208 251 236 361 209 397 219 317 289 187 175 229
400 338 465 296 206 268 325 261 300 321 292 431 293 228 221 219 215 242 252 241
181 198 177 134

MYN-T45A 49
178 188 160 170 144 126 107 142 133 140 148 116 121 115 156 244 219 144 155 144
143 166 147 151 186 181 196 218 146 132 155 104 73 73 106 123 304 187 134 145
126 113 134 127 155 126 127 82 87

MYN-T45B 49
180 187 161 171 150 121 98 148 134 139 143 124 122 107 162 247 207 151 151 141
151 155 147 153 184 179 194 213 144 130 145 103 68 75 100 142 299 186 136 156
139 117 134 132 151 120 104 83 78

MYN-T46A 87
351 345 395 271 286 286 243 473 573 394 417 338 489 403 383 386 364 454 639 549
508 359 438 449 353 286 234 281 220 256 200 138 276 249 164 140 182 159 275 240
265 351 263 194 152 120 218 211 246 203 227 273 259 193 191 269 164 165 119 138
143 135 119 112 186 135 114 127 170 149 124 145 113 136 119 130 125 162 131 116
135 125 123 117 132 90 100

MYN-T46B 87
333 357 393 271 292 290 256 476 574 389 417 341 484 404 387 387 373 448 616 539
516 347 446 447 352 289 227 289 239 244 206 141 266 236 152 139 177 161 245 239
265 348 262 193 153 119 219 207 231 178 226 262 249 186 186 257 173 162 123 130
147 134 117 117 186 133 111 138 168 146 135 141 116 149 116 122 131 169 130 112
135 126 123 128 132 100 79

MYN-T47A 78
278 285 206 161 98 241 206 392 321 218 232 240 334 245 186 168 318 292 334 400

123 193 245 332 445 202 273 202 305 229 606 850 593 439 299 406 241 381 289 176
114 176 138 209 212 182 205 87 114 138 203 159 212 151 87 159 133 140 88 111
79 133 127 192 194 141 142 151 161 183 173 195 117 156 226 144 157 155

MYN-T47B 78
304 277 204 153 100 233 219 391 325 255 231 243 330 247 186 171 317 295 317 425
134 226 247 330 451 207 258 208 327 211 607 856 592 441 293 400 251 386 292 180
119 170 144 209 209 166 209 94 108 122 211 155 217 144 88 151 135 137 98 100
89 126 139 186 193 144 141 153 159 180 173 188 132 146 231 153 164 160

MYN-T48A 70
216 160 143 163 157 124 133 179 137 190 136 149 202 182 150 127 121 105 136 126
113 114 159 174 176 228 202 188 182 140 158 177 206 124 179 186 161 160 128 173
131 115 93 93 107 88 120 121 149 129 115 95 120 111 147 83 119 93 78 93
85 82 91 99 110 77 101 99 120 122

MYN-T48B 70
220 150 149 158 156 134 132 178 129 194 135 144 201 179 156 127 123 103 136 123
115 114 157 174 177 232 203 187 182 143 160 182 210 123 179 190 175 154 132 175
131 111 95 90 105 79 94 125 127 114 99 85 113 105 155 79 111 94 79 88
82 88 96 92 110 87 116 80 124 103

MYN-T49A 92
335 264 163 223 169 156 190 199 270 391 157 274 221 136 210 170 291 216 137 148
252 166 179 175 111 144 113 277 222 293 319 202 142 123 154 261 175 171 151 180
155 185 172 193 188 231 166 275 141 170 186 104 117 132 185 169 212 146 149 223
203 181 182 214 197 193 176 131 174 175 160 219 182 181 182 150 154 120 159 171
150 223 238 138 181 125 162 140 173 174 155 210

MYN-T49B 92
341 254 183 281 175 164 199 204 275 403 139 250 203 134 177 212 276 235 148 146
252 160 180 186 115 119 119 271 217 278 315 184 146 130 165 273 169 162 149 193
154 173 171 175 222 253 173 257 146 170 171 109 108 128 163 164 248 146 144 207
206 187 174 192 201 186 177 126 168 170 164 228 164 180 184 147 137 129 160 167
148 209 208 123 160 131 146 159 202 159 131 247

MYN-T50A 74
293 244 451 394 266 395 332 352 246 237 202 369 236 228 284 131 127 127 207 166
271 370 261 254 155 247 245 217 184 169 321 178 204 218 253 222 231 149 190 102
131 171 108 81 111 213 164 260 135 109 120 123 150 160 186 219 379 253 250 203
233 223 250 238 230 188 293 187 173 118 244 192 236 227

MYN-T50B 74
292 241 451 397 267 391 338 351 243 241 195 359 243 228 297 119 132 129 204 163
273 372 259 242 162 249 243 219 178 168 321 183 211 224 258 219 235 153 184 105
131 177 113 82 115 222 146 266 147 107 119 120 142 160 172 215 383 257 233 188
221 217 236 234 222 186 278 175 167 122 238 195 234 240

