WESTMINSTER ABBEY, LONDON
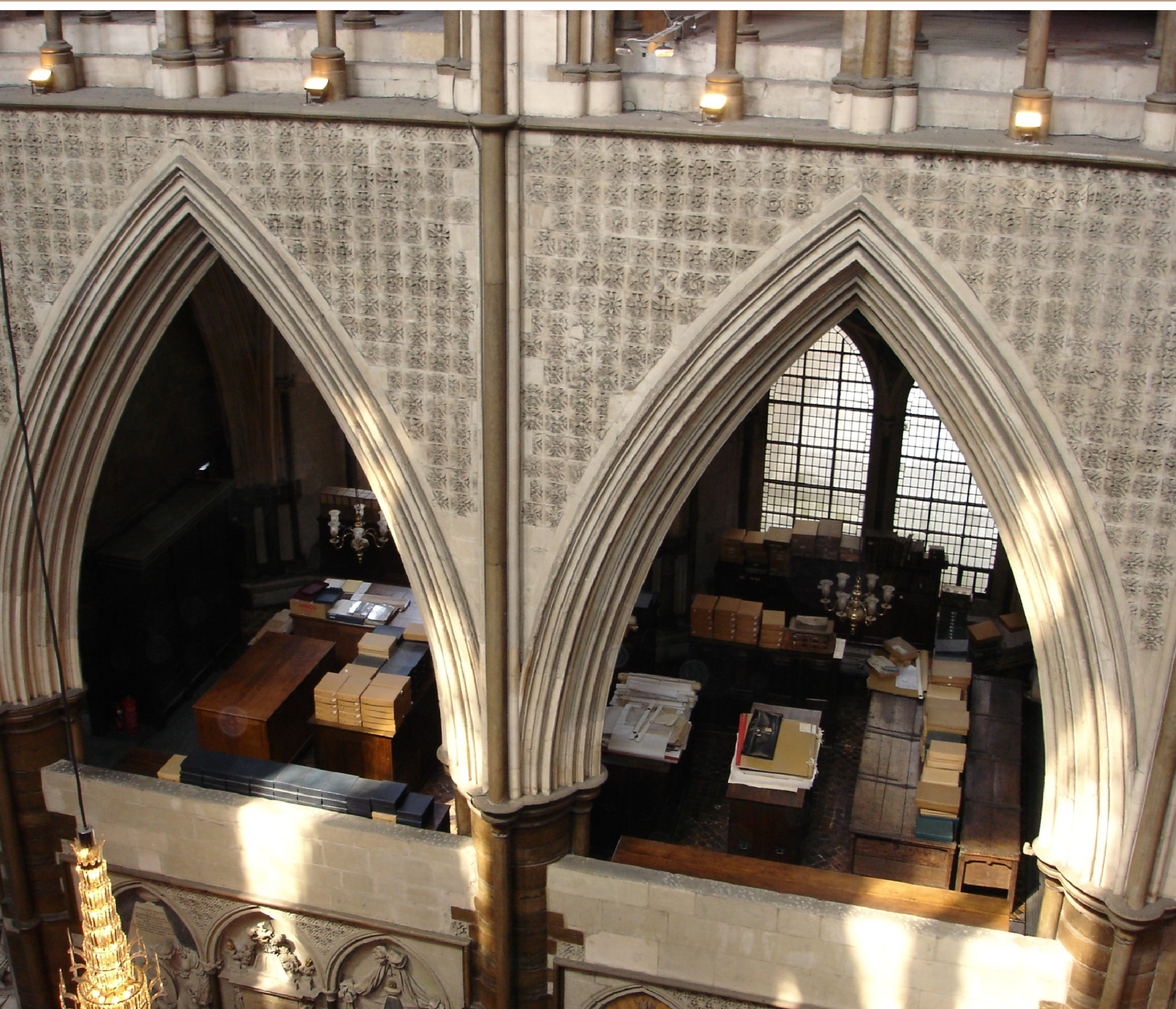## TREE-RING DATING OF THE CHESTS AND FITTINGS

SCIENTIFIC DATING REPORT

Dr Daniel Miles and Dr Martin Bridge

ENGLISH HERITAGE

WESTMINSTER ABBEY, LONDON

TREE-RING DATING OF THE CHESTS AND FITTINGS

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SUMMARY

Eight chests, two groups of panels, and an armoire, many of which had been dated by Dr John Fletcher in the 1970s, were analysed, and all objects were successfully dated.

The earliest items were reused panels forming a shelf or canopy in the Pyx Chamber, which were felled in AD 1162–94, and the Long Chest in the Muniment Room, which produced a felling date range of AD 1167–99. Four chests were dated to the thirteenth century: the hutch-type chest in the Lapidarium (AD 1237–69), the Large Chest in the Muniment Room (AD 1239–71), the Lesser Treaty Chest in the Pyx Chamber (AD 1271–87), and the Deep Chest in the Muniment Room (AD 1274–90).

Although the twelfth-century timbers were of local origin, the Large Chest was made from both English and German boards, and possible matches with German chronologies suggest that slower-grown timbers in the hutch-type chest were also probably imported. This suggests that timber supplies went through a transition during the reign of Henry III (1216–72). By the time of Edward I (1272–1306), imports were more common, and both the Lesser Treaty Chest and the Deep Chest were made entirely of German timber.

The remaining objects, of Baltic oak, dated to the fourteenth or early fifteenth century: the Cope Chest (*c* AD 1375–1400) and the Greater Treaty Chest (AD 1379–95) in the Pyx Chamber, the Panelled Chest in the Lapidarium (AD 1405–21), the Richard II Cupboard in the Muniment Room (AD 1377–93), and the partition panel next to the Muniment Room partition (AD 1348–64).

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ARCHIVE LOCATION

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INTRODUCTION

Westminster Abbey (Fig 1; NGR TQ 300 795) is one of the country's most important historical buildings. The earliest church on this site was the church of St Peter at Westminster – there is debate as to whether it was founded in AD 616, but it was certainly in existence during the eighth century (RCHM 1924). During the next three centuries the church was enlarged and rebuilt. Edward the Confessor came to the throne in AD 1042 and embarked on rebuilding the abbey church at an unknown date, but work was certainly in progress in AD 1051. By the time of the Confessor's death early in January AD 1066, the church was thought to have been basically completed, and indeed had been dedicated on Holy Innocents' Day on 28 December 1065. In the thirteenth century the Saxon church was rebuilt by Henry III. Between AD 1220 and c 1245 the Lady Chapel was built to the east of the Confessor's church. Following on from this, between AD 1245 and 1254 the eastern end of the Saxon church was demolished and the chancel, north and south transepts, ambulatory and eastern chapels were constructed. It is thought that the Chapter House and its vestibule, together with the north and east sides of the cloister, were reconstructed. Between AD 1254 and 1269 the choir was replaced up to the Saxon nave, which was not replaced until the last quarter of the fourteenth century (Lethaby 1906).

Associated with the Abbey building are a number of early medieval timber doors, chests, and other wooden fittings. Six doors have previously been reported on, including the late Saxon door called 'Pyx' (Miles and Bridge 2005). This report summarises the study and analysis of eight medieval chests including the cope chest, a cupboard, and two sets of boards or panels. As with the doors already studied, the study attempted to phase and provenance the timber used in their construction, and their relationship to the perceived sequence of building at the Abbey.

In addition, the previous dendrochronological studies of some of the woodwork by Dr John Fletcher during the 1970s was reviewed. However, the first dendrochronological investigation of the chests in Westminster Abbey was by Dr John Harvey and A W G Lowther. In 1948 Harvey sanded the edges of boards of a number of chests including the Greater Treaty Chest in the Pyx Chamber, and the Long and Big chests in the Muniment room, and made graticule measurements. These he passed on to Lowther who analysed them using a series of mathematical tests as well as visual comparisons. The results of this work were published in 1957 (Schove and Lowther 1957), expanding on and revising some initial conclusions published in 1951 (Lowther 1951).

Between 1970 and 1984 Dr Fletcher reviewed Lowther's material and took measurements from additional boards from the Greater Treaty Chest and the Long and Big chests, as well as the Lesser Treaty Chest, Cope chest, and tester or canopy boards in the Pyx Chamber, and from the Deep chest and Richard II cupboard or armoire in the Muniment Room. Detailed results were published in 1976 on the Greater Treaty Chest (Fletcher 1976), and on the other items in 1984 (Fletcher and Tapper 1984). An incomplete series of punch cards for all of the items except the Richard II cupboard were found in the Fletcher archive held by the Oxford Dendrochronology Laboratory and were converted to machine-readable format for the analysis.

DESCRIPTION OF THE WOODWORK

Of the 11 items of woodwork studied, four were in located in the Pyx Chamber, four in the Muniment Room overlooking the south transept, and three were in the Lapidarium, located at triforium level over the Jesus Chapel and the Chapel of St John the Baptist (Fig 2). Throughout the following descriptions, the use of the term 'board', 'plank', and 'timber' have been used somewhat inconsistently. Boards generally are 1–2in (25–50mm) in thickness, whilst planks are generally 2in (50mm) or more thick. In describing the analysis procedure, the term timber refers to boards, planks, or other wooden members.

Lesser Treaty Chest, Pyx Chamber

This chest, together with the Greater Treaty Chest adjacent, had housed treaties and other documents relating to foreign policy. Both chests have white painted inscriptions inside their lids naming foreign states, and S E Rigold assigned the hand to the early sixteenth century (Rigold 1976, 35). This chest is often referred to as the 'regalia' chest today, but there is no specific basis for this, and it is not known whether regalia were kept in this, or the other chest, before the sixteenth century (Rodwell pers comm).

It measures 3ft 3in (0.99m) high, 3ft 1in (0.94m) wide, and 6ft 7in (2.0m) long, and is a plank and style chest, in which the front and rear is composed of 14½in (37mm) wide plank styles between which a series of three boards are tongued in flush to the outside (Figs 3 and 4). The ends are a series of three boards which are let into the back sides of the styles, and set back from the edge. The lid is composed of three boards, the top being level but the outer boards being tapered. Like the lid, all of the boards are tapered, and are flush on the outside. However, the bottom boards are of consistently ½in (12mm) thick. The boards are also not cut parallel, but are often tapered along their length. The top boards are secured on the ends by a rail with a wide chamfer with a run-out stop with bar, as well as a centre bar. The rail is let into an open slot in the rear styles and secured with an iron pin to form a wooden hinge (Fig 5). The top is reinforced with three straps which are chained to the rear of the chest and terminate in hasps at the front (Fig 6). Other simple iron bands are used to strengthen the chest; the only decoration is a compact, flat *fleur-de-lis* with squared seating at the top of the middle strap just beneath the centre lock plate. Other features include a central divider and a till inside on the left-hand side.

During the twentieth century this chest has been in different positions in the Pyx Chamber. When Fletcher measured this chest in the 1970s (Fig 7), it was on the low plinth which runs along the south side of the room at the east end. In 1986 it was placed on the north side of the room, just inside the door. At the present time it is again on the south side of the room, but this time at the west end of the plinth. Thus, this chest has often been referred to as the 'east' chest due to its previous position at the east end of the plinth. Tree-ring analysis during the 1970s by Fletcher gave a date range of AD 1285–1300 (Fletcher and Tapper 1984).

Greater Treaty Chest, Pyx Chamber

This large chest measures 3ft 6in (1.07m) high, 3ft 8in (1.12m) wide, and 7ft 6in (2.29m)

long, and is a plank and style chest with 10in (250mm) wide styles (Figs 8 and 9). The front and back boards are edge-dowelled into each other as well as into the styles, and all planks or boards except the bottom and central divider are tapered, the thickest planks being placed at the edges of the chest. The ends have boards set back and housed into the styles over which are placed three horizontal cleats which are dovetailed into the edges of the styles, and two vertical cleats which are halved over the centre horizontal and dovetailed into the top and bottom cleats. The chest is perfectly plain with no chamfers or mouldings. The ironwork includes five strap hinges, three of which extend to form hasps with an incised star pattern and stippled decoration. The hasps end in knobs with a radiating incised pattern. The three countersunk lock plates are later replacements (Eames 1977, 149, fig 20; Geddes 1999). The lid is slightly convex. There were four iron bands placed on the bottom of the chest which turned up about 11in (275mm) from the bottom on the front face. Eames postulated that the chest was originally of hutch form and that the legs had decayed and were subsequently sawn off and the iron bands added to secure the bottom (Eames 1977, 150). Given that the boards comprising the bottom extend underneath the styles and lower side boards, it is unlikely that this was the case, and from the present evidence the chest in its present form is as originally built.

Like the Lesser Treaty Chest, this has historically been used to store treaties, and the names of various foreign nations are written in chalk or paint on the underside of the lid. For much of the nineteenth and twentieth centuries it stood on the floor under the shelf or canopy, to the east of the central column. When Fletcher studied the chest, it was at the west end of the southern plinth, but it was moved on the floor of the Pyx in 1986, and was put back on the plinth in 1986, but at the east end of the plinth. In previous publications, it has been sometimes referred to as the 'west' chest due to its previous position on this plinth.

Tree-ring analysis by Lowther in the late 1940s and early 1950s produced a date of AD 1244–1361 for one board (Lowther 1951) which was subsequently revised to AD 1246–1363 (Schove and Lowther 1957), which also dated another style to AD 1292–1480, concluding that the chest was constructed *c*1490. During the 1970s more work by Fletcher gave a date range of AD 1390–1405, derived from a last heartwood ring date of AD 1367 (Fletcher and Tapper 1984).

Cope Chest, Pyx Chamber

Medieval cope chests are exceptionally rare in Britain, with only seven known (Hewett 1988). The Westminster cope chest is in the shape of a 94° quadrant with a 6ft 6in (1.98m) radius and 2ft 2in (0.66m) high, but was originally constructed as a third of a circle, of 115° (Figs 10 and 11). The left-hand side had subsequently been truncated, with the top and bottom rails shortened (Figs 12 and 13). The front arc is in two panels with a centre post, and the top rail is scarfed with a mortice and tenoned joint. The two curved panels are from single boards about ½in (12mm) thick held within grooves. The front frame is simply chamfered with no stops. The bottom frame consists of a stretcher running from the rear post to the centre post, into which are tenoned struts from the two front corner posts. The bottom is floored with boards edge-dowelled radiating out from the rear corner post (Fig 14). The lid consists of a series of 1in (25mm) boards running parallel to the front corner posts, and as they are set at about 90° to the back

edge rather than 115°, they probably relate to the present truncated shape of the chest. The lid boards are held together by four softwood cleats on the underside, and a series of three iron straps fixed to the top surface. Apart from the straps, there is little ironwork except four large strap hinges to the lid and a more modern hasp and staple.

During the nineteenth century the chest was located in the Triforium (Scott 1863), and shortly after 1924 it was moved to the Undercroft Museum where it remained until 1965. It was then stored in the open cloister in 1970 at which time the Dean and Chapter offered it to the Ministry of Works and it was placed in the Chapter House, then the Pyx Chamber. After a being illegally moved to Dover Castle in 1981, it was returned to the Pyx Chamber, then moved back to the Undercroft Museum in 2002, and finally back to the Pyx in 2006.

The chest has been variously been dated stylistically to the fourteenth century (Cox and Harvey 1907) or the fifteeth century (RCHME 1924). Geddes (1999) dated it to between the early fifteenth century on account of the use of tangential boarding, or later in the century by the skilled panelling. At least one lid board had been measured *in situ* by Fletcher, but no dates had ever been reported for it. Fletcher apparently assigned it to the 'end of the fourteenth century' (reported in Hewett 1988, 121).

Shelf or Canopy, Pyx Chamber

This is a timber framework which sits on the capital of the central column and the corresponding respond capital to the east (Figs 15 and 16). It was probably used to hold parchment rolls. It measures just over 13ft (4m) long by 3ft 4in (1.01m) and is made up of a series of 15 boards, the first and last boards cut through by the masonry arch. The boards measure between ½in (12mm) and ¾in (18mm) thick and are between 9in (23mm) and 13in (325mm) wide, and although two are diagonally cut, most are reasonably parallel. They sit on a pair of bearers which are relatively new, possibly having been replaced in the mid-nineteenth century by Scott.

The boards are radially cut and are V-edged, with the unusual feature of having a rounded gullet in the corresponding groove (Fig 17). Ten boards retain their tongues, and five retain their original grooves, the rest have been cut down to fit their present arrangement. Each board was fixed with four large nails, two at each end, to the previous bearers. The nails have large heads ¾in (18mm) to 1in (25mm) in diameter, some flat, some faceted. The top sides of the boards have never been decorated, and are more roughly finished than the smooth soffits. There are a series of scratched assembly marks across the boards starting at the west end (board 15) and running sequentially to the east (Fig 18). The present numbering system of 1 to 15 from the east end has been used in this investigation, rather than the scribed Roman assembly marks. There are also some large gouged assembly marks on the backs which must relate to an earlier use.

An important feature of the boards is the surface decoration of the soffits (Fig 19). The earliest surface decoration is a white-washed ground with a series of black dots on a red band. On boards 4 to 8, and 10, the red band is ¼in (6mm) to $^3/_8$in (9mm) wide with black dots of similar diameter placed at 1in (25mm) to 1¼in (32mm) centres. This band of decoration is placed along the V-joint of the boards to mask the joint. On board 9 the

band of red is ½in (12mm) wide and is in the centre of the board rather than the edge, and has black dots ¼in (6mm) to $^3/_8$in (9mm) in diameter set at 2in (50mm) centres. What is especially significant about this decoration is that it predates its present arrangement in the Pyx, in that the decorated surface extends over the bearers. In all cases, the ends of the boards exhibit saw-cuts, truncating the decoration and showing that they have been cut down for use in their present position. In some instances, saw-marks occur on the sides of the *c* nineteenth-century bearers, where the boards were trimmed *in situ*, after being nailed down. Two boards had previously been measured by Fletcher in 1984, and a date of after AD 1435 offered for this structure (Fletcher and Tapper 1984).

Long Chest (Chest 1), Muniment Room

This exceptional chest is almost 13ft (4m) long, 2ft (0.61m) wide, and 2ft 5in (0.74m) high (Figs 20 and 21). It is situated at the north end of the Muniment Room, overlooking the Choir. Although all the three chests in the Muniment room at present hold documents, they were most likely to have been originally constructed to hold royal treasure. The tills inside several of these chests were designed to hold small and precious objects (Rodwell pers comm). There are three large styles front and back: the ends measure 14in (0.35m) wide and the middle one 18in (0.45m). The front styles have D-shaped indents closed by small columns with Romanesque cushion capitals (Fig 22). The front boards are single planks which were tapered with the widest part at the bottom, but were then hollowed out internally to give parallel faces to the inner face of the plank. They are tenoned into the styles and set back slightly from the face of the styles and pegged with a number of pegs with large decorative iron studs nailed over. The end planks were similarly hollowed out internally and were housed in the styles. The bottom of the chest is made up of two V-jointed tapered boards, the groove having a ¼in (5mm) round gullet (Fig 17).

The lid is in two halves, each with an outer rail with decorated chamfer and central bar and ogee run-out end stops. This is cut so that it forms a pivot, or carpenter's hinge, over the rear styles. Each lid is made up of two boards, which are held together by three straps with staples at each end, having a hasp on the front (Fig 23) and a chain to the back, giving added security (Fig 24). There is little ironwork apart from the hinge bands and chains with the exception of a strap on the underside turning up over halfway up the front face. A relatively modern wrought-iron hasp, dating from the eighteenth or nineteenth century, now secures each lid. The lid boards are fixed to the side rails by square pegs covered with large decorative wrought nails. Other features include an early fabric lining and a till on the right-hand side of the right compartment with a round lock plate (Fig 25).

This chest has been stylistically dated to the late twelfth or early thirteenth century, and has long been considered the oldest chest in the Abbey. Lowther had published a date of *c* AD 850–1138 for one sequence from a lid of this chest (Schove and Lowther 1957). Measurements taken from additional boards and planks from this chest by Fletcher produced a construction date range of after AD 1185, derived from a last measured heartwood ring date of AD 1161 (Fletcher and Tapper 1984).

Large Chest (Chest 2), Muniment Room

Set immediately to the south of the Long Chest, at the north end of the Muniment Room, this chest is the largest in the Abbey (Fig 26). It measures 13ft 6in (4.11m) long, 3ft 8½in (1.13m) wide, and 2ft 9in high (0.84m) (Fig 27). The front and back of the chest have three styles each about 12¾in (320mm) wide, which have simple quarter-round hollow chamfers with circular terminations. The lid is in two halves, longitudinally as well as transversely, and is hinged by six long double-knuckled hinges, the middle two connecting with a hasp. An interesting feature which is not entirely understood is a secret locking mechanism which was activated by a pair of movable decorative studs on each lid (Fig 28) which engaged with a bar that slid along the inside of the front panel and somehow connected with the central hasp. The evidence for this still remains in the form of an open cut-out slot a little bit below the top of the front board (Fig 29). Each lid had two subsidiary lock plates fixed on the front, the hasps to which are now missing, but the remains of the straps on the tops still remain. There are also two hasp and staples, probably dating from the eighteenth or nineteenth century.

The boards are tapered with the exception of the thin, ¾in (18mm) thick bottom boards which are secured by a thickened foot of the bottom side plank, much like the Long Chest. The boards are all glued together, those forming the front panels are so finely joined that it is almost impossible to see the joint in places.

A number of tapering iron straps, casually placed, reinforce the joints on the front, sides, and back of the chest. The top is made up of four boards per half, two per lid section, and are slightly concave, with the underside of the lid being flush. The ends of the lids are supported by a small ledger or rail with a simple chamfer with a stepped, run-out stop.

Stylistically this chest was dated slightly later than the Long Chest, due to its simpler decoration. Fletcher published a date of after AD 1225 for this chest from measurements taken from the lid boards, derived from last heartwood ring dates of between AD 1200 and 1203 (Fletcher and Tapper 1984).

Deep Chest (Chest 3), Muniment Room

This chest is located in the north end of the Muniment Room, at right angles to the south-west side of the Large Chest (Fig 30). It measures just over 3ft (0.92m) tall, 2ft 8in (0.81m) wide, and 5ft 11in (1.80m) long (Fig 31). It has styles just over 12in wide (310mm) clamping three boards front and back, the top and bottoms of which are very tapered, from a maximum of 1½in (38mm) to the thickness of the middle one at ½in (12mm). The side panels are housed in the styles and are skew-pegged with $^3/_8$in (9mm) almost square pegs.

The top boards are secured on the ends by a rail with a wide chamfer with a run-out stop with bar, as well as a centre bar. The rail is let into an open slot in the rear styles and secured with an iron pin to form a wooden hinge. Inside there is a till on the left-hand side (Fig 32).

The only ironwork on this chest consists of two hasps and lock plates, plus a centre hasp and staple probably dating from the eighteenth or nineteenth century. Adjacent to the centre hasp is a lock plate without hasp which is probably medieval in date.

Both Lowther and Fletcher worked on dating this chest. Lowther dated one of the lid boards to AD 1054–1261 (Schove and Lowther 1957), and Fletcher dated a number of other boards and styles with last heartwood rings ranging from AD 1238 to 1265, suggesting a felling date range to after AD 1290 (Fletcher and Tapper 1984).

Richard II Cupboard or Armoire, Muniment Room

This is an exceptional piece of furniture, measuring 8ft 2½in (2.50m) high, 8ft 4½in (2.55m) wide, and 2ft 2in (0.66m) wide (Figs 33 and 34). It is situated against the northern side of the timber partition below the seated white hart, the emblem of Richard II (1377–99). The front frame consists of four uprights measuring 4½in (113mm) wide by 3in (76mm) deep. The tops are jointed into a large, elaborately moulded cornice 8in (203mm) high, which has a disused groove in the top for some sort of lost fretwork. The cornice returns on both sides with mitred corners, and the right-hand cornice has been cut away in the past to fit against some sort of obstruction, suggesting that it was probably in a different position. The bottoms of the front posts have a lower rail between them, and a hollow chamfer cut all around. Above the bottom rail is a 7in (178mm) panel with a recessed rail above forming the bottom of the three cupboard doors. Each of the three sections has four boards, the outer boards are fixed, and the middle two are glued together to form the 12in (305mm) wide doors. The left and centre sections of the doors are cut into two, and on the right section the upper door is cut into two, making seven in total. Inside are a number of thin shelves supported on front and back ledgers, the shelves made up of two or more $^3/_8$in (9mm) thick quartered oak boards. All the boards are of the highest quality and have a perfectly smooth finish.

The ironwork on this cupboard is also of the highest quality. The strap hinges have rectangular enlargements at their hanging ends decorated by a cold-cut stepped pattern (Fig 35). The straps terminate in a cut-out six-petalled rosette, decorated with punched dots on each petal (Fig 36). The ring pulls are fastened to a cut-out flat rosette or quatrefoil with punched dots on each petal. Each door has a lock, and some still retain their wooden turnbuckles with multifaceted central nail (Geddes 1999).

Traditionally, the cupboard was thought to have been built in 1381, but this was for a chest with 13 hinges and was of elm, leading Fletcher to conclude that this reference did not relate to this cupboard. Dendrochronological work by Fletcher in the 1970s concluded that the cupboard was constructed between AD 1390 and 1400, with terminal rings of between AD 1353 and 1364 (Fletcher and Tapper 1984). Eames placed this cupboard later, in the fifteenth century (Geddes 1999). Certainly it was originally constructed to hold documents, like those at Wells and Winchester (Rodwell pers comm).

Large Oak Chest, Lapidarium

This large chest with double lid is in the Lapidarium museum over the Chapel of St John

the Baptist (Fig 37). It measures 6ft 9in (2.06m) long, 2ft 5½in (0.75m) high, and 3ft 11in (1.19m) wide. The plank styles are almost 18in (0.45m) wide, and vary considerably in character, with the wood of the rear styles being exceptionally slow-grown, whilst that of the front styles is exceptionally fast-grown. Some of the planks used to construct the sides are also very fast-grown, whilst the lid boards are of average quality. The planks used to construct the sides are 1½in (38mm) thick at the base, and are then reduced to a consistent thickness of ¾in (18mm) above the floor of the chest. The planks used to form the front and back are tongued and pegged into the styles, with a haunch used for the top board. The butting edges of the boards are edge-dowelled together (Fig 38).

The lids are presently hinged together in the centre, but originally were designed to open outwards from the centre. The back leaf is hinged by the ledger, forming a pivot in the style, and the front leaf was originally hinged this way also. The back lid is not fixed down. The hinge pins were covered with pear-shaped cover plates of which only one now survives. The lid is presently connected together with three strap hinges, and a well-wrought and decorated hasp now locks the front down (Fig 39). There remains part of an early locking device which consisted of a lock, set well in from the edge which had long bolts that locked into the central bearer and into the front styles. The top is made up of three boards for the back lid, and two for the front lid. The meeting of the two lids is not parallel to the front or back of the chest. The end panels are noticeably out of parallel and are housed into the styles and pegged through.

There are traces of original decoration on the chest – the sides were red, whilst the top appears to have been coloured green. The chest has been in many different locations in the Abbey including the Muniment Room, the Triforium above the Chapel of St Benedict, and the Chapel of St Edmund before being moved to its present location. The chest has been variously dated stylistically as thirteenth-century, with the modifications to the lid as dating from around 1500 (Tony Platt pers comm).

Large Panelled Chest, Lapidarium

This well-moulded chest is situated adjacent to the Lapidarium museum over the Jesus Chapel (Fig 40). It measures 8ft 8in (2.64m) long, 3ft 5in (1.04m) wide, and 2ft 7in (0.79m) high (Fig 41). The front is divided into three panels, and the sides into two. The top rail and muntins measure 2¾in (70mm) thick, and the base is slightly thicker at 3¼in (80mm), and the mouldings are all jointed with mason's mitres. The panels are made up of boards ranging from 6in (150mm) to 14in (350mm) wide, and ½in (12mm) thick. The lid is divided into two unequal sections which are hinged from a 9½in (240mm) back-board. The lids are made up of four boards each $1^1/_8$in (30mm) thick and ranging from 6in (151mm) and 9in (227mm) in width. The lids are secured by five sets of hinges, two for the left-hand lid and three for the larger right-hand lid. The hinges are T-shaped and are of good quality with pierced terminations (Fig 42). The surface of the chest has evidence of red colouring.

The earliest location for this chest is in the RCHME *Inventory* (1924) which shows it in the Lower Islip Chapel, although it is unlikely to have been its original location. In 1988 the chest was in the Triforium above the Chapel of St Edmund, and was moved to its present location in 2000. The dating of the chest has been put to be no earlier than AD 1500,

and probably during the first quarter of the sixteenth century (John Muir, unpubl report to Westminster Abbey 2003).

Wall Panel from Muniment Room, now in Lapidarium

This section of partition boarding measures approximately 5ft (1.5m) by 8ft (2.4m) tall (Figs 43 and 44). It consists of a door post with a mortice for a door head, a rail, and ten boards with a fragment of an eleventh. The door post is chamfered with a stepped run-out stop at the top, a flat bevelled stop at the bottom, and a mason's mitre stop where it intersected the door head. The boards are all V-edged riven boards measuring between 5in (125mm) and 6½in (160mm) in width. The boards form a small borrowed light through the omission of the upper part of two boards. The boards are decorated with a series of painted stars similar to the boarding on the south side of the Richard II partition in the Muniment Room.

The location of this section of panelling is thought to have been in the southern half of the Muniment Room which was partitioned into several smaller rooms, although its precise location is not clear. However, in a photograph from 1891 the partition appears to have been the one separating the staircase from the lower chamber (Tony Platt pers comm). These partitions were cleared shortly afterwards and in 1920 it was recorded as having been in the Undercroft Museum. In 1988 the panel was found leaning against a wall in the South East Triforium and in 1997 it was moved to the Lapidarium.