MYN-T51A 88
239 204 232 166 223 153 205 145 195 173 120 75 131 251 175 275 144 133 222 240
246 297 281 241 209 201 144 213 150 155 184 181 200 206 147 121 124 122 172 176
183 208 170 151 157 132 142 207 171 152 248 162 211 178 251 258 214 185 183 122
266 71 101 96 104 112 116 141 143 142 236 175 220 145 144 144 140 118 127 158

189 215 169 131 112 93 92 124

MYN-T51B 88
264 209 220 172 217 155 206 146 199 173 119 74 133 253 173 266 145 134 217 249
244 282 276 245 217 200 141 209 154 146 188 181 74 207 143 124 125 122 171 178
182 208 161 167 151 131 142 210 166 151 253 153 207 181 247 260 217 193 176 122
257 75 96 96 108 111 116 135 148 148 235 178 214 144 149 140 140 120 129 170
178 215 166 145 112 88 87 130

MYN-T52A 88
128 137 119 106 93 80 98 96 118 93 122 111 111 127 88 107 104 91 99 112
112 110 95 108 113 120 107 116 157 126 161 119 121 148 126 97 94 110 120 104
104 68 97 96 82 91 88 94 91 78 88 91 78 95 85 114 118 108 110 94
96 86 94 65 78 86 72 92 104 84 94 101 93 90 114 118 79 89 79 76
79 84 97 99 108 107 90 100

MYN-T52B 88
123 145 92 120 104 69 109 90 123 97 111 125 108 133 79 107 101 101 102 116
111 114 104 110 114 125 97 122 140 118 166 121 127 147 121 101 92 108 122 100
106 70 97 93 86 83 90 95 89 76 89 93 84 90 87 108 120 102 112 90
91 95 81 77 63 87 74 87 101 87 98 96 87 98 107 124 77 89 85 80
79 79 99 105 103 113 107 109

MYN-T53A 71
158 144 117 159 129 124 156 136 144 160 165 156 179 141 172 150 142 182 183 208
194 193 186 233 182 202 178 117 136 137 155 174 134 94 107 84 83 73 104 95
77 88 86 60 90 97 99 117 111 95 117 81 73 92 102 93 76 87 90 131
115 64 118 118 75 109 137 147 175 164 133

MYN-T53B 90
215 174 184 218 158 214 157 201 281 212 257 285 197 163 158 187 152 193 145 107
162 149 118 162 114 121 137 120 130 144 136 149 149 124 139 129 184 156 167 155
208 173 191 186 100 108 116 114 127 125 119 124 103 102 96 133 105 84 89 88
77 99 98 118 95 125 105 113 77 81 88 98 84 74 86 88 123 85 71 88
100 60 73 99 95 85 115 82 95 97

MYN-T54A 78
145 114 188 151 111 126 133 100 154 141 166 136 179 157 180 96 111 126 126 103
93 126 99 184 102 74 126 111 84 82 141 114 180 198 139 180 176 125 132 133
137 115 123 100 83 83 115 92 110 111 96 94 58 75 78 104 106 85 113 97
95 85 92 88 101 94 93 154 126 105 107 133 113 78 83 125 151 146

MYN-T54B 78
161 116 184 149 112 133 131 102 155 143 166 140 171 158 181 100 111 126 126 102
89 132 100 175 109 70 126 115 77 93 135 115 181 200 134 179 178 124 134 130
129 122 120 97 90 79 116 91 107 107 97 89 64 80 83 93 102 94 106 92
91 88 95 94 102 91 101 156 127 106 110 126 116 82 81 122 153 152

MYN-T55A 81
187 159 155 147 128 158 155 153 133 162 145 153 138 126 156 180 167 130 287 260
153 183 130 137 188 146 97 104 104 128 214 158 166 128 148 205 240 229 304 173
245 215 160 257 175 130 143 161 108 210 178 168 152 161 195 229 194 169 166 135
125 125 145 147 173 169 161 189 142 150 160 116 141 174 227 192 157 154 188 134

116

MYN-T55B 81
180 171 152 143 135 164 160 155 138 167 152 147 151 132 165 180 159 134 263 259
150 187 121 138 182 155 105 110 100 134 216 156 154 130 136 199 243 227 302 162
246 220 158 247 178 119 155 153 112 208 194 158 149 158 197 224 184 177 169 130
131 126 142 158 185 183 162 178 151 147 160 120 122 178 231 188 162 163 169 126
114

MYN-T56A 80
176 204 172 180 170 184 155 166 147 116 125 156 185 180 153 150 136 130 128 156
188 168 142 146 139 122 153 146 179 140 164 141 152 116 127 109 118 127 101 112
140 161 119 91 152 146 96 78 175 155 209 260 176 237 193 118 163 187 200 170
182 137 126 141 180 175 180 165 132 123 91 112 121 130 133 97 132 122 112 111

MYN-T56B 80
171 201 177 166 172 189 167 162 137 122 128 158 177 186 153 165 129 125 136 155
190 169 133 148 134 120 148 152 168 131 164 137 156 117 121 115 117 118 109 111
141 155 123 90 152 148 94 83 174 148 215 263 174 241 192 117 157 178 194 163
179 139 138 131 180 179 181 156 134 116 106 109 115 136 132 107 127 112 111 117

MYN-T58A 80
121 109 134 115 215 157 133 140 157 130 159 137 177 229 187 194 246 134 141 166
151 152 122 152 145 224 158 106 151 185 94 101 147 163 159 151 110 146 126 108
114 103 111 91 85 87 73 88 95 71 128 125 82 89 76 82 83 96 121 85
89 80 89 89 91 101 104 98 115 163 137 116 124 129 119 95 87 113 153 142

MYN-T58B 80
123 110 125 115 212 167 145 144 161 125 151 143 176 215 187 194 254 137 137 169
163 150 126 149 142 219 153 98 164 177 93 92 141 158 159 153 112 133 129 108
105 104 111 90 93 81 74 87 109 74 127 123 86 88 74 80 88 92 127 77
94 84 93 79 95 101 99 107 106 161 136 103 118 122 119 84 89 108 145 131

MYN-T59A 82
129 130 149 148 113 97 125 165 132 102 100 125 97 121 120 140 144 136 134 138
109 98 124 111 112 113 104 111 151 142 101 141 169 115 92 120 108 161 145 98
131 114 90 116 115 108 112 106 99 69 106 129 111 107 118 88 98 72 80 82
101 102 76 118 93 88 75 122 119 105 114 113 163 147 116 123 121 114 83 83
101 105

MYN-T59B 82
132 134 144 144 115 102 126 159 133 106 100 120 98 116 121 142 140 135 130 142
102 106 119 111 108 121 101 107 156 137 98 142 174 111 93 121 112 155 147 100
133 109 97 108 113 113 110 105 99 70 113 119 111 105 120 78 106 68 87 78
101 97 68 126 93 86 84 136 119 114 110 113 167 147 117 128 119 109 92 80
100 103

MYN-T60A 55
137 93 117 124 141 128 120 116 113 113 129 91 136 115 102 169 124 100 140 135
111 103 130 157 128 157 144 163 127 253 189 180 164 163 328 207 138 134 168 189
114 102 149 183 222 253 59 54 53 64 60 44 49 74 68

MYN-T60B 55

134 107 119 133 126 117 120 116 103 105 119 96 131 119 106 157 127 103 142 134
114 98 133 159 123 169 146 152 138 237 203 174 155 168 312 207 137 133 168 179
123 106 149 183 240 254 57 54 57 55 56 54 54 69 59

MYN-T61A 54
157 168 151 125 157 158 172 131 159 131 131 171 154 194 157 180 183 204 171 185
177 131 148 174 196 201 189 195 165 150 153 150 248 188 201 180 182 164 174 151
170 230 214 222 260 159 168 173 143 168 137 148 156 141

MYN-T61B 54
152 182 141 123 156 157 168 129 159 127 135 169 154 198 162 173 180 207 170 184
189 127 158 167 198 195 197 185 164 149 149 146 255 185 196 176 182 156 166 150
182 231 202 231 243 160 168 176 154 159 137 156 157 119

MYN-T62A 48
201 226 201 199 127 177 130 134 107 109 144 112 134 115 141 122 202 137 116 135
195 233 161 129 114 145 167 104 91 149 158 216 225 113 84 88 110 116 73 75
145 134 145 124 125 157 119 141

MYN-T62B 48
215 221 201 240 108 183 139 146 102 113 136 118 128 121 140 110 219 131 118 141
184 218 171 134 119 139 159 118 93 158 151 219 225 116 83 86 109 117 76 77
142 130 148 121 123 163 127 155

MYN-T63A 49
180 217 299 309 338 326 253 246 318 240 217 223 105 157 191 167 187 192 162 151
130 124 173 239 205 182 180 181 168 190 161 167 141 200 165 245 142 182 251 155
181 141 206 127 253 179 127 214 109

MYN-T63B 49
167 216 303 296 338 326 259 256 322 241 215 217 119 150 190 160 185 197 158 155
131 125 182 234 209 174 191 185 169 187 161 163 146 196 180 243 148 187 198 183
188 142 200 137 238 176 124 229 125

MYN-T64A 60
435 434 315 362 365 474 401 469 402 542 515 694 604 624 359 422 421 286 247 217
328 280 388 349 227 338 282 266 250 243 308 316 374 405 509 370 256 174 153 225
159 132 140 136 236 236 185 211 200 175 146 79 113 110 115 105 126 244 225 182

MYN-T64B 60
422 449 301 350 369 479 389 470 400 533 516 698 602 620 367 415 427 293 254 211
319 287 379 337 214 328 264 270 239 251 307 308 372 407 504 363 252 169 166 199
152 130 132 144 212 244 189 208 226 151 130 88 124 107 109 120 117 247 214 175

APPENDIX: TREE-RING DATING

The Principles of Tree-Ring Dating

Tree-ring dating, or dendrochronology as it is known, is discussed in some detail in the Nottingham Tree-ring Dating Laboratory's Monograph, *An East Midlands Master Tree-Ring Chronology and its uses for dating Vernacular Buildings* (Laxton and Litton 1988) and *Dendrochronology: Guidelines on Producing and Interpreting Dendrochronological Dates* (English Heritage 1998). Here we will give the bare outlines. Each year an oak tree grows an extra ring on the outside of its trunk and all its branches just inside its bark. The width of this annual ring depends largely on the weather during the growing season, about April to October, and possibly also on the weather during the previous year. Good growing seasons give rise to relatively wide rings, poor ones to very narrow rings and average ones to relatively average ring widths. Since the climate is so variable from year to year, almost random-like, the widths of these rings will also appear random-like in sequence, reflecting the seasons. This is illustrated in Figure A1 where, for example, the widest rings appear at irregular intervals. This is the key to dating by tree rings, or rather, by their widths. Records of the average ring widths for oaks, one for each year for the last 1000 years or more, are available for different areas. These are called master chronologies. Because of the random-like nature of these sequences of widths, there is usually only one position at which a sequence of ring widths from a sample of oak timber with at least 70 rings will match a master. This will date the timber and, in particular, the last ring.