OBJECTIVES OF DATING

The primary objective of dating the chests and fittings at Westminster Abbey is to relate these to the historical development of the Abbey complex. Therefore, the following objectives were set forth:

- to ascertain the dates of the Greater and Lesser Treaty Chests in the Pyx Chamber and whether the dates previously published by John Fletcher were confirmed

- to try and date the Cope Chest and establish whether the lid is contemporaneous with the base

- to establish the date of the Canopy or shelf in the Pyx Chamber and to confirm the dating by John Fletcher

- to try and determine the dates of the Long, Large, and Deep Chests in the Muniment Room, as well as the Richard II cupboard or armoire, and to confirm whether the dating of these four objects by John Fletcher can be confirmed

- to assess the early pioneering work of A W G Lowther from the late 1940s and 1950s and determine if any of these published dates for the Westminster chests were correct

- to refine the felling periods for the chests already dated by John Fletcher with the introduction of more samples with heartwood/sapwood boundaries

- to ascertain the date of the large hutch-type chest and the large panelled chest in the Lapidarium

- to determine the date of the section of partition panelling thought to have originated from the southern part of the Muniment Room

- to determine through dendrochronology whether the timber used in the chests and fittings was English, or imported

- to produce further replicated tree-ring chronologies for the Abbey from both local and imported timber.

ASSESSMENT

The chests and other wooden fittings were assessed during early 2005.

All of the chests appeared to have excellent dendrochronological potential with wide, slow-grown, radially converted timber. Similarly, the Richard II cupboard and the two groups of panels had exceptionally long ring sequences and were ideal for dendrochronological analysis. The timbers were of such high quality and slow grown that it likely that many of them would have been imported from eastern Europe or other sources.

The cope chest, whilst having excellent ring counts on the boards, was found to be much less satisfactory with fewer rings on the framing members. Here the timbers were converted from whole trees which were faster growing, resulting in samples with as few as 30 years' growth. However, many of these retained complete sapwood, so it was considered worth sampling them just in case they did match together conclusively, and the resulting master date.

The major overriding requirement in sampling the woodwork was to use minimal interventionist techniques. This precluded the sampling of many elements such as thin panels where the edges were not accessible and surfaces obscured by historic finishes or patination.

SAMPLING STRATEGY

Prior to sampling the various chests and boards, a search was made through the Fletcher archive for any data sets relating to the Westminster chests and boards. A number of these were found in punch-card format. These were converted to machine-readable format and dated.

Previous work by Lowther in the late 1940s and early 1950s resulted in the sanding of edges of a number of boards in order to obtain a clean enough surface to enable the rings to be accurately measured *in situ*. This has unfortunately resulted in the disfigurement and loss of patination of a number of visible edges, and such an approach would not be acceptable today. Therefore, it was decided in the first instance to photograph the already cleaned-up edges of boards and try and measure from them, resulting in no intervention whatsoever. This would also allow the comparison of some of the Fletcher datasets to be checked with the readings from the photographs.

However, one of the objectives was to refine the dating of the chests, and for this additional samples would be needed with some evidence of heartwood/sapwood boundaries. Here, core samples would need to be taken from those timbers with the micro-borer. Therefore, samples would first be restricted to those studied by Lowther and Fletcher, and additional samples would then be taken to augment the data sets for each object.

Samples from the Long Chest in the Muniment Room were numbered using the prefix **wa** followed by numbers 101–8 (Fig 21), with multiple samples from the same timber being labelled a, b, etc. Segments of cores which had broken during drilling were labelled a1, a2, etc. Samples from the Large Chest in the Muniment Room were numbered 111–18 (Fig 27), and samples for the Deep Chest were numbered 121–7 (Fig 31). Those from the Lesser Treaty Chest in the Pyx Chamber were numbered 131–7 (Fig 4), the Greater Treaty Chest 141–9 (Fig 9), and Canopy or shelf boards 151–7 (Fig 16). In the Lapidarium the large hutch-type chest samples were numbered 161–5 (Fig 38), those from the large panelled chest 171–6 (Fig 41). The panels from the demolished Muniment Room partition were numbered 181–5 (Fig 44). The Richard II cupboard or armoire samples in the Muniment Room were numbered 191–5 (Fig 34), and samples from the Cope Chest, now back in the Pyx Chamber, were numbered 201–12 (Figs 11 and 14).

METHODOLOGY

Most samples were taken from what appeared to be primary first-use oak (*Quercus* spp.) timbers with reasonably long ring sequences, or with some indication of sapwood. Exceptions to this were samples taken from certain chests or panels which themselves showed evidence for having been reused entire. Details of the samples taken, together with dates produced, are shown in Table 1.

As the surfaces of the planks or boards were generally too abraded or damaged to allow the rings to be accurately measured, and cleaning the surface would cause unacceptable visual intervention to the timberwork, a micro-borer was used to extract the samples. This system was initially developed for work on the medieval doors at the Tower of London, commissioned by the Historic Royal Palaces Agency. This minimal intervention approach was accomplished by using a small 8mm outside diameter hollow drill bit which extracts a 5mm diameter core. The drill bit is cooled and cleared of dust with the aid of compressed air which is channelled through the inside of the cutting tube and clears the waste from around the outside of the bit. The drill bit is accurately aligned by the use of a series of guides fitted to a jig which is clamped to the face of the board or plank (Fig 45).

In this manner the drill can be used to bore through a number of boards as thin as 15mm thick and as wide as one metre or longer (Fig 46). Thus a number of boards could be drilled in succession with the need to make only a single hole, which is afterwards plugged with an oak pellet and stained. The cores thus extracted were mounted on grooved timber mounts and prepared by being sanded on a linisher using 60 to 1200 grit abrasive paper, and cleaned with compressed air to allow the ring boundaries to be clearly distinguished. They were then measured under a ×10/×45 variable-focus microscope using a travelling stage electronically displaying displacement to a precision of 0.001mm, rounded to the nearest 0.01mm.

Where the edges of boards and planks had already been resurfaced through previous efforts, these were photographed with a scale. A 5.1 megapixel digital camera was used in macro mode to take overlapping photographs along the length of the series. Where possible, the camera was mounted on a tripod. In most cases a ruler was temporarily taped to the article being photographed so that the resulting prints included a scale. This also assisted in recognising the points of overlap between the photographs. The images were enhanced using standard photographic software and printed on photographic paper. The prints were then mounted on the normal dendrochronological measuring stage, measured, rescaled, and processed as the core samples above.

A number of large boards forming the shelf or canopy in the Pyx Chamber were temporarily removed where loose and taken to the laboratory for measurment. These were too long to conveniently measure under the microscope, and were therefore measured using a graticule to a precision of 0.01mm.

After measurement, the ring-width series for each sample was plotted as a graph of width against year on log-linear graph paper. The graphs of each of the samples in the phase under study are then compared visually at the positions indicated by the computer matching and, if found satisfactory and consistent, are averaged to form a mean curve for the site or phase. These mean curves, together with the individual ring sequences, are then compared against dated reference chronologies to obtain an absolute calendar date for each sequence.

In comparing one sample or site master against other samples or chronologies, t-values over 3.5 are considered significant, although in reality it is common to find demonstrably spurious t-values of 4 and 5 because more than one matching position is indicated. For this reason, dendrochronologists prefer to see some t-value ranges of 5, 6, and higher, and for these to be well replicated from different, independent chronologies with both local and regional chronologies well represented. Where two individual samples match together with a t-value of 10 or above, and visually exhibit exceptionally similar ring patterns, they most likely would have originated from the same parent tree. Same-tree matches can also be identified through the external characteristics of the timber itself, such as knots and shake patterns. For shorter ring sequences from the same tree, lower t-values are often encountered.

Here cross-matching and dating were accomplished by using a combination of both visual matching and a process of qualified statistical comparison by computer. The ring-width series were compared on an IBM compatible 486SX computer for statistical cross-matching using a variant of the Belfast CROS program (Baillie and Pilcher 1973). A version

of this and other programmes were written in BASIC by D Haddon-Reece, and latterly rewritten in Microsoft Visual Basic by M R Allwright and P A Parker. Further software by Tyers (2004) was also employed.

Ascribing Felling Dates and Date Ranges

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

A review of the geographical distribution of dated sapwood data from historic building timbers has shown that a 95% range of 9–41 rings is more appropriate for the southern part of England. For timbers from the Baltic region which includes Poland and regions to the north and east, a 95% sapwood estimate of 8–24 rings has been used (Tyers 2001a). West of this in the area centring on Germany, the sapwood range increases to 8–38 rings (Hillam *et al* 1987).

Where two of more timbers are shown to have originated from the same parent tree, and have heartwood/sapwood boundaries which differ by one or more years, these are averaged to give an average heartwood/sapwood boundary date for the mean. This, and the resutling felling date range, would be applied to all samples making up the group, including those with no evidence for sapwood. Similarly, a felling date range might be produced for a group of timbers making up a structure or object by applying at felling date range to the average heartwood/sapwood boundary date for all of the dated timbers or same-tree means.

It must be emphasised that dendrochronology can only date when a tree has been felled, not when the timber was used to construct the structure or object under study. Generally, it was common practice to build timber-framed structures with green or unseasoned timber and that construction usually took place within twelve months of felling. Furniture and other fittings on the other hand usually utilised boards which had been seasoned, but this was usually through air-seasoning, which usually equated to one inch per year in thickness (Miles 1997; 2005; 2006).

CROSS-MATCHING AND SITE CHRONOLOGIES

The following section is arranged by individual objects, generally arranged first by room and then chronologically. All refer to samples whose details are given in Table 1, which is

similarly arranged. Individual sequences which are combined together to form same-timber and same-tree means are illustrated by *t*-value matrices showing *t*-values over years overlaps presented in Table 2. Those same-timber and same-tree means, together with individual timber samples, which are combined to form site masters are similarly supported by *t*-value matrices presented in Table 3. The ring width data for the site master curves and dated individual sequences are given in Table 4. Dating evidence for these is given in individual tables referenced in the text.

Long Chest (Chest 1), Muniment Room

Altogether 15 sequences were obtained from eight timbers. Five timbers were measured *in situ* with a graticule by Fletcher during the 1970s and were transcribed from punch cards, including three lid boards and two styles. Six sequences from five boards were photographed, and four of these timbers were those measured by Fletcher. These were cross-checked with the graticule measurements and were found to match satisfactorily. Four micro-bore sequences were taken from two timbers. Including the Fletcher measurements, five timbers had multiple radii which were first combined to form same-timber means: **wa101a1**, **wa101a2**, and **wa101b** were combined to form the mean **wa101**; **wa103a** and **wa103b** were combined to form the mean **wa103**; **wa104a1**, **wa104a2**, and **wa104b** were combined to form the mean **wa104**; **wa105a** and **wa105b** were combined to form the mean **wa105**; and **wa108a** and **wa108b** were combined to form the mean **wa108**.

It is unclear what the relationship is between **wa106** and **wa108b**, both described on the Fletcher punch cards as 'styles I/III'. Sample **wa108b** is from the front right style as the sequence is virtually identical to the photograph of the same style, but it is not known where the other style (**wa106**) was located. It is unlikely to be **wa107**, as there was no significant match between them. It is probable that **wa106** was from one of the rear styles, which were not photographed in the present investigation.

These same-timber means were then compared with the other individual datasets and three were found to have originated from the same tree. The statistical matching between the timbers was not as high as expected (Table 2), probably as the result of one sequence showing more pronounced changes than the other two, but the plots nevertheless show very similar growth. Thus **wa103**, **wa106**, and **wa108** were all combined to form the same-tree mean **wa10368** . This was found to match satisfactorily with **wa101**, **wa102**, **wa104**, and **wa105** to form the 312-year site master **WMNSTR9**. This dated best with English chronologies, spanning the years AD 850–1161 (Table 5). Sample **wa107**, with 92 rings, failed to match any of the other samples, or with any of the reference chronologies, both local and European.

Large Chest (Chest 2), Muniment Room

Here 12 sequences from eight timbers were obtained. Three of these were graticule measurements by Fletcher, seven were from photographs, and two were from micro-bores. As with the Long Chest, the Fletcher measurements were cross-checked with photographs from the same timbers and were found to match. Therefore, sequences **wa114a1**, **wa114a2**, and **wa114b** were combined to form the mean **wa114**; **wa115a** and

wal15b were combined to form the mean **wal15**; and **wal18a** and **wal18b** were combined to form the mean **wal18**. These same-timber means were then compared with the other sequences and two same-tree means were found: **wal14** and **wal17** were combined to form the same-tree mean **wal147**, and **wal15** and **wal16** were combined to form the same-tree mean **wal156**. The mean **wal147** was found to match **wal11**, **wal12**, and **wal13** to form the 269-year site master **WMNSTR10**. This was compared with reference chronologies from all over Europe and was found to match best with German chronologies (Table 6).

The same-tree mean **wal156**, and the individual timber **wal18** were compared individually with the reference chronologies and were found to match, spanning the years AD 998–1212 and AD 1127–1200 respectively (Tables 7 and 8). Unlike the site master **WMNSTR10**, these two sequences matched best with chronologies from England.

Deep Chest (Chest 3), Muniment Room

A total of ten sequences was obtained from seven timbers, which included lid boards and styles. Five of these were *in situ* graticule readings from four timbers, which had been preserved on punch cards. Six sequences were from photographs, and one was from a micro-bore. Three of the photographed boards were compared with Fletcher's data, and as the matches were satisfactory, they were combined to form a same-timber mean. Therefore **wal21a** and **wal21b** were combined to form the mean **wal21**; **wal24a**, **wal24b1**, and **wal24b2** were combined to form the mean **wal24**; and **wal26a1**, **wal26a2**, and **wal26b** were combined to form the mean **wal26**. These were compared with the other sequences from the chest and some correlation was noted between samples **wal21**, **wal22**, **wal24**, **wal25**, and **wal27**. Because the matches between samples were not outstanding, all of these were first checked independently with the reference chronologies which confirmed their end dates (Tables 9, 10, 11, 12, and 13). These were therefore combined to form the 235-ring site master **WMNSTR11**, which dated, spanning the years AD 1031–1265. The best matches were with chronologies from the region around Germany (Table 14). Two samples, **wal23** and the composite **wal26**, despite having 119 and 135 rings respectively, failed to match either any of the other sequences, or individually with the reference chronologies.

Lesser Treaty Chest, Pyx Chamber

A total of eight sequences was obtained from seven boards from this chest. Three were graticule measurements recorded *in situ* by Fletcher, three were from photographs, and two were from micro-bores. One of the micro-bores was compared with the Fletcher data and was found to match. Thus samples **wal31a** and **wal31b** were combined to form the same-timber mean **wal31**. This was compared with the other sequences from the chest and was found to match with sample **wal37**. The matches were so good that it is likely that they originated from the same parent tree. Therefore they were combined to form the 224-year site master **WMNSTR12**. This was compared with the reference chronologies and was found to match, spanning the years AD 1040–1263 (Table 15). Again, the best matches were with German chronologies. Two other samples, **wal33** and **wal34** were found to match together strongly enough to be considered to have been from the same parent tree, and were combined to form the mean **wmn1334**. However,

this, as well as the remaining individual samples (**wal32**, **wal35**, and **wal36**) did not match any of the reference chronologies strongly enough to be considered dated.

Greater Treaty Chest, Pyx Chamber

Nine timbers were sampled from the Greater Treaty Chest. Three were graticule measurements by Fletcher, three were photographs, and four were micro-bores. Elements sampled included side boards, lid boards, and styles. One of the micro-bores fractured with a few rings lost in-between, and were therefore labelled **wal42a1** and **wal42a2**, giving ten sequences altogether. Five of the sequences were found to have originated from the same tree and were combined to form the same-tree mean **wal41269**.