If the bark is still on the sample, as in Figure A1, then the date of the last ring will be the date of felling of the oak from which it was cut. There is much evidence that in medieval times oaks cut down for building purposes were used almost immediately, usually within the year or so (Rackham 1976). Hence if bark is present on several main timbers in a building, none of which appear reused or are later insertions, and if they all have the same date for their last ring, then we can be quite confident that this is the date of construction or soon after. If there is no bark on the sample, then we have to make an estimate of the felling date; how this is done is explained below.

The Practice of Tree-Ring Dating at the Nottingham Tree-Ring Dating Laboratory

1. Inspecting the Building and Sampling the Timbers.
Together with a building historian the timbers in a building are inspected to try to ensure that those sampled are not reused or later insertions. Sampling is almost always done by coring into the timber, which has the great advantage that we can sample in situ timbers and those judged best to give the date of construction, or phase of construction if there is more than one in the building. The timbers to be sampled are also inspected to see how many rings they have. We normally look for

timbers with at least 70 rings, and preferably more. With fewer rings than this, 50 for example, sequences of widths become difficult to match to a unique position within a master sequence of ring widths and so are difficult to date (Litton and Zainodin 1991). The cross-section of the rafter shown in Figure A2 has about 120 rings; about 20 of which are sapwood rings – the lighter rings on the outside. Similarly the core has just over 100 rings with a few sapwood rings.

To ensure that we are getting the date of the building as a whole, or the whole of a phase of construction if there is more than one, about 8–10 samples per phase are usually taken. Sometimes we take many more, especially if the construction is complicated. One reason for taking so many samples is that, in general, some will fail to give a date. There may be many reasons why a particular sequence of ring widths from a sample of timber fails to give a date even though others from the same building do. For example, a particular tree may have grown in an odd ecological niche, so odd indeed that the widths of its rings were determined by factors other than the local climate! In such circumstances it will be impossible to date a timber from this tree using the master sequence whose widths, we can assume, were predominantly determined by the local climate at the time.

Sampling is done by coring into the timber with a hollow corer attached to an electric drill and usually from its outer rings inwards towards where the centre of the tree, the pith, is judged to be. An illustration of a core is shown in Figure A2; it is about 150mm long and 10mm diameter. Great care has to be taken to ensure that as few as possible of the outer rings are lost in coring. This can be difficult as these outer rings are often very soft (see below on sapwood). Each sample is given a code which identifies uniquely which timber it comes from, which building it is from and where the building is located. For example, CRO-A06 is the sixth core taken from the first building (A) sampled by the Laboratory in Cropwell Bishop. Where it came from in that building will be shown in the sampling records and drawings. No structural damage is done to any timbers by coring, nor does it weaken them.

During the initial inspection of the building and its timbers the dendrochronologist may come to the conclusion that, as far as can be judged, none of the timbers have sufficient rings in them for dating purposes and may advise against sampling to save further unwarranted expense.

All sampling by the Laboratory is undertaken according to current Health and Safety Standards. The Laboratory's dendrochronologists are insured.

Figure A1: A wedge of oak from a tree felled in 1976. It shows the annual growth rings, one for each year from the innermost ring to the last ring on the outside just inside the bark. The year of each ring can be determined by counting back from the outside ring, which grew in 1976

Figure A2: Cross-section of a rafter, showing sapwood rings in the left-hand corner, the arrow points to the heartwood/sapwood boundary (H/S); and a core with sapwood; again the arrow is pointing to the H/S. The core is about the size of a pencil

Figure A3: Measuring ring widths under a microscope. The microscope is fixed while the sample is on a moving platform. The total sequence of widths is measured twice to ensure that an error has not been made. This type of apparatus is needed to process a large number of samples on a regular basis

Figure A4: Three cores from timbers in a building. They come from trees growing at the same time. Notice that, although the sequences of widths look similar, they are not identical. This is typical

2. *Measuring Ring Widths.*

Each core is sanded down with a belt sander using medium-grit paper and then finished by hand with flourgrade-grit paper. The rings are then clearly visible and differentiated from each other with a result very much like that shown in Figure A2. The core is then mounted on a movable table below a microscope and the ring-widths measured individually from the innermost ring to the outermost. The widths are automatically recorded in a computer file as they are measured (see Fig A3).