Samples **wal44** and **wal45** form the 234-year site master **WMNSTR13**. This was compared with reference chronologies from England and Europe and was found to match best with chronologies from the Baltic, spanning the years AD 1113–1346 (Table 16). The same-tree mean **wal41269** was matched with sample **wal47** and were combined to form the 239-year site master **WMNSTR14**. This was found to match the Baltic chronologies spanning the years AD 1137–1375 (Table 17). Because the matches were not exceptional, sequences **wal47** and **wal41269** were dated individually, as shown in Tables 18 and 19 respectively. Sample **wal48** did not match the others, but was dated individually to AD 1146–1365 (Table 20), again best matching Baltic chronologies. Eight of the timbers were successfully dated, but one sample, **wal43**, failed to date. This ring sequence was relatively short in comparison to the rest of the material analysed from this chest, and an individual, particularly of such length, is far less likely to be successfully dated.

Shelf or Canopy Boards, Pyx Chamber

A total of 12 graticule sequences was obtained from seven boards. Three sequences from two boards were measured by Fletcher in 1984. Because none of the boards were thick enough to sample with the micro-bore, all had to be measured from an exposed end. Because many of these boards had bands of very narrow rings, this required particularly high quality surface preparation. Two had already been sanded by Fletcher and were loose, and five other loose boards were identified and were removed to the Laboratory for careful surface preparation. Only those edges which had recently been sawn when fitted onto the present modern bearers were sanded, and where possible the southern, less visible ends were measured.

Analysis of the sequences revealed two errors in Fletcher's measurements for board 6, due primarily to the very narrow rings and the rough surface of the board end. One ring was removed from sequence **wal56a1** and an extra ring inserted into sequence **wal56a2**. These were combined to form the sequence **wal56a**, which was then compared and combined with **wal56b** to form the same-timber mean **wal56**.

Sequences **wal51a** from Fletcher's graticule measurements and **wal51b** from measurements taken after the board was re-prepared allowed an extra 39 rings to be measured. The two measurements were therefore combined to form the mean **wal51**. Finally, two sequences were taken from each end of board 8, as the north end had 11

rings of sapwood surviving. Thus samples **wa155a** and **wa155b** were combined to form the mean **wa155**.

Three timbers, **wa153**, **wa155**, and **wa156**, were found to match together and were combined to form the 322-year site master **WMNSTR15**. This was compared with the reference chronologies and was found to match best with English chronologies, spanning the years AD 827–1148 (Table 21). Two other boards, **wa151** and **wa154**, were matched together to form the site master **WMNSTR16**, which dated, spanning the years AD 1007–1143 (Table 22). One other individual sample, **wa157**, did not match the other site masters but did date individually, spanning the years AD 970–1090 (Table 23). Again, these matched best with English chronologies. One sample, **wa152**, with 93 rings, failed to match any of the other samples or with the reference chrononologies.

Hutch-Type Chest, Lapidarium

Five samples were taken with a micro-bore from this chest. Two were from the rear styles, and three from the lid boards. Two of the lid boards, **wa164** and **wa165**, matched each other and were combined to form the 105-year site master **WMNSTR17**. This dated, spanning the years AD 1124–1228, matching best with English chronologies (Table 24). The dating of the two composite sequences comprising the site master was confirmed by dating them individually (Tables 25 and 26). The two rear styles **wa161** and **wa162** matched together and were combined to form the mean **wa1612**. The degree of match was such that they must have originated from the same tree. Although some matches were obtained with German chronologies of the same period as the dated English boards, there was not enough replication to consider this mean sequence dated. One other sample from the lid, **wa163** with 96 rings, also failed to date. Given the mean ring width of 2.4mm, it is probably of English origin, as are the dated lid boards.

Large Panelled Chest, Lapidarium

Six samples were taken from the lid boards of this chest with the micro-borer. All six samples, **wa171** to **wa176**, were found to match each other and were combined to form the 203-year long site master **WMNSTR18**. This was compared with the reference chronologies and found to date, spanning the years AD 1200–1402 (Table 27). The best matches were with chronologies from the Baltic.

Panels from Demolished Partition from Muniment Room, now in Lapidarium

Five samples were obtained by sawing off the tops of the boards where they had previously been sawn when removed from their original position. All five samples, **wa181** to **wa185**, were found to match together and were combined to form the 200-year site master **WMNSTR19**. This was found to date, spanning the years AD 1146–1345 (Table 28). The best matches were with the Baltic chronologies.

Richard II Cupboard or Armoire, Muniment Room

Five timbers were photographed, one three times, resulting in seven sequences. Because

the panels were so thin, and a number of edges on the doors had previously been sanded, the micro-borer was not used on this piece of furniture. Samples **wa191a**, **wa191b**, and **wa191c** were all taken from the face of the left-hand return panel, which showed seven rings of sapwood. However, the surface of the panel was not clean enough to allow clear readings to be taken, and as it was not possible to clean the panels without causing unacceptable intervention to the surface of the timber. Therefore, it was not possible to reconcile these measurements and these sequences remain undated. The other four timbers, two shelf boards and two door boards from the right-hand cupboard, had been previously prepared, although Fletcher's measurements have not been located. All four samples, **wa192**, **wa193**, **wa194**, and **wa195** were found to match, and were combined to form the 219-year site master **WMNSTR20**. This dated, spanning the years AD 1151–1369, matching best with chronologies from the Baltic (Table 29).

Cope Chest, Pyx Chamber

A total of 17 sequences from 12 timbers was obtained from the cope chest. All were micro-bores except for one graticule measurement of a lid board by Fletcher. Three other lid boards were sampled, as was one bottom board, three posts, and four rails or bearers. The boards all had good ring counts, but the bearers and posts were much faster grown and were from boxed-heart timbers, three with complete sapwood. Three radii from **wa205** matched together with **wa206** with good enough visual matches to consider them to be from the same tree, and were combined to form the same-tree mean **wa2056**. This cross-matched with **wa207**, but unfortunately the resulting mean **wa20567**, with 79 rings, failed to date conclusively. However, four of the boards did match together to form the 192-year site master **WMNSTR21**. This dated, spanning the years AD 1169–1360, matching best with chronologies from the Baltic region (Table 30). Samples **wa208**, **wa209**, **wa210**, and **wa211** all had too few rings for reliable cross-matching.

INTERPRETATION AND DISCUSSION

Long Chest (Chest 1), Muniment Room

Of the eight timbers sampled, seven were successfully dated. Micro-bore samples through the front (**wa101**) and rear (**wa102**) panels had clear evidence of partial sapwood on the underside, giving heartwood/sapwood boundary dates of AD 1154 and AD 1160 respectively. Also, the rear left-hand lid board (**wa103**) and the front right style (**wa108**) both had heartwood/sapwood boundary dates of 1161, and as they were from the same parent tree as another unidentified style measured by Fletcher (**wa106**), an average heartwood/sapwood boundary date of AD 1161 could also be ascribed to this timber too. Therefore an average heartwood/sapwood boundary date of AD 1158 could be calculated, from which a felling date range of AD 1167–99 can be ascribed to the group. The other dated boards and planks had last measured heartwood rings ranging from AD 1146 to 1161, and are consistent with the period of felling.

This places this chest firmly in the latter part of the twelfth century, and as such is one of the earliest chests to be scientifically dated in Britain. It is the oldest chest in the Abbey,

and pre-dates the Henry III rebuilding by about half a century, and therefore is a relic of the old Norman Abbey. The successful dating of styles, front and back boards, and lid boards has shown that the chest is still complete in its components with no replacements noted. This, together with the quality of the decoration, makes it a piece of national importance.

This chest has previously been studied by Harvey, Lowther, and Fletcher over a period of 30 years, and various dates have been published. Lowther published a date of one lid board from this chest spanning the years AD 850–1138 (Schove and Lowther 1957), although Fletcher was not clear which board this was when writing to the Keeper of the Muniments in 1970. Significantly, however, one of the lid boards measured by Fletcher (**wa105b**) did span the years AD 850–1009, and another measurement taken from photographs during this research (**wa105a**) dated the rings AD 854–1161. This corresponded to the sequence produced by Fletcher, but the first few rings were not clear enough to measure from the photograph, whereas Fletcher was able to get back to the year AD 850 with a graticule. On the basis of the information to hand, it would appear that Lowther, using the measurements taken by Harvey, was able to successfully date one of the lid boards as early as the 1950s.

Fletcher further prepared the boards and measured more of them; in his latest summary he stated that five lids and styles were dated, and that the latest measured rings ranged from AD 1146–61 (Fletcher and Tapper 1984). Sample **wa104b** transcribed from the Fletcher punch cards finished at AD 1146, and three other of the Fletcher samples (**wa103b**, **wa105b**, and **wa108b**) corresponded precisely to the dates recorded in a more detailed unpublished summary from the Fletcher Archive dating from 1977. The outer punch cards for **wa105b** were not found, however, and this sequence thus extends from AD 850 to 1009 only. We can only conclude here that Fletcher had the dating of these timbers perfectly correct as early as the 1970s. In his unpublished summary from 1977, he proposed a date range of AD 1190 to 1200 as a likely date of construction. This is consistent with the empirical felling date range of AD 1167–99 given by the present analysis.

Large Chest (Chest 2), Muniment Room

Of the eight timbers sampled, all were successfully dated. Micro-bore samples were taken through the front left board, made up of two boards glued together (**wa111**) and rear (**wa112**). Neither had any evidence of heartwood/sapwood boundaries, but the first board did terminate at AD 1227, the latest measured ring in the whole group. The five boards which were included in the chronology **WMNSTR10** were clearly of German origin (Table 6), but, as none of these boards included a clear heartwood/sapwood boundary, only *termini post quem* dates can be offered, ranging from after AD 1198 to after AD 1212, based on an empirical sapwood range of 8–38 years.

Fortunately, the right rear lid board (**wa118**) had an area of timber previously prepared which extended up to the year AD 1200, with a further 30 rings counted beyond the area of previously-sanded end grain to a clear heartwood/sapwood boundary at the back of the board. This single board therefore produced a felling date range of AD 1239–71. This is based on the felling date range of 9–41 years for English timbers, as the

chronologies with which it is dated with suggests an English rather than a German provenance (Table 8). Two other timbers of English provenance were dated: **wa115** and **wa116** (Table 7). Although neither of these retained any evidence for sapwood, they nevertheless originated from the same parent tree, and gave a *terminus post quem* date of after AD 1221. Therefore, the Large Chest was found to have been constructed of some timbers imported from the region around Germany which included some of the front boards, lid boards, and styles, whilst some other lid boards were found to have an English origin. The felling date range of AD 1239–71 for one of these English lid boards is consistent with the *termini post quem* dates from the other English and German boards. It therefore appears that the two groups of boards are contemporary and that the chest is in its original configuration.

Lowther does not appear to have dated any of the boards from this chest, but Fletcher had analysed measurements from five boards, of which three have been recovered from the Fletcher punch cards. One of his samples, **wa118b**, from the right-hand rear lid board, had 74 rings and dated, with a last measured ring date of AD 1200. In his unpublished summary from 1977, he listed five sequences, including the 74-ring sample, but with no dates ascribed. However, in the 1984 published summary, he lists latest measured rings ranging from AD 1200 to 1203, so it is possible the AD 1200 date relates to sample **wa118b**. Given the uncertainty of missing punch cards, etc, it is not possible to either confirm or refute the dating on the other two sequences analysed. However, Fletcher's estimate for construction of after AD 1225 does not conflict with the AD 1239–71 range produced by the present analysis.

Deep Chest (Chest 3), Muniment Room

Here seven boards were sampled, with dates obtained for five of them. These were combined to form the site master **WMNSTR11**, which was found to be of German origin (Table 14). However, the sourcing of the boards appears to be somewhat diverse, given the lack of exceptional cross-matching between them, which would normally be expected with long sequences of imported material. Fortunately, four of the five dated boards retained evidence of sapwood, allowing for an average heartwood/sapwood boundary of AD 1266 to be determined. Two of these boards had 5 (**wa122**) and 30 (**wa127**) rings counted, but not measured, to the heartwood/sapwood transition. By applying the 8–38 sapwood range for German timber to the average heartwood/sapwood transition date of AD 1266, a felling date range of AD 1274–90 is produced for this chest. Given that both styles and lid boards were dated, this chest appears to be a complete and integral unit.

Previous work by Lowther shows a single sample with 207 rings dating, spanning the years AD 1054–1261. It is not known which board this relates to, but only one timber sequence from the chest had enough rings, and that is the right front style (**wa121**). There were two sequences for this, one from Fletcher's punch cards spanning the years AD 1031–1150, but might well be missing the later cards, and the other from a micro-bore of 211 rings which spanned the years AD 1055 to 1265. One cannot be certain, but it is quite possible that Lowther's sample is from this style, and that Fletcher was able to measure an additional 23 rings at the beginning of the sequence.

Fletcher showed in his unpublished 1977 summary that all four styles originated from the

same tree, with the latest sequence ending at AD 1265, and that a lid board sequence finished in AD 1241. In the 1984 summary, the last measured rings range from AD 1238 to 1265 (Fletcher and Tapper 1984). Without any further details of the individual dates derived by Fletcher for the various boards dated, one cannot be certain of how closely his dates correlated, but given the fact that the both his summaries give an AD 1265 date for the styles, exactly the same as that obtained from samples from the present investigations, it is suggested that his dates were most likely correct. Fletcher postulated a date range of AD 1285–95 for this collection of boards (Fletcher 1977 unpubl) and after AD 1290 (Fletcher and Tapper 1984), which is somewhat later than the AD 1274–90 range produced by this study.

Lesser Treaty Chest, Pyx Chamber

Of the seven boards sampled from this chest, only two dated. Both the timbers were styles, the rear left one (wa131) retaining a clear heartwood/sapwood boundary, dated to AD 1263. The front right style (wa137) matched the rear style very well, and probably originated from the same tree. The two samples were combined to form the site master WMNSTR12, which dated best with chronologies from the Baltic region. Therefore, by applying the 8–24 empirical sapwood range appropriate for this region, a date range of AD 1271–87 is given for this chest. None of the three boards comprising the lid could be dated, nor could one of Fletcher's from an unknown location, despite having between 80 and 210 rings.

Fletcher showed five graticule readings having been taken from the chest, with last ring dates ranging from AD 1220 and 1261 (Fletcher and Tapper 1984). Three of these readings have been recovered, and two of them are the ones which have dated. Although it is not known how many rings were in the AD 1261 sample in Fletcher's article, his transcribed punch-cards for the rear left style wa131b also finished in AD 1261, leading one to the conclusion that his dating of this timber was probably correct. He postulated a felling date range of AD 1285–1300 for this chest, which is slightly later than the AD 1271–87 range produced during the present analysis. However, this is probably due to his samples not having a heartwood/sapwood boundary, and his conservative estimate for the time required for seasoning.

Greater Treaty Chest, Pyx Chamber

Here eight out of nine boards were successfully dated. Two lid boards were combined to form the site master WMNSTR13. Two side boards, a style, and one of Fletcher's measurements from an unknown location (but probably a style) were all found to have originated from the same parent tree, and were combined with another style to form another site master, WMNSTR14. Both site masters matched well with Baltic chronologies, but matched each other with a $t = 4.9$. This uninspiring match between the two groups suggests that the timber was imported from different sources within the Baltic. One of the dated timbers, the rear left style (wa149) retained 4 rings of sapwood, and a heartwood/sapwood boundary of AD 1371. Applying the 8–24 empirical sapwood range, this produced a felling date range of AD 1379–95. The *termini post quem* dates, ranging from after AD 1349 to after AD 1373, are consistent with this felling date range, and it is clear that all of the dated timbers form a coeval group of boards.

Lowther did some initial analysis on this chest, although his conclusions do not appear to have been confirmed. His dating of the front left style **wa147** was published as spanning the years AD 1292–1480 (it actually dates to AD 1180–1362), and his dating of the front lid board **wa145** evidently spanned the years AD 1188–1363 (Schove and Lowther 1957). This second board had earlier been dated to AD 1244–1361 (Lowther 1951). Whilst it is just possible that his dating might relate to the actual date of AD 1113–1341, if it had been measured from the other end of the board, thereby encountering grain drift, the variation in the number of rings is worrying.

Fletcher managed to get a much better result from his analysis of this chest, however. His results on the analysis of the four lid boards and four styles were published in detail, including the number of rings and the dates they spanned. Unfortunately, only two of his punch-card datasets were found: that for the front left style **wa147**, which spanned the years AD 1180–1362, compared to his published dates of AD 1156–1361, and the front right style **wa148**, which spanned the years AD 1146–1365, compared to his published dates of AD 1133–1360 (Fletcher 1976). These do not exactly coincide, but what is not known is whether the punch cards were older versions, or newer ones which had additional measured rings. Although it was not possible to conclusively confirm the dating of these sequences, they are certainly very close indeed, and the felling date range of AD 1390–1400 is not too far out from the AD 1379–95 date range produced from the present analysis.

Shelf or Canopy Boards, Pyx Chamber

Ring sequences from seven of the fifteen boards making up the canopy were analysed, and six boards were successfully dated. They were of exceptional length by modern-day standards, with some over 300 years in length. Three of the boards had evidence for heartwood/sapwood transition. It was possible to count the number of unmeasured heartwood rings to the sapwood boundary on samples **wa153** and **wa154**, giving heartwood/sapwood boundaries of AD 1154 and AD 1152 respectively. This produced felling date ranges of AD 1163–95 for **wa153**, and AD 1161–93 for **wa154**. Sample **wa155b** had 11 rings of sapwood surviving at one end of the board, with a heartwood/sapwood boundary of AD 1137, giving a felling date range of AD 1149–78. However, the other end of the board had no sapwood, with a last heartwood ring of AD 1140. Variation in the number of sapwood rings within a single tree is not unusual (Miles 1997), but it is quite likely that the AD 1149–78 range for sample **wa155b** is probably too early when applied to **wa155a**, and the mean **wa155**. Therefore, this timber was excluded from the calculation of a felling date range for the group of timbers as a whole, and only **wa153** and **wa154** were used. This gave an average heartwood/sapwood boundary date of AD 1153, from which a felling date range of AD 1162–94 is given for this group. A sapwood estimate of 9–41 years was used for this group as they were found to have originated from an English provenance (Table 19).

Fletcher had analysed two of the boards (**wa151a** and **wa156a**) during 1984, and arrived at last measured ring dates of AD 1411 and 1415 (Fletcher and Tapper 1984). The actual last measured ring dates of these sequences were AD 1104 and 1103 respectively. This mis-dating is probably due in part to a missing ring in one part of a sequence, and an extra

ring found in another part. It must be said that the rings in question were very narrow and indistinct due to the rough edge of the board. During the present analysis these were re-measured once the ends of the boards were re-sanded to allow the rings to be more clearly defined. This example illustrates the importance of thoroughly preparing the sample, and for using a high enough magnification when measuring the rings.

As to what the boards might have originally have been used for, there are a number of possibilities. As they are finished and decorated on only one side, they were unlikely to have been used as movable screens. However, they probably were part of some sort of partition. There is a watercolour dating from 1819 in the Abbey Library showing the southernmost end of the Undercroft Museum (bay 5) showing a timber boarded partition between bays 4 and 5. It is quite possible that other parts of the undercroft were subdivided in the Middle Ages, and bay 2, at least, seems to have been used as a chapel in the twelfth century, and has red-painted decoration on the wall arch on the east (Rodwell pers comm).

Hutch-Type Chest, Lapidarium

Most of the timber used to construct this chest was medium to very fast-grown, up to 10mm per annual growth ring, so only five samples were taken, using the micro-borer. Two samples from the lid boards were dated, one (**wa165**) with a heartwood/sapwood boundary at AD 1228. As this sample was of English provenance, a felling date range of AD 1237–69 was obtained. The second dated sample from the lid, **wa164**, also English, had a last measured ring of AD 1220, giving a *terminus post quem* date of after AD 1229. These timbers were of average mean ring width from trees not more than 100 to 150 years old when felled.

Conversely, the two rear styles **wa161** and **wa162** were very slow grown, with 239 and 308 rings respectively. The left style (**wa161**) had a last measured ring which appeared to be at the heartwood/sapwood boundary, whilst the right hand style (**wa162**) had a last measured ring, without any hint of sapwood, 22 year later. The two styles were found to have originated from the same parent tree, however. Although a variation of 10 or even 20 years in the heartwood/sapwood boundary date within one tree is not unusual, the early occurrence of sapwood in the left style (**wa161**) may represent a sapwood inclusion.

Given that only one of the dated boards retained any evidence of sapwood, the AD 1237–69 felling date range for sample **wa165** is therefore representative for the chest as a whole.

Large Panelled Chest, Lapidarium

Six samples were taken from this chest through the use of the micro-borer. The side panels were too thin, but the lid boards were substantial enough to be cored. All samples matched together, and the site master matched best with chronologies from the Baltic region. Two of the samples, **wa172** and **wa175**, had evidence of sapwood, with heartwood/sapwood boundary dates of AD 1395 and 1398 respectively. The second core finished at AD 1396, but by following the grain drift along the edge of the board, another two rings were counted to reach the heartwood/sapwood transition at AD 1398.

These two heartwood/sapwood boundary dates were combined to give an average of AD 1397, from which a felling date range of AD 1405–21 was produced.

One other board, **wa176**, had no heartwood/sapwood transition, but finished at AD 1402. As it is not known how many more rings were lost to the heartwood/sapwood boundary, and consequently to the bark edge, all that can be said is that the felling date range of AD 1405–21 is possibly slightly too early. Nevertheless, there is no evidence to suggest that the lid is not coeval with the lower part of the chest, even though the dates are a century earlier than that postulated on stylistic grounds.

Panels from Demolished Partition from Muniment Room, now in Lapidarium

Five samples were obtained from boards making up the section of partition panelling. All five dated, and two of these retained some sapwood. Sample **wa181** had a heartwood/sapwood boundary date of AD 1342, whilst sample **wa182** had a heartwood/sapwood boundary date of AD 1338. One other sample, **wa183**, had no evidence of sapwood but had a last measured heartwood ring date of AD 1341. By taking the average of these three at AD 1340, a felling date range appropriate for the Baltic provenance of the timbers is calculated at AD 1348–64.

This has interesting implications on the Richard II partition in the Muniment Room, against which this panel was presumed to have been built. If this was the case, then the partition, and this panel, would have predated the reign of Richard II (AD 1377–99) by at least a decade or two.

Richard II Cupboard or Armoire, Muniment Room

Five boards were measured from this cupboard, of which four dated. One of the dated samples (**wa194**) had a heartwood/sapwood boundary of AD 1369. As the samples and resulting site master matched best with Baltic chronologies, a sapwood estimate of 8–24 was used to produce a felling date range of AD 1377–93. This is consistent with the *termini post quem* dates of after AD 1350, after AD 1372, and after AD 1373 for the other three dated samples. This places this exquisite piece of furniture in the early part of Richard II's reign.

Fletcher undertook the analysis of five boards: four doors and one shelf. Unfortunately, none of the original punch cards containing his graticule measurements were found. However, in an unpublished 1977summary of his work in the Abbey, he gives the dates for the shelf as spanning AD 1151–1366. Photographs of this shelf (**wa192**) produced a sequence spanning the years AD 1151–1330, plus about 35 rings not measured, making this coincide perfectly with the dates arrived at by Fletcher. He also gives a mean of four doors as spanning the years AD 1181–1364. Although only one of his door panels was measured (**wa194**), it spanned the years AD 1185–1364, most probably relating to one of his door panels. He estimated a felling period of AD 1390–1400, which is again somewhat conservative, given that none of his samples retained any sapwood.

Cope Chest, Pyx Chamber

Of the twelve timbers sampled, only four boards matched together to form a group. None of these retained any hint of a heartwood/sapwood boundary, so only *termini post quem* dates could be given. As the boards were of Baltic origin, the minimum number of sapwood rings is added to the last measured ring date. The three lid boards gave *termini post quem* dates of after AD 1356, after AD 1361, and after AD 1368, while a board from the bottom of the chest gave a *terminus post quem* date of after AD 1361. Given the close clustering of dates, and previous evidence from studies of Baltic material, it is likely that a minimum number of heartwood rings was removed with the sapwood, and therefore a felling date range of between *c* AD 1375 and 1400 is offered for this chest.

One of the lid boards, **wa201**, had been measured *in situ* by Fletcher, and the ring width measurements were found. Fletcher never reported a date for this board, and the present analysis also failed to date his sequence.

It is evident from the carpentry of the chest that the lid boards had been replaced when the cope chest was reduced in size. However, the bottom boards clearly relate to the original design of the chest. Yet the closeness of last measured ring dates from the top and bottom boards suggest that they are of a broadly similar date, as well as from a similar source. As there is no obvious signs of reuse for the lid boards, it is postulated that the cutting down of the cope chest took place soon after it was constructed.

A number of structural members making up the base of the chest were sampled, and three retained complete sapwood. However, none of these dated, due primarily to there being too few rings. It had been hoped that they might have matched some other contemporary timbers within the Abbey, but nothing conclusive was found.

CONCLUSIONS

The programme of dendrochronology has successfully dated eight chests, one cupboard or armoire, and two sets of boards or panels. Thirteen new chronologies were produced, many of them over 200 years in length. Four are of English origin, three of German provenance, and six originating from the Baltic. The sources of the timbers used seem to correlate very well with chronological period, with those timbers felled in the twelfth century and very early thirteenth century originating from England, those during the majority of the thirteenth century originating from the German region, and those from the fourteenth century originating further east in the Baltic area (Fig 47). These periods of regional imports are consistent with those noted by other researchers (Tyers 2003; Tyers and Tyers 2007).

The two oldest objects dated were the reused boards forming the Shelf or Canopy in the Pyx Chamber, which produced a felling date range of AD 1162–94, and the Long Chest in the Muniment Room, which produced a felling date range of AD 1167–99. This makes both objects Norman in period and of exceptional interest. The twelfth century date of

the Pyx Canopy is some three centuries older than previously thought, and the decorative painting scheme deserves more study. One feature found in both sets of boards is the shape of the V-groove jointing. With the sole exception of these two sets of boards, the groove is cut to a sharp point to accommodate the V-shaped tongue. Here, the gullet of the groove is rounded with a ¼in (5mm) radius (Fig 17).

Four chests were found to date from the thirteenth century. This included the hutch-type chest in the Lapidarium (AD 1237–69), the Large Chest in the Muniment Room (AD 1239–71), the Lesser Treaty Chest in the Pyx Chamber (AD 1271–87), and the Deep Chest in the Muniment Room (AD 1274–90). The earlier two of these, as well as the twelfth-century Long Chest, have the interesting feature of the side boards being hollowed out so as to be a constant thickness, with a thick L-shaped bottom which is grooved to take the bottom panels.

It is interesting to note that the Large Chest (AD 1239–71) and the Westminster Retable (AD 1232–70) (Tyers 2002a) both dated to the reign of Henry III, and both employed a combination of local English and imported German boards in their construction. The Hutch-Type Chest in Lapidarium (AD 1237–69) also dated from this period, and possible matches with German chronologies suggest that the slower-grown timbers were also probably imported. This would suggest a period of transition between local and foreign imports during the reign of Henry III (1216–72). Clearly these chests were not imported, but some of the raw materials were. By the time of Edward I (AD 1272–1306), imports had become more commonplace, as demonstrated by the Lesser Treaty Chest in the Pyx Chamber (AD 1271–87) and the Deep Chest in the Muniment Room (AD 1274–90), both of which were constructed entirely of imported German timber. However, these were most likely constructed here as they are very plain, utilitarian, and comparable with other English chests. Hence, a very strong case would need to be argued for importing such objects in their finished form (Rodwell pers comm).

With the exception of the Large Chest, the other four earliest chests have wooden pivot hinges made by cutting a slot in the rear styles to allow the extended cleat to pivot. Other similarities can be found between the Lesser Treaty and Deep chests, both of which have a side clamp which is hinged with a wooden pivot and has similar chamfers with bar stops.

The next three chests dated are from the fourteenth century or early fifteenth century and include the Cope Chest (c AD 1375–1400), and the Greater Treaty Chest (AD 1379–95), both in the Pyx Chamber, and the Panelled Chest in the Lapidarium (AD 1405–21). Also dated to this period are the Richard II Cupboard in the Muniment Room (AD 1377–93) and the partition panel in the Lapidarium (AD 1348–64), which suggests that the earlier partition in the Muniment Room, assumed to date from the reign of Richard II, is actually much older than previously thought. All of these items were constructed of oak imported from the Baltic. Other features found in common with all of the chests is that boards often are not cut parallel, but can be noticeably tapered.

The early work of A W G Lowther was reviewed, and it is clear that he had some success with the measurements taken in 1948 by J H Harvey. One of the boards from the Long Chest seems to correlate precisely with the dates arrived at independently during this research project, and one from the Deep Chest and another from the Greater Treaty Chest might have been correctly dated, but, without the original dataset, this cannot be

confirmed. That any of these might have been correctly dated is, quite frankly, astounding, given the total lack of chronologies in England at the time. It must be acknowledged that Lowther was the real pioneer of dendrochronology in this country, even though he used other methods of comparisons, such as major trends in ring widths, outstanding maxima and minima in tree-ring plots, varves, and cycle analysis. However, he did use statistical analysis as well to compare tree-ring sequences, and it is possible that early collaboration with Huber in Germany may have assisted in dating some of the chest material which, as the present analysis has shown, originated from the region around Germany and the Baltic. Therefore it is concluded that whilst some of the samples studied by Lowther have not proved to be correctly dated, nevertheless, the positive results he achieved are of immense importance in the development of dendrochronology in this country.

The work of Dr John Fletcher was also assessed. He had worked on all of the chests, cupboards, and panels from both the Pyx Chamber and the Muniment Room, a total of eight objects. Dates had been published for seven of these, and the present analysis has confirmed absolutely the dates he derived for the Long Chest and the Richard II Cupboard, whilst it is likely that his dates for the Large Chest, the Deep Chest, and the Lesser and Greater Treaty Chests are probably correct, but without more of his data it is not possible to be certain. Only one object was found to be incorrectly dated, and that is the Shelf or Canopy in the Pyx Chamber, which due to a number of measuring errors associated with exceptionally narrow rings caused a date some three centuries later to be proposed. Overall, the successful dating of the Westminster material by Fletcher is significant, given that at the time he did not realise that some of the material originated from Germany and the Baltic.