3. *Cross-Matching and Dating the Samples.*

Because of the factors besides the local climate which may determine the annual widths of a tree's rings, no two sequences of ring widths from different oaks growing at the same time are exactly alike (Fig A4). Indeed, the sequences may not be exactly alike even when the trees are growing near to each other. Consequently, in the Laboratory we do not attempt to match two sequences of ring widths by eye, or graphically, or by any other subjective method. Instead, it is done objectively (ie statistically) on a computer by a process called cross-matching. The output from the computer tells us the extent of correlation between two sample sequences of widths or, if we are dating, between a sample sequence of widths and the master, at each relative position of one to the other (offsets). The extent of the correlation at an offset is determined by the *t*-value (defined in almost any introductory book on statistics). That offset with the maximum *t*-value among the *t*-values at all the offsets will be the best candidate for dating one sequence relative to the other. If one of these is a master chronology, then this will date the other. Experiments carried out in the past with sequences from oaks of known date suggest that a *t*-value of at least 4.5, and preferably at least 5.0, is usually adequate for the dating to be accepted with reasonable confidence (Laxton and Litton 1988; Laxton *et al* 1988; Howard *et al* 1984–1995).

This is illustrated in Figure A5 with timbers from one of the roofs of Lincoln Cathedral. Here four sequences of ring widths, LIN-C04, 05, 08, and 45, have been cross-matched with each other. The ring widths themselves have been omitted in the bar diagram, as is usual, but the offsets at which they best cross-match each other are shown; eg the sequence of ring widths of C08 matches the sequence of ring widths of C45 best when it is at a position starting 20 rings after the first ring of C45, and similarly for the others. The actual *t*-values between the four at these offsets of best correlations are in the matrix. Thus at the offset of +20 rings, the *t*-value between C45 and C08 is 5.6 and is the maximum found between these two among all the positions of one sequence relative to the other.

It is standard practice in our Laboratory first to cross-match as many as possible of the ring-width sequences of the samples in a building and then to form an average from them. This average is called a site sequence of the building being dated and is illustrated in Figure A5. The fifth bar at the bottom is a site sequence for a roof at Lincoln Cathedral and is constructed from the matching sequences of the four timbers. The site sequence width for each year is the average of the widths in each of the sample sequences which has a width for that year. Thus in Fig A5 if the widths shown are 0.8mm for C45, 0.2mm for C08, 0.7mm for C05, and 0.3mm for

C04, then the corresponding width of the site sequence is the average of these, 0.55mm. The actual sequence of widths of this site sequence is stored on the computer. The reason for creating site sequences is that it is usually easier to date an average sequence of ring widths with a master sequence than it is to date the individual component sample sequences separately.

The straightforward method of cross-matching several sample sequences with each other one at a time is called the 'maximal *t*-value' method. The actual method of cross-matching a group of sequences of ring-widths used in the Laboratory involves grouping and averaging the ring-width sequences and is called the 'Litton-Zainodin Grouping Procedure'. It is a modification of the straightforward method and was successfully developed and tested in the Laboratory and has been published (Litton and Zainodin 1991; Laxton *et al* 1988).

4. Estimating the Felling Date.

As mentioned above, if the bark is present on a sample, then the date of its last ring is the date of the felling of its tree (or the last full year before felling, if it was felled in the first three months of the following calendar year, before any new growth had started, but this is not too important a consideration in most cases). The actual bark may not be present on a timber in a building, though the dendrochronologist who is sampling can often see from its surface that only the bark is missing. In these cases the date of the last ring is still the date of felling.

Quite often some, though not all, of the original outer rings are missing on a timber. The outer rings on an oak, called sapwood rings, are usually lighter than the inner rings, the heartwood, and so are relatively easy to identify. For example, sapwood can be seen in the corner of the rafter and at the outer end of the core in Figure A2, both indicated by arrows. More importantly for dendrochronology, the sapwood is relatively soft and so liable to insect attack and wear and tear. The builder, therefore, may remove some of the sapwood for precisely these reasons. Nevertheless, if at least some of the sapwood rings are left on a sample, we will know that not too many rings have been lost since felling so that the date of the last ring on the sample is only a few years before the date of the original last ring on the tree, and so to the date of felling.

Various estimates have been made and used for the average number of sapwood rings in mature oak trees (English Heritage 1998). A fairly conservative range is between 15 and 50 and that this holds for 95% of mature oaks. This means, of course, that in a small number of cases there could be fewer than 15 and more than 50 sapwood rings. For example, the core CRO-A06 has only 9 sapwood rings and some have obviously been lost over time – either they were removed originally by the carpenter and/or they rotted away in the building and/or they were lost in the coring. It is not known exactly how many sapwood rings are missing, but using the above range the Laboratory would estimate between a minimum of 6 (=15-9) and a maximum of 41 (=50-9). If the last ring of CRO-A06 has been dated to 1500, say, then the estimated felling-date range for the tree from which it came originally would be between 1506 and 1541. The Laboratory uses this estimate for sapwood in areas of England where it has no prior information. It also uses it when dealing with samples with very many rings, about 120 to the last heartwood ring. But in other areas of England where the Laboratory has accumulated a number of samples with complete sapwood, that is, no sapwood lost since felling, other estimates in place of the conservative range of 15 to 50 are used. In the East Midlands (Laxton *et al* 2001) and the east to the south down to Kent (Pearson 1995) where it has sampled extensively in the past, the Laboratory uses the shorter estimate of 15 to 35 sapwood rings in 95% of mature oaks growing in these parts. Since the sample CRO-A06 comes from a house in Cropwell Bishop in the East Midlands, a better estimate of sapwood rings lost since felling is between a minimum of 6 (=15-9) and 26 (=35-9) and the felling would be estimated to have taken place between 1506 and 1526, a shorter period than before. Oak boards quite often come from the Baltic region and in these cases the 95% confidence limits for sapwood are 9 to 36 (Howard *et al* 1992, 56).

Even more precise estimates of the felling date and range can often be obtained using knowledge of a particular case and information gathered at the time of sampling. For example, at the time of sampling the dendrochronologist may have noted that the timber from which the core of Figure A2 was taken still had complete sapwood but that some of the soft sapwood rings were lost in coring. By measuring into the timber the depth of sapwood lost, say 20mm, a reasonable estimate can be made of the number of sapwood rings lost, say 12 to 15 rings in this case. By adding on 12 to 15 years to the date of the last ring on the sample a good tight estimate for the range of the felling date can be obtained, which is often better than the 15 to 35 years later we would have estimated without this observation. In the example, the felling is now estimated to have taken place between AD 1512 and 1515, which is much more precise than without this extra information.

Even if all the sapwood rings are missing on a sample, but none of the heartwood rings are, then an estimate of the felling-date range is possible by adding on the full compliment of, say, 15 to 35 years to the date of the last heartwood ring (called the heartwood/ sapwood boundary or transition ring and denoted H/S). Fortunately it is often easy for a trained dendrochronologist to identify this boundary on a timber. If a timber does not have its heartwood/sapwood boundary, then only a *post quem* date for felling is possible.

5. Estimating the Date of Construction.

There is a considerable body of evidence collected by dendrochronologists over the years that oak timbers used in buildings were not seasoned in medieval or early modern times (English Heritage 1998; Miles 1997, 50–5). Hence, provided that all the samples in a building have estimated felling-date ranges broadly in agreement with each other, so that they appear to have been felled as a group, then this should give an accurate estimate of the period when the structure was built, or soon after

(Laxton *et al* 2001, fig 8; 34–5, where 'associated groups of fellings' are discussed in detail). However, if there is any evidence of storage before use, or if there is evidence the oak came from abroad (eg Baltic boards), then some allowance has to be made for this.

6. Master Chronological Sequences.

Ultimately, to date a sequence of ring widths, or a site sequence, we need a master sequence of dated ring widths with which to cross-match it, a Master Chronology. To construct such a sequence we have to start with a sequence of widths whose dates are known and this means beginning with a sequence from an oak tree whose date of felling is known. In Figure A6 such a sequence is SHE-T, which came from a tree in Sherwood Forest which was blown down in a recent gale. After this other sequences which cross-match with it are added and gradually the sequence is 'pushed back in time' as far as the age of samples will allow. This process is illustrated in Figure A6. We have a master chronological sequence of widths for Nottinghamshire and East Midlands oak for each year from AD 882 to 1981. It is described in great detail in Laxton and Litton (1988), but the components it contains are shown here in the form of a bar diagram. As can be seen, it is well replicated in that for each year in this period there are several sample sequences having widths for that year. The master is the average of these. This master can now be used to date oak from this area and from the surrounding areas where the climate is very similar to that in the East Midlands. The Laboratory has also constructed a master for Kent (Laxton and Litton 1989). The method the Laboratory uses to construct a master sequence, such as the East Midlands and Kent, is completely objective and uses the Litton-Zainodin grouping procedure (Laxton *et al* 1988). Other laboratories and individuals have constructed masters for other areas and have made them available. As well as these masters, local (dated) site chronologies can be used to date other buildings from nearby. The Laboratory has hundreds of these site sequences from many parts of England and Wales covering many short periods.

7. Ring-Width Indices.

Tree-ring dating can be done by cross-matching the ring widths themselves, as described above. However, it is advantageous to modify the widths first. Because different trees grow at different rates and because a young oak grows in a different way from an older oak, irrespective of the climate, the widths are first standardized before any matching between them is attempted. These standard widths are known as ring-width indices and were first used in dendrochronology by Baillie and Pilcher (1973). The exact form they take is explained in this paper and in the appendix of Laxton and Litton (1988) and is illustrated in the graphs in Figure A7. Here ring-widths are plotted vertically, one for each year of growth. In the upper sequence of (a), the generally large early growth after 1810 is very apparent as is the smaller later growth from about 1900 onwards when the tree is maturing. A similar phenomenon can be observed in the lower sequence of (a) starting in 1835. In both the widths are also changing rapidly from year to year. The peaks are the wide rings and the troughs are the narrow rings corresponding to good and poor growing seasons, respectively. The two corresponding sequence of Baillie-Pilcher indices are plotted in (b) where the differences in the immature and mature growths have been removed and only the rapidly changing peaks and troughs remain, that are associated with the common climatic signal. This makes cross-matching easier.