The study here has shown that those samples taken from physical samples such as those produced by the micro-borer gave the best results, whilst those taken from photographs proved difficult for a number of reasons. Sometimes the rings were not clear enough, but additional surface preparation would have been damaging to the appearance of the timber. At other times the rings were so narrow, or indistinct, that accurate measurements were not possible. Some photographic sequences did date satisfactorily, however. The study of the chests and fittings at Westminster was successful in that the research questions were answered with little or no intervention into the fabric of the objects themselves.

REFERENCES

Becker, B, 1981 Fällungsdaten Römischer Bauhölzer, *Fundberichte aus Baden-Wurtemberg*, **6**, 369–86

Bonde, N, and Jensen, J S 1995 The dating of a Hanseatic cog-find in Denmark, in *Shipshape, Essays for Ole Crumlin-Pedersen* (O Olsen, J S Madsen and F Rieck), Vikingeskibshallen i Roskilde, 103–22

Bridge, M C, 1983 *The use of tree-ring widths as a means of dating timbers from historical sites*, unpubl PhD thesis, CNAA

Bridge, M C, 1988 The dendrochronological dating of buildings in southern England, *Medieval Archaeol*, **32**, 166–74

Bridge, M C, 1996 List 69 – Tree-ring dates, *Vernacular Architect*, **27**, 91–2

Cox, J C, and Harvey, A, 1907 *English Church Furniture*, London, 317

Delorme, A, 1978 A mean curve for the oaks of the southern Weser and Leine uplands: its usefulness and characteristics, in *Dendrochronology in Europe* (ed J M Fletcher), BAR **51**

Eames, P, 1977 *Furniture in England, France and the Netherlands from the Twelfth to the Fifteenth Century,* London, Furniture Hist Soc

Fletcher, J, 1976 Oak antiques: tree-ring analysis, *Antique Collecting and Antique Finder*, Oct 1976, 9–13

Fletcher, J M, and Tapper, M C, 1984 Medieval artefacts and structures dated by dendrochronology, *Medieval Archaeol*, **28**, 112–32

Geddes, J, 1999 *Medieval Decorative Ironwork in England*, Soc Antiq London Res Rep **59**

Groves, C, 1992 *Dendrochronological analysis of timbers from New Baxtergate, Grimsby, Humberside, 1986,* Anc Mon Lab Rep, **8/1992**

Groves, C, 2002 *Dendrochronological analysis of Bowhill, Exeter, Devon*, Centre for Archaeol Rep, **23/2002**

Groves, C, and Hillam, J, 1987 *Tree-date analysis of timbers from Swan Lane, City of London*, Anc Mon Lab Rep, **30/87**

Groves, C, Locatelli, C, and Bridge, M, 2005 *Tree-ring analysis of oak timbers from Wymondleybury, Little Wymondley, Hertfordshire*, Centre for Archaeol Rep, **14/2005**

Hewett, C A, 1988 English medieval cope chests, *J Brit Archaeol Assoc*, **141**, 105–23

Hillam, J, 1991 *Tree-ring analysis of native and Baltic timbers from Blaydes Staithe, Hull, Humberside*, Anc Mon Lab Rep, **108/91**

Hillam, J, 1994 Compilation of chronologies from the Bristol area, unpubl computer file BRISTOL, Sheffield Dendrochronology Laboratory

Hillam, J, and Groves, C, 1993 *Tree-ring analysis of oak timbers from the south range roof of the Blackfriars Priory, Gloucester, Gloucestershire*, Anc Mon Rep, **26/93**

Hillam, J, and Groves, C, 1994 Compilation of master chronologies from the North, unpubl computer file NORTH, Sheffield Dendrochronology Laboratory

Hillam, J, and Tyers, I, 1995 Reliability and repeatability in dendrochronological analysis: tests using the Fletcher archive of panel-painting data, *Archaeometry*, **37(2),** 395–405

Hillam, J, Morgan, R A, and Tyers, I, 1987 Sapwood estimates and the dating of short ring sequences, in *Applications of tree-ring studies: current research in dendrochronology and related areas* (ed R G W Ward), BAR Int Ser, **333**, 165–85

Hollstein, E, 1980 *Eine Mitteleuropäische Eichenchronologie*, Mainz am Rhein

Howard, R E, Laxton, R R, and Litton, C D, 1997 *Tree-ring analysis of timbers from Westwick Cottage, Westwick Row, Leverstock green, Hemel Hempstead, Hertfordshire*, Anc Mon Lab Rep, **77/1997**

Howard, R E, Laxton, R R, and Litton, C D, 2001 *Tree-Ring Analysis of Timbers from Dover Castle Keep, Dover, Kent*, Centre for Archaeol Rep, **44/2001**

Howard, R E, Laxton, R R, and Litton, C D, 2002 *Tree-Ring Analysis of Timbers from the Presbytery Roof, Abbey Church of St Alban's, St Albans, Hertfordshire (Part III)*, Centre for Archaeol Rep, **53/2002**

Huber, B, and Giertz-Siebenlist, V, 1978 Our 1000-year oak annual ring chronology, in *Dendrochronology in Europe* (ed J M Fletcher), BAR Int Ser, **51**

Leggett, P A, Hibbert, F A, Hughes, M K, Fletcher, J M, and Morgan, R, 1982 Tree-ring dates for buildings with oak timber, *Vernacular Architect*, **13**, 48

Lethaby, W R, 1906 *Westminster Abbey & the Kings' Craftsmen – A Study of Mediaeval Building*, London (Duckworth)

Lowther, A W G, 1951 The date of timbers from the spire of Chilcomb church and from the wreck in the river Hamble: some evidence from dendrochronology, *Proc Hants Field Club Archaeol Soc*, **XVII** (ii), 129–33

Miles, D H, 1995 Working compilation of 71 reference chronologies centred around Shropshire by various researchers, unpubl computer file SALOP95, Oxford Dendrochronology Laboratory

Miles, D H, 1997a The interpretation, presentation, and use of tree-ring dates, *Vernacular Architect*, **28**, 40–56

Miles, D H, 1997b Working compilation of 58 reference chronologies centred around Wales by various researchers, unpublished computer file WALES97, Oxford Dendrochronology Laboratory

Miles, D, 2003 Dating buildings and dendrochronology in Hampshire, in *Hampshire Houses 1250– 1700: Their Dating and Development* (ed E Roberts), 220–6, Southampton (Hampshire County Council)

Miles, D H, 2004 Working compilation of reference chronologies centred around Somerset by various researchers, unpubl computer file SOMRST04, Oxford Dendrochronology Laboratory

Miles, D W H, 2005 *New developments in the interpretation of dendrochronology as applied to oak building timbers*, unpubl DPhil thesis, Hertford College, Oxford Univ

Miles, D H, 2006 Refinements in the interpretation of tree-ring dates for oak building timbers in England and Wales, *Vernacular Architect*, **37**, 84–96

Miles, D, 2007 *The tree-ring dating of the White Tower, H M Tower of London (TOL99 & TOL100)*, EH Res Dept Rep Ser, **35/2007**

Miles, D H, and Haddon-Reece, D, 1995 List 64 – Tree-ring dates, *Vernacular Architect*, **26**, 60–74

Miles, D, and Bridge, M, 2005 *The tree-ring dating of the early medieval doors at Westminster Abbey, London,* Centre for Archaeol Rep, **38/2005**

Miles, D H, and Worthington, M J, 2000 Tree-ring dates, *Vernacular Architect*, **31**, 90–113

Miles, D H, and Worthington, M J, 2001 Tree-ring dates, *Vernacular Architect*, **32**, 74–86

Miles, D, and Worthington, M, 2006 *The tree-ring dating of the bell tower and cloister door, New College, Oxford*, Engl Heritage Res Dep Rep Ser, **56/2006**

Miles, D H, Worthington, M J, and Bridge, M C, 2004 Tree-ring dates, *Vernacular Architect*, **35**, 95–113

Nayling, N, 1991 *Dendrochronology report on timbers from Thames Exchange, City of London*, MoL EAS Dendro Rep, **07/91**

Rigold, S, 1976 *The Chapter House and the Pyx Chamber, Westminster Abbey*, (DoE/HMSO)

Rodwell, W, 2002 *Chapter House and Pyx Chamber, Westminster Abbey* (Engl Heritage)

Royal Commission on Historical Monuments (England), 1924 *An Inventory of the Historical Monuments in London – Vol I: Westminster Abbey*, London (HMSO)

Scott, G G, 1861 *Gleanings from Westminster Abbey: with appendices supplying further particulars, and completing the history of the Abbey buildings*, Oxford and London (J H and Jas Parker)

Schove, D J, and Lowther, A W G, 1957 Tree-rings and medieval archaeology, *Medieval Archaeol*, **1**, 78–95

Tyers, I, 1988a *Dendrochronological spot dates: Merton Priory coffins*, MoL EAS Dendro Rep, **SPT17/88**

Tyers, I, 1988b Appendix 1 – dendrochronological analysis of the spire, in *The Tower and Rhenish Helm Spire of St Mary's Church, Sompting* (eds F G Aldsworth and R Harris), *Sussex Archaeol Collect*, **126**, 140–2

Tyers, I, 1990 List 37 – Tree-ring dates, *Vernacular Architect*, **21**, 45–6

Tyers, I, 1991 *Interim dendrochronology report on timbers from the Horsefair site, Kingston*, MoL

EAS Dendro Rep, **06/91**

Tyers, I, 1994 *Dendrochronological spot date report: Abbots Lane – door and barrel (ABB87)*, MoLAS Dendro Rep, **06/94**

Tyers, I, 1995 *Tree-ring analysis of timbers from an archaeological evaluation at Turk's Boatyard, Kingston (TUR95)*, MoLAS Dendro Rep, **08/95**

Tyers, I, 1996 Appendix 1. Dendrochronology of shipping from London, twelfth to seventeenth centuries in *Shipping and the Port of London: twelfth to seventeenth centuries* (P Marsden), Engl Heritage Archaeol Rep, **5**, 193–7

Tyers, I, 1998 *Tree-ring analysis and wood identification of timbers excavated on the Magistrates Court Site, Kingston upon Hull, East Yorkshire*, ARCUS Rep, **410**

Tyers, I, 1999 *Dendrochronological spot-dates of timbers from the Millennium Foot Bridge sites (MBC98) and (MFB98) London*, ARCUS Rep, **521**

Tyers, I, 2000 *Tree-ring analysis of re-used boat timbers excavated at Chapel Lane Staith, Hull*, ARCUS Rep, **570**

Tyers, I, 2001a *Tree-ring analysis of coffin timbers excavated at the Church of St Peter, Barton on Humber, North Lincolnshire*, Centre for Archaeol Rep, **48/2001**

Tyers, I, 2001b Appendix 2 Tree-ring analysis of the Roman and medieval timbers from medieval London Bridge and its environs in *London Bridge: 2000 years of a river crossing* (B Watson, T Brigham, and T Dyson), MoLAS Monograph Series, **8**, 180–90

Tyers, I, 2002a *Tree-ring Analysis of the Westminster Retable*, ARCUS Report, **499**

Tyers, I, 2002b *Tree-ring analysis of the Thornham Parva Retable*, ARCUS Rep, **499b**

Tyers, I, 2003 The eastern Baltic timber trade in *The Thornham Parva Retable* (A Massing), Cambridge (Hamilton Kerr Inst)

Tyers, I, 2004 *Dendro for Windows Program Guide 3rd edn*, ARCUS Report, **500b**

Tyers, I, and Boswijk, G, 1997 *Dendrochronological spot dates for 30 timbers from Bull Wharf (BUF90 & UPT90), City of London and Belvedere Road (BVD97),Waterloo*, ARCUS Rep, **335**

Tyers, I, and Boswijk, G, 1998 *Tree-ring analysis of oak timbers from Dore Abbey, Abbey Dore, Herefordshire*, Anc Mon Lab Rep, **18/98**

Tyers, I, and Hibberd, H, 1993 *Dendrochronology, wood identification, and wattle analysis for the Fleet Valley developers report*, MoLAS Dendro Rep, **03/93**

Tyers, C, and Tyers, I, 2007 *Peterborough Cathedral, City of Peterborough, Cambridgeshire: scientific dating report – tree-ring analysis of the nave ceiling*, EH Res Dept Rep Ser, **4/2007**

TABLES

Table 1: *Summary of tree-ring dating, Westminster Abbey chests and fittings*

Sample number	type	Timber and position	Dates AD spanning	H/S bdry	Sapwood complement	No of rings	Mean width (mm)	Std devn (mm)	Mean sens (mm)	Felling date ranges (AD)
The Long Chest (Chest 1) in Muniment Room										
wa101a1	mc	Left front board	911–1005			95	1.95	0.96	0.237	
wa101a2	mc	ditto	1122–1155	1154	1	34	0.86	0.15	0.157	
wa101b	mc	ditto	952–1155	1154	1	204	1.54	0.60	0.200	
* wa101		Mean of wa101a1, wa101a2, + wa101b	911–1155	1154	1	245	1.68	0.80	0.201	1163–95
* wa102	mc	Right rear board	987–1160	1160	H/S	174	2.08	0.81	0.203	1169–1201
wa103a	p	Left rear lid board	966–1159			194	1.59	0.48	0.196	
wa103b	g	J M Fletcher board 4E	966–1161	1161	H/S	196	1.59	0.45	0.201	
wa103		Same-timber mean of **wa103a** + **wa103b**	966–1161	1161	H/S	196	1.59	0.45	0.194	(1170–1202)
wa104a1	p	Left front lid board	1009–1044			36	1.58	0.39	0.185	
wa104a2	p	ditto	1055–1148			94	1.70	0.49	0.208	
wa104b	g	J M Fletcher lid board 3 start 1	993–1146			154	1.80	0.51	0.207	
* wa104		Same-timber mean of **wa104a1, a2, + b**	993–1148			156	1.49	0.50	0.203	After 1157
wa105a	p	Right front lid board	854–1161			308	1.49	0.67	0.255	
wa105b	g	J M Fletcher board 1	850–1009			160	1.50	0.54	0.232	
* wa105		Same-timber mean of **wa105a** + **wa105b**	850–1161			312	1.41	0.57	0.240	After 1170
wa106	g	J M Fletcher styles I/III	976–1115	(1161)		140	1.96	0.43	0.159	(1170–1202)
wa107	p	Left front style	–			92	1.64	1.53	0.209	
wa108a	p	Right front style	996–1160			165	2.11	0.71	0.200	
wa108b	g	J M Fletcher styles I/III	996–1161	1161	H/S	166	2.11	0.69	0.166	
wa108		Same-timber mean of **wa108a** + **wa108b**	996–1161	1161	H/S	166	2.11	0.69	0.179	1170–1202
* wa10368		Same-tree mean of **wa103, wa106, + wa108**	966–1161	1161	H/S	196	1.81	0.47	0.158	1170–1202
* = WMNSTR9 Site Master (English)			850–1161	1158	Avg H/S	312	1.71	0.56	0.182	1167–99

Key: *, †, = sample included in site-masters; type of sample: c = core, g = graticule, mc = micro-core; ½C, C = bark edge present, partial or complete ring: ½C = summer/autumn (ring not measured), or C = winter felling (ring measured); H/S bdry = heartwood/sapwood boundary - last heartwood ring date; std devn = standard deviation; mean sens = mean sensitivity. Sapwood estimate (95% confidence) of 8–24 for Baltic oak boards (Tyers 1998), 8–38 for German oak boards (Hillam *et al* 1987), and 9–41 used for English boards timbers (Miles 1997a). Given the lack of any heartwood/sapwood boundaries, a *terminus post quem* date has been given for each board by adding the minimum number of sapwood rings to the last measured ring date, as adjusted by adding any unmeasured core segments beyond (+NM). Felling date ranges in brackets denote those ascribed from other samples with heartwood/sapwood boundaries from the same parent tree.