t-value/offset Matrix

	C45	C08	C05	C04
C45		+20	+37	+47
C08	5.6		+17	+27
C05	5.2	10.4		+10
C04	5.9	3.7	5.1	

Bar Diagram

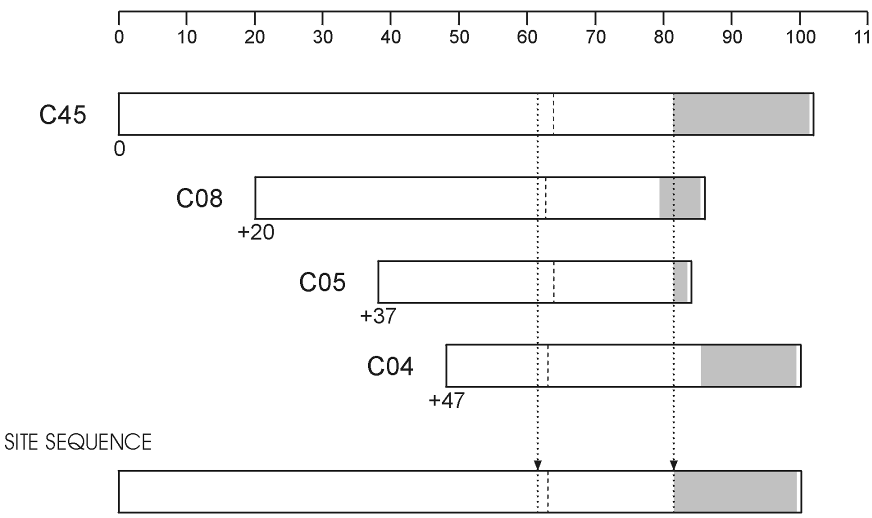


Figure A5: Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them

The bar diagram represents these sequences without the rings themselves. The length of the bar is proportional to the number of rings in the sequence. Here the four sequences are set at relative positions (offsets) to each other at which they have maximum correlation as measured by the *t*-values. The *t*-value/offset matrix contains the maximum *t*-values below the diagonal and the offsets above it. Thus, the maximum *t*-value between C08 and C45 occurs at the offset of +20 rings and the *t*-value is then 5.6. The site sequence is composed of the average of the corresponding widths, as illustrated with one width.

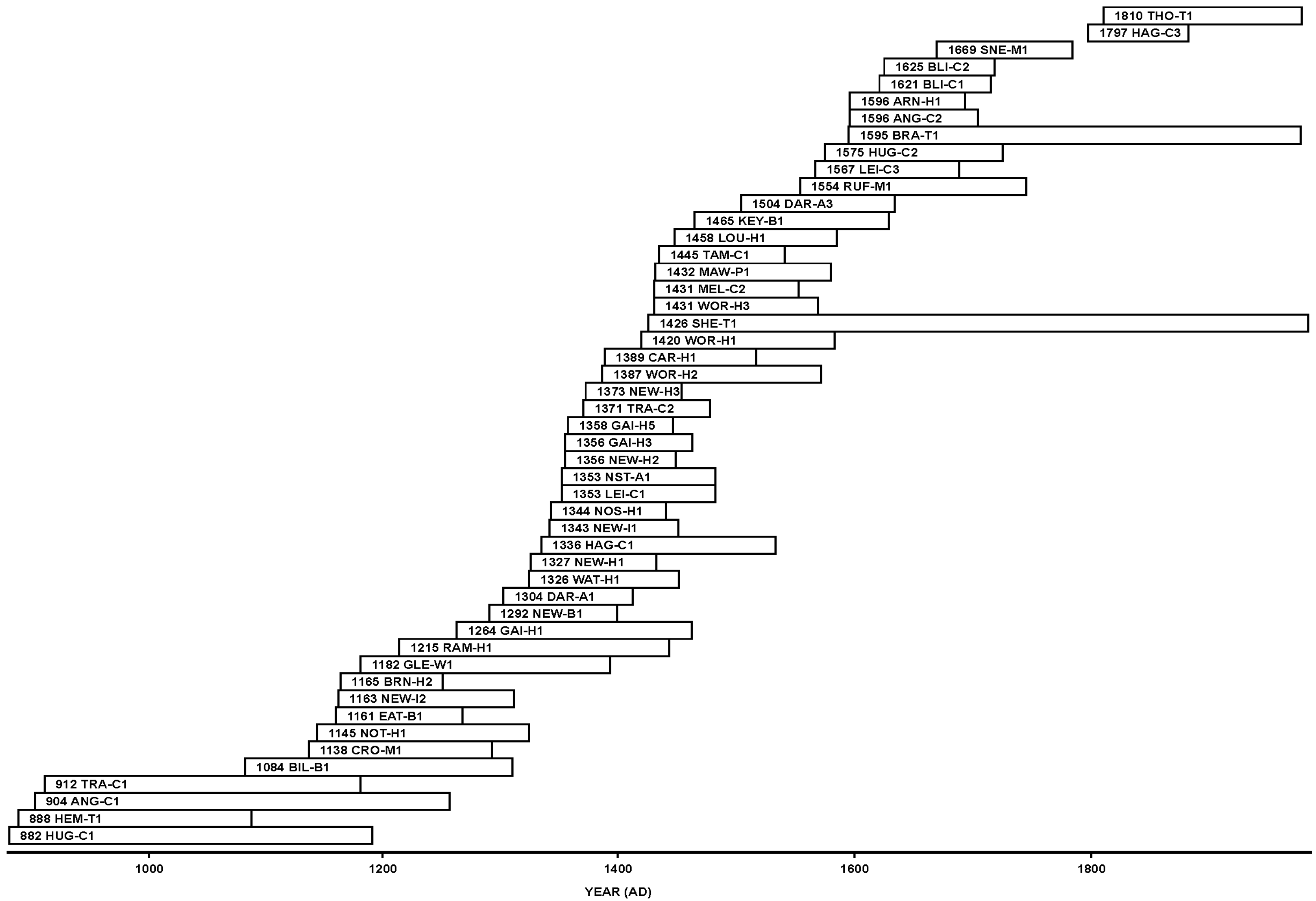
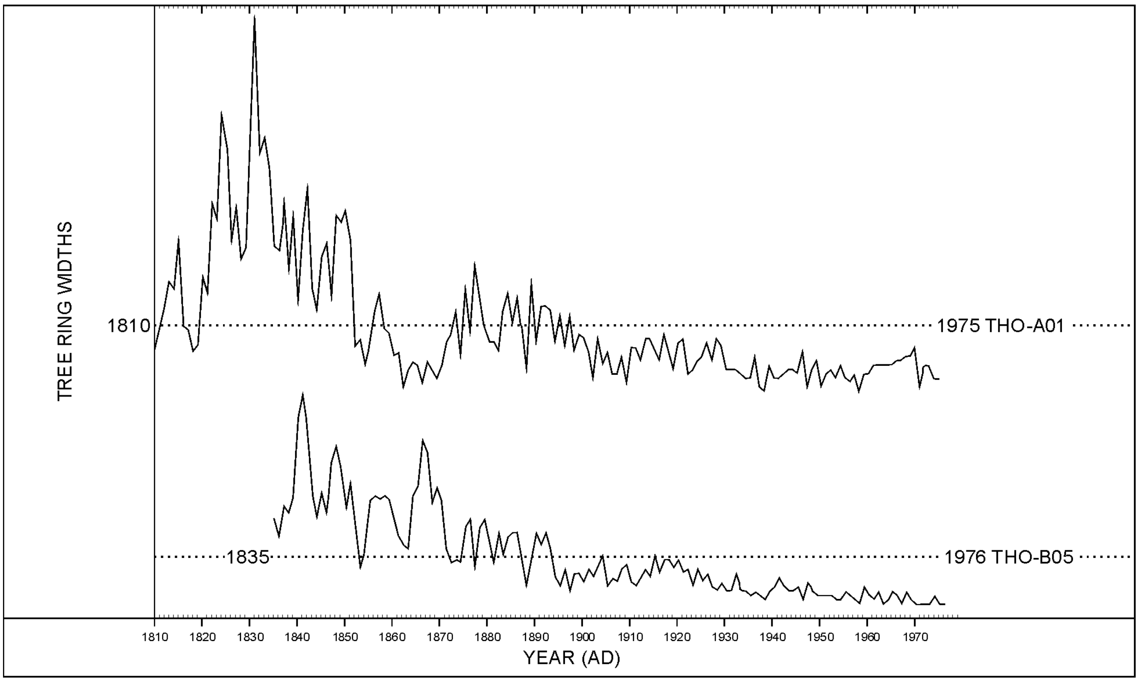


Figure A6: Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87

(a)



(b)

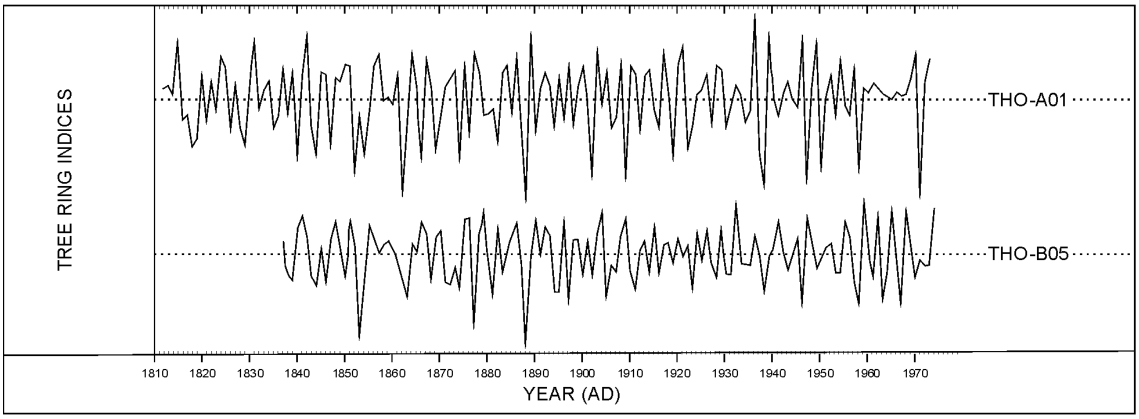


Figure A7 (a): The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known

Here the ring widths are plotted vertically, one for each year, so that peaks represent wide rings and troughs narrow ones. Notice the growth-trends in each; on average the earlier rings of the young tree are wider than the later ones of the older tree in both sequences

Figure A7 (b): The Baillie-Pilcher indices of the above widths

The growth trends have been removed completely

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