Sample number	type	Timber and position	Dates AD spanning	H/S bdry	Sapwood complement	No of rings	Mean width (mm)	Std devn (mm)	Mean sens (mm)	Felling date ranges (AD)
The Large Chest (Chest 2) in Muniment Room										
* wal11	mc	Top left front board	980–1227			248	1.28	0.45	0.224	After 1235
* wal12	mc	Bottom left front board	1000–1190			191	1.33	0.31	0.166	After 1198
* wal13	p	Left front style	959–1211			253	1.87	0.35	0.168	After 1219
wal14a1	p	Right lid, 2nd board from rear	1019–1099			81	1.59	0.32	0.170	
wal14a2	p	ditto	1105–1201			97	1.72	0.34	0.178	
wal14b	g	J M Fletcher board 7	983–1142			160	1.44	0.28	0.170	
wal14		Same-timber mean of **wal14a1**, **a2**, + **b**	983–1201			219	1.55	0.32	0.164	(After 1212)
wal15a	p	Left lid, rear board (English)	1084–1212			129	1.51	0.44	0.156	
wal15b	g	J M Fletcher board 4	1029–1212			184	1.70	0.38	0.158	
wal15		Same-timber mean of **wal15a** + **wal15b**	1029–1212			184	1.66	0.39	0.152	After 1221
wal16	p	Left lid, 2nd board from rear (English)	998–1193			196	1.42	0.36	0.156	(After 1221)
wal17	p	Left lid, front board	960–1204			245	1.41	0.25	0.163	After 1212
wal18a	p	Right lid, rear board (English)	1127–1200			74+30NM[1]	2.86	1.02	0.224	
wal18b	g	J M Fletcher E board 8	1127–1200			74+30NM[1]	3.15	1.13	0.219	
wal18		Same-timber mean of **wal18a** + **wal18b**	1127–1200	(1230)	74		3.01	1.06	0.215	1239–71
* wal147		Same-tree mean of **wal14** + **wal17**	960–1204			245	1.48	0.27	0.162	After 1212
wal156		Same-tree mean of **wal15** + **wal16** (English)	998–1212			215	1.54	0.33	0.145	After 1221
❋ = WMNSTR10 Site Master (German)			959–1227			269	1.49	0.32	0.147	1239–71

[1] To H/S boundary

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	Sample number	type	Timber and position	Dates AD spanning	H/S bdry	Sapwood complement	No of rings	Mean width (mm)	Std devn (mm)	Mean sens (mm)	Felling date ranges (AD)
	The Deep Chest (Chest 3) in Muniment Room										
	wal21a	mc	Right front style	1055–1265	1265	H/S	211	1.12	0.45	0.158	
	wal21b	g	J M Fletcher Chest 3 style 2/2	1031–1150			120	1.65	0.32	0.161	
*	wal21		Same-timber mean of **wal21a** + **wal21b**	1031–1265	1265	H/S	235	1.24	0.39	0.149	1273–89
*	wal22	p	Rear lid board	1046–1261	(1266)		216+*c* 5NM[1]	1.28	0.36	0.178	*c* 1274–90
	wal23	p	Rear left style	–			119+*c* 25NM[1]	1.84	0.44	0.192	
	wal24a	p	Front left style	1119–1264	1264	H/S	146	1.52	0.57	0.272	
	wal24b1	g	J M Fletcher Chest 3 board C	1120–1197			78	1.49	0.72	0.326	
	wal24b2	g	ditto	1186–1254			69	1.30	0.39	0.240	
*	wal24		Same-timber mean of **wal24a**, **b1**, + **b2**	1119–1264	1264	H/S	146	1.58	0.61	0.272	1272–88
*	wal25	p	Lid board, 2nd from rear	1113–1236			124	1.15	0.37	0.182	After 1244
	wal26a1	p	Front lid board	–			39	1.35	0.46	0.341	
	wal26a2	p	ditto	–		H/S	93	1.28	0.37	0.271	
	wal26b	g	J M Fletcher Chest 3 board A	–			114	1.70	0.54	0.285	
	wal26		Same-timber mean of **wal26a1**, **a2**, + **b**	–		H/S	135	1.47	0.46	0.280	
*	wal27	g	Rear right style (J M Fletcher Chest 3, 2/1)	1087–1239	(1269)		153 +*c* 30NM	1.88	0.47	0.186	*c* 1277–93
	* = WMNSTR11 Site Master (German)			1031–1265	1266	Avg H/S	235	1.44	0.30	0.133	1274–90

[1] To H/S boundary

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Sample number	type	Timber and position	Dates AD spanning	H/S bdry	Sapwood complement	No of rings	Mean width (mm)	Std devn (mm)	Mean sens (mm)	Felling date ranges (AD)
Lesser Treaty Chest in Pyx Chamber										
wal31a	mc	Rear left style	1121–1263	1263	H/S	143	2.56	0.81	0.230	
wal31b	g	ditto (J M Fletcher PYX 15)	1072–1261			190	2.25	0.58	0.190	
* wal31		Same-timber mean of **wal31a + wal31b**	1072–1263	1263	H/S	192	2.41	0.63	0.200	1271–87
wal32	mc	Top left side board	–		H/S	95	2.73	0.57	0.124	
wal33	p	Front lid board	–			173	2.37	0.90	0.191	
wal34	p	Middle lid board	–			170	1.85	0.71	0.177	
wal35	p	Rear lid board	–			210	2.00	0.59	0.216	
wal36	g	J M Fletcher PYX 20 II unknown location	–			80	1.83	0.57	0.216	
* wal37	g	Front right style (J M Fletcher PYX 16)	1040–1257	(1263)		218	1.97	0.59	0.245	(1271–87)
wal334		Same–tree mean of **wal33 + wal34**	–			175	2.24	0.84	0.169	
* = WMNSTR12 Site Master (Baltic)			1040–1263	1263	H/S	224	2.16	0.55	0.210	1271–87
Greater Treaty Chest in Pyx Chamber										
wal41	mc	Top left side board	1148–1356			209	1.03	0.28	0.190	(1379–95)
wal42a1	mc	Middle left side board	1139–1301			163	1.04	0.32	0.201	
wal42a2	mc	ditto	1304–1368			65	1.07	0.26	0.144	(1379–95)
wal42b	g	J M Fletcher PYX W27	1137–1369			233	1.22	0.26	0.167	
wal42		Mean of wal42a1, 142a2, + 142b	1137–1369			233	1.14	0.26	0.162	
wal43	p	Rear right style	–		2	65	1.40	0.25	0.159	
* wal44	p	2nd lid board from back	1184–1346			163	1.57	0.43	0.182	After 1354
* wal45	p	Front lid board	1113–1341			229	1.00	0.35	0.180	After 1349
wal46	g	J M Fletcher PYX W27 unknown location	1137–1369			233	1.22	0.26	0.167	(1379–95)
† wal47	g	Front left style (J M Fletcher PYX W24)	1180–1362			183	1.22	0.33	0.178	After 1370
wal48	g	Front right style (J M Fletcher PYX 22 II/I)	1146–1365			220	1.29	0.33	0.180	After 1373
wal49	mc	Rear left style	1157–1375	1371	4	219	1.03	0.24	0.158	1379–95
† wal41269		Same-tree mean of **wal41, 142a1, 142a2, 146, + 149**	1137–1375	1371	4	239	1.12	0.25	0.156	1379–95
* = WMNSTR13 Site Master (Baltic)			+			234	1.31	0.33	0.174	After 1354
† = WMNSTR14 Site Master (Baltic)			1137–1375	1371	4	239	1.17	0.23	0.152	1379–95

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Sample number	type	Timber and position	Dates AD spanning	H/S bdry	Sapwood complement	No of rings	Mean width (mm)	Std devn (mm)	Mean sens (mm)	Felling date ranges (AD)
Shelf or Canopy Boards in Pyx Chamber										
wa151a	g	Board 14 (I) – JMF	1007–1104			98	1.76	0.73	0.182	
wa151b	g	ditto	1007–1143			137	1.55	0.67	0.188	
† wa151		Same-timber mean of **wa151a** + **wa151b**	1007–1143			137	1.56	0.68	0.185	(1161–93)
wa152	g	Board 12 (II–III)	–			93	2.23	1.29	0.217	
∗ wa153	g	Board 11 (III–IIII)	862–1115	(1154)		254+39 NM[1]	0.98	0.29	0.176	1163–95
† wa154	g	Board 10 (IIII–V)	1029–1132	(1152)		104+20 NM[1]	1.75	0.58	0.181	1161–93
wa155a	g	Board 8 (VI–VII)	846–1140			295	0.89	0.29	0.200	After 1149
wa155b	g	ditto	1056–1148	1137	11	93	0.95	0.30	0.186	1149–78
∗ wa155		Same-timber mean of **wa155a** + **wa155b**	846–1148			303	0.89	0.30	0.195	
wa156a1	g	Board 6 (VIII–VIIII) – JMF (corrected)	864–1002			139	0.75	0.27	0.182	
wa156a2	g	ditto – JMF (corrected)	1003–1103			101	0.96	0.40	0.189	
wa156a	g	Same-timber mean of **wa156a1** + **wa156a2**	864–1103			240	0.84	0.34	0.185	
wa156b	g	ditto	827–1132			306	0.88	0.35	0.206	
∗ wa156		Same-timber mean of **wa156a** + **wa156b**	827–1132			306	0.88	0.34	0.192	After 1141
wa157	g	Board 2 (XII–XIII) (English)	970–1090			121	2.28	0.63	0.212	After 1099
∗ = WMNSTR15 Site Master (English)			827–1148	(1148)		322	0.93	0.28	0.153	
† = WMNSTR16 Site Master (English)			1007–1143			137	1.66	0.55	0.173	
Hutch–Type Chest in Lapidarium										
wa161	mc	Rear LH style	–		H/S?[2]	239	1.00	0.19	0.168	
wa162	mc	Rear RH style	–			308	1.01	0.27	0.164	
wa1612		mean of **wa161** + **wa162**	–			308	1.02	0.26	0.157	
wa163	mc	Front board, front lid	–		H/S	96	2.40	0.81	0.196	
∗ wa164	mc	2nd board from front, front lid	1124–1220			97	1.93	0.75	0.184	After 1229
∗ wa165	mc	Rear board, rear lid	1140–1228	1228	H/S	89	2.46	0.74	0.221	1237–69
∗ = WMNSTR17 Site Master (English)			1124–1228	1228		105	2.28	0.68	0.186	1237–69

[1] To H/S boundary

[2] Possibly a sapwood inclusion

Key: ∗, †, = sample included in site–masters; type of sample: c = core, g = graticule, mc = micro–core; ½C, C = bark edge present, partial or complete ring: ½C = summer/autumn (ring not measured), or C = winter felling (ring measured); H/S bdry = heartwood/sapwood boundary – last heartwood ring date; std devn = standard deviation; mean sens = mean sensitivity. Sapwood estimate (95% confidence) of 8–24 for Baltic oak boards (Tyers 1998), 8–38 for German oak boards (Hillam *et al* 1987), and 9–41 used for English boards timbers (Miles 1997a). Given the lack of any heartwood/sapwood boundaries, a *terminus post quem* date has been given for each board by adding the minimum number of sapwood rings to the last measured ring date, as adjusted by adding any unmeasured core segments beyond (+NM). Felling date ranges in brackets denote those ascribed from other samples with heartwood/sapwood boundaries from the same parent tree.

Sample number	type	Timber and position	Dates AD spanning	H/S bdry	Sapwood complement	No of rings	Mean width (mm)	Std devn (mm)	Mean sens (mm)	Felling date ranges (AD)
Large Panelled Chest in Lapidarium										
* wa171	mc	Front board, left lid	1274–1389			116	1.38	0.39	0.196	After 1397
* wa172	mc	2nd board from front, left lid	1308–1395	1395	H/S	88	2.07	0.41	0.171	1403–1419
* wa173	mc	Front board, right lid	1240–1384			145	1.32	0.35	0.214	After 1392
* wa174	mc	2nd board from front, right lid	1200–1385			186	1.15	0.54	0.200	After 1393
* wa175	mc	3rd board from front, right lid	1309–1396	(1398)		88+2NM	2.17	0.50	0.203	1406–1422
* wa176	mc	4th board from front, right lid	1340–1402			63	2.91	0.83	0.254	After 1410
* = WMNSTR18 Site Master (Baltic)			1200–1402	1397	Avg H/S	203	1.42	0.57	0.184	1405–21
Panels from Demolished Partition from Muniment Room, now in Lapidarium										
* wa181	s	Board 1 from post	1185–1345	1342	3	161	0.99	0.42	0.246	1350–66
* wa182	s	Board 2 from post	1256–1339	1338	1	84	1.66	0.58	0.289	1346–62
* wa183	s	Board 3 from post	1209–1341			133	1.10	0.29	0.178	After 1349
* wa184	s	Board 5 from post	1146–1312			167	0.82	0.31	0.275	After 1320
* wa185	s	board 7 from post	1205–1334			130	1.21	0.39	0.243	After 1342
* = WMNSTR19 Site Master (Baltic)			1146–1345	1340	Avg H/S	200	1.07	0.30	0.230	1348–64
Richard II Cupboard or Armoire in Muniment Room										
wa191a	p	Left return panel, middle board			7	84	1.07	0.27	0.201	
wa191b	p				7	70	1.23	0.30	0.155	
wa191c	p					97	2.22	0.55	0.217	
* wa192	p	Shelf board 3 from left, RH centre shelf	1151–1330			180+c 35NM	1.36	0.32	0.173	After c 1373
* wa193	p	Shelf board 2 from left, RH centre shelf	1229–1342			114	1.08	0.30	0.224	After 1350
* wa194	p	Right lower door inner board	1221–1369	1369	H/S	149	1.43	0.32	0.179	1377–93
* wa195	p	Right lower door outer board	1185–1364			180	0.93	0.24	0.191	After 1372
* = WMNSTR20 Site Master (Baltic)			1151–1369	1369	H/S	219	1.25	0.26	0.152	1377–93

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	Sample number	type	Timber and position	Dates AD spanning	H/S bdry	Sapwood complement	No of rings	Mean width (mm)	Std devn (mm)	Mean sens (mm)	Felling date ranges (AD)
	Cope Chest , Pyx Chamber										
	wa201	g	2nd board from back of lid (J M Fletcher)	–			71	1.51	0.34	0.148	
*	wa202	mc	4th board from back of lid	1171–1348			178	1.29	0.32	0.141	After 1356
	wa203a1	mc	5th board from back of lid	–			61	1.53	0.39	0.270	
*	wa203a2		ditto	1207–1353			147	0.87	0.24	0.131	After 1361
*	wa204	mc	6th board from back of lid	1169–1360			192	1.33	0.26	0.126	After 1368
	wa205a	mc	Front left post	–			26	2.07	1.05	0.294	
	wa205b	mc	ditto	–			46	1.19	0.94	0.221	
	wa205c	mc	ditto	–			41	1.47	0.45	0.197	
	wa205d	mc	ditto	–			29	1.18	0.36	0.197	
	wa206	mc	Centre front post	–			71	1.32	0.73	0.226	
	wa2056		Same–tree mean of wa205a, c, d, + wa206	–			71	1.55	0.76	0.219	
	wa207	mc	Rear centre post	–	H/S		49	1.76	0.50	0.198	
	wa20567		Mean of wa2056 + 207	–			79	1.72	0.69	0.216	
	wa208	mc	RH cross–bearer	–		22C	48	1.99	1.22	0.235	
	wa209	mc	Centre radial bearer	–		13	38	1.56	0.67	0.238	
	wa210a	mc	LH bottom rail	–		10	40	2.65	1.20	0.197	
	wa210b	mc	ditto	–		6C?[1]	6	1.37	0.19	0.079	
	wa210		Same-timber mean of wa210a + wa210b	–		11C?[1]	41	2.62	1.28	0.193	
	wa211	mc	LH cross–bearer	–		14C	33	1.69	0.67	0.221	
*	wa212	mc	Bottom board	1207–1353			147	1.09	0.29	0.179	After 1361
* = WMNSTR21 Site Master (Baltic)				1169–1360			192	1.20	0.28	0.123	*c* 1375–1400

[1] Possibly complete sapwood

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Table 2: *Matrix of* t-*values and overlaps for same-timber and same-tree means.*

No overlap between ring sequences is denoted by <u>0.00</u>
0

Components of same-timber mean **wa101**

Sample: *Last ring date AD:*	wa101a2 1155	wa101b 1155
wa101a1 1005	<u>0.00</u> 0	<u>33.76</u> 54
wa101a2		<u>10.79</u> 34

Components of same-timber mean **wa103**

Sample: *Last ring date AD:*	wa103b 1161
wa103a 1159	<u>27.16</u> 194

Components of same-timber mean **wa104**

Sample: *Last ring date AD:*	wa104a2 1148	wa104b 1146
wa104a1 1044	<u>0.00</u> 0	<u>8.00</u> 36
wa104a2		<u>18.80</u> 92

Components of same-timber mean **wa105**

Sample: *Last ring date AD:*	wa105b 1009
wa105a 1161	<u>22.71</u> 156

Components of same-timber mean **wa108**

Sample: *Last ring date AD:*	wa108b 1161
wa108a 1160	<u>22.01</u> 165

Components of same-tree mean **wa10368**

Sample: *Last ring date AD:*	wa106 1115	wa108 1161
wa103 1161	<u>14.04</u> 140	<u>4.36</u> 166
wa106		<u>15.00</u> 120

Components of same-timber mean **wa114**

Sample: *Last ring date AD:*	wa114a2 1201	wa114b 1142
wa114a1 1099	<u>0.00</u> 0	<u>20.53</u> 81
wa114a2		<u>11.73</u> 38

Components of same-timber mean **wa115**

Sample: *Last ring date AD:*	wa115b 1212
wa115a 1212	<u>13.30</u> 129

Table 2 (cont): Matrix of t-values and overlaps for same-timber and same-tree means

Components of same-timber mean **wal18**

Sample: Last ring date AD:	wal18b 1200
wal18a 1200	<u>18.93</u> 74

Components of same-timber mean **wal147**

Sample: Last ring date AD:	wal17 1204
wal14 1201	<u>18.11</u> 219

Components of same-tree mean **wal156**

Sample: Last ring date AD:	wal16 1193
wal15 1212	<u>12.75</u> 165

Components of same-timber mean **wal21**

Sample: Last ring date AD:	wal21b 1150
wal21a 1265	<u>9.51</u> 96

Components of same-timber mean **wal24**

Sample: Last ring date AD:	wal24b1 1197	wal24b2 1254
wal24a 1264	<u>26.09</u> 78	<u>24.07</u> 69
wal24b1		<u>134.05</u> 12

Components of same-timber mean **wal26**

Sample: Relative last ring date:	wal26a2 135	wal26b 114
wal26a1 39	<u>0.00</u> 0	<u>15.37</u> 39
wal26a2		<u>24.75</u> 72

Components of same-timber mean **wal31**

Sample: Last ring date AD:	wal31b 1261
wal31a 1263	<u>11.87</u> 141

Components of same-tree mean **wal334**

Sample: Relative last ring date:	wal34 175
wal33 173	<u>12.24</u> 168

Components of same-timber mean **wal42**

Sample: Last ring date AD:	wal42a2 1368	wal42b 1369
wal42a1 1301	<u>0.00</u> 0	<u>12.85</u> 163
wal42a2		<u>7.45</u> 65

Components of same-tree mean **wal41269**

Sample: Last ring date AD:	wal42 1369	wal46 1369	wal49 1375
wal41 1356	<u>20.74</u> 209	<u>13.17</u> 209	<u>16.36</u> 200
wal42		<u>39.05</u> 233	<u>17.42</u> 213
wal46			<u>13.44</u> 213

Table 2 (cont): *Matrix of t-values and overlaps for same-timber and same-tree means*

Components of same-timber mean **wa151**

Sample:	**wa151b**
Last ring date AD:	1143
wa151a	<u>16.80</u>
1104	98

Components of same-timber mean **wa155**

Sample:	**wa155b**
Last ring date AD:	1148
wa155a	<u>7.91</u>
1140	85

Components of same-timber mean **wa156**

Sample:	**wa156b**
Last ring date AD:	1132
wa156a	<u>22.78</u>
1103	240

Components of same-tree mean **wa1612**

Sample:	**wa162**
Relative last ring date:	308
wa161	<u>12.96</u>
292	239

Components of same-tree mean **wa2056**

Sample:	**wa205c**	**wa205d**	**wa206**
Relative last ring date:	61	71	71
wa205a	<u>4.00</u>	<u>0.00</u>	<u>6.16</u>
35	15	0	26
wa205c		<u>5.66</u>	<u>8.85</u>
		19	41
wa205d			<u>4.81</u>
			29

Components of mean **wa20567**

Sample:	**wa207**
Relative last ring date:	79
wa2056	<u>4.09</u>
71	41

Table 3: *Matrix of* t-*values and overlaps for dated site masters*

Components of **WMNSTR9**

Sample: Last ring date AD:	wal02 1160	wal04 1148	wal05 1161	wal0368 1161
wal01 1155	8.00 169	4.54 156	7.08 245	6.23 190
wal02		6.70 156	4.19 174	5.90 174
wal04			4.82 156	4.26 156
wal05				6.49 196

Components of **WMNSTR10**

Sample: Last ring date AD:	wal12 1190	wal13 1211	wal147 1204
wal11 1227	5.40 191	5.31 232	6.84 225
wal12		6.63 191	6.79 191
wal13			10.71 245

Components of **WMNSTR11**

Sample: Last ring date AD:	wal22 1261	wal24 1264	wal25 1236	wal27 1239
wal21 1265	6.48 216	3.28 147	3.96 124	6.92 153
wal22		4.17 144	4.65 124	8.23 153
wal24			2.57 119	3.30 122
wal25				3.30 124

Table 3 (cont): *Matrix of t-values and overlaps for site masters*

Components of **WMNSTR12**

Sample:	wa137
Last ring date AD:	1257
wa131	<u>10.35</u>
1263	185

Components of **WMNSTR13**

Sample:	wa145
Last ring date AD:	1341
wa144	<u>7.22</u>
1346	158

Components of **WMNSTR14**

Sample:	wa141269
Last ring date AD:	1375
wa147	<u>4.25</u>
1362	183

Components of **WMNSTR15**

Sample:	wa155	wa156
Last ring date AD:	1148	1132
wa153	<u>9.42</u>	<u>5.54</u>
1115	254	254
	wa155	<u>6.35</u>
		287

Components of **WMNSTR16**

Sample:	wa154
Last ring date AD:	1126
wa151	<u>6.23</u>
1143	104

Components of **WMNSTR17**

Sample:	wa165
Last ring date AD:	1228
wa164	<u>4.74</u>
1220	81

Components of **WMNSTR18**

Sample:	wa172	wa173	wa174	wa175	wa176
Last ring date AD:	1395	1384	1385	1396	1402
wa171	<u>6.03</u>	<u>6.34</u>	<u>6.87</u>	<u>7.52</u>	<u>5.23</u>
1389	82	111	112	81	50
	wa172	<u>3.72</u>	<u>6.59</u>	<u>6.54</u>	<u>2.02</u>
		77	78	87	56
		wa173	<u>4.35</u>	<u>4.55</u>	<u>5.15</u>
			145	76	45
			wa174	<u>3.84</u>	<u>2.33</u>
				77	57
				wa175	<u>5.73</u>
					57

Table 3 (cont): *Matrix of t-values and overlaps for site masters*

Components of **WMNSTR19**

Sample: *Last ring* *date AD:*	wal82 1339	wal83 1341	wal84 1312	wal85 1334
wal81 1345	3.61 84	4.60 133	4.74 128	5.26 130
	wal82	4.28 84	4.95 57	4.23 79
		wal83	8.22 104	3.13 126
			wal84	2.57 108

Components of **WMNSTR20**

Sample: *Last ring* *date AD:*	wal93 1342	wal94 1369	wal95 1364
wal92 1330	3.69 102	3.38 110	4.12 146
	wal93	3.69 114	6.42 114
		wal94	5.53 144

Components of **WMNSTR21**

Sample: *Last ring* *date AD:*	wa203a2 1353	wa204 1360	wa212 1353
wa202 1348	5.39 142	9.87 178	6.17 142
	wa203a2	5.65 147	8.32 147
		wa204	6.92 147

Table 4: *Ring-width data for site master curves and dated individuals*

WMNSTR9 (AD 850–1161): Long Chest, Muniment Room – English oak
7-timber mean of **wal01 + wal02 + wal04 + wal05 + wal0368**
312 rings, starting date AD 850

ring widths (0.01mm)

210	170	330	380	112	82	104	119	173	187
187	109	175	213	185	161	238	205	281	216
282	243	205	155	119	222	349	241	255	254
407	281	198	222	96	105	238	285	242	224
297	311	321	235	287	217	184	196	235	254
234	221	139	138	144	178	159	220	196	220
147	349	370	339	278	265	190	247	200	236
247	304	223	192	186	230	200	242	187	165
180	180	324	177	221	186	220	188	232	190
192	173	123	117	89	99	124	87	102	96
139	159	202	170	196	106	76	98	158	91
83	101	92	110	118	94	147	147	172	126
133	101	151	140	116	177	131	160	130	152
165	123	141	153	119	194	166	146	166	276
188	216	221	203	163	189	229	238	214	289
193	173	156	200	228	186	209	190	256	206
163	148	192	195	150	180	179	201	191	150
153	208	212	187	223	220	246	200	190	187
258	223	198	222	181	240	212	249	168	170
230	207	211	225	160	173	159	209	179	179
119	127	183	158	141	208	217	137	176	168
167	157	147	141	140	113	146	192	225	174
156	159	157	191	186	175	197	176	161	170
177	135	160	173	145	157	176	138	154	175
148	169	183	210	190	192	175	172	179	162
190	145	132	137	131	131	152	149	169	144
114	132	131	137	151	183	173	135	161	137
129	89	129	156	170	142	140	142	169	125
132	119	127	131	113	120	87	86	113	91
127	146	130	128	128	122	117	122	112	119
114	119	117	150	122	125	172	146	134	155
125	128								

number of samples in master

1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	3	3	3	3
3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	4	4	4
4	4	4	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5
5	5	5	5	5	5	5	5	5	4
4	4	4	4	4	4	3	3	3	3
3	2								

WMNSTR10 (AD 959–1227): Large Chest, Muniment Room – German oak
5-timber mean of **wal11** + **wal12** + **wal13** + **wal147**
269 rings, starting date AD 959

ring widths (0.01mm)

```
336 181 137 190 243 214 190 118 141 247
195 193 156 217 140 131 212 244 167 184
198 154 150 205 162 203 197 172 203 199
151 139 166 152 156 134 149 157 164 166
167 155 150 198 181 117 131 148 146 164
118 110 131 140 171 144 143 151 120 106
144 136 184 139 180 155 138 164 134 146
151 201 167 139 174 142 140 153 195 180
151 187 173 149 140 135 152 144 191 145
168 156 139 176 163 132 141 193 194 151
183 172 145 128 143 165 172 152 215 190
158 132 163 144 166 169 169 182 157 124
158 186 160 183 169 186 209 176 158 129
174 170 135 149 173 149 164 177 180 151
143 143 127 126 150 165 145 156 120 132
145 136 161 154 166 165 151 112 119 176
167 163 127 176 164 158 150 156 155 158
102 125 134 138 128 150 116 143 133 138
103 131 144 121 143 129 147 123 139 140
157 168 137 137 159 132 126 144 120 108
128 147 147 124 148 124 132 118 106 113
 98 115 110 116 137 135 141 140 130 127
122 116 101 144 183 156 151 179 174 144
141 153 151 149 162 114 167 128 115 138
157 148 179 133 125 144 129 119  97 110
124 113 122  84  63  56  63  79  83  84
139 106 124 120 111  95 151 108 103
```

number of samples in master

```
1 2 2 2 2 2 2 2 2 2
2 2 2 2 2 2 2 2 2 2
2 3 3 3 3 3 3 3 3 3
3 3 3 3 3 3 3 3 3 3
3 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 3 3 3 3 3 3 3 3
3 3 3 3 3 3 2 2 2 2
2 2 2 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1
```

wall56 (AD 998–1212): Large Chest, Muniment Room – German oak
2-timber mean of **wall5 + wall6**
215 rings, starting date AD 998

ring widths (0.01mm)										number of samples in master									
82	77	94	108	128	103	107	111	96	131	1	1	1	1	1	1	1	1	1	1
143	166	152	124	192	194	200	171	182	163	1	1	1	1	1	1	1	1	1	1
168	211	182	229	201	180	155	130	137	167	1	1	1	1	1	1	1	1	1	1
201	127	139	124	113	137	113	147	142	146	1	2	2	2	2	2	2	2	2	2
134	124	123	151	168	211	204	185	210	186	2	2	2	2	2	2	2	2	2	2
164	149	127	122	130	173	167	187	175	138	2	2	2	2	2	2	2	2	2	2
176	167	192	171	174	172	135	87	122	139	2	2	2	2	2	2	2	2	2	2
112	132	176	143	174	165	198	251	206	242	2	2	2	2	2	2	2	2	2	2
158	167	172	144	121	181	167	117	122	97	2	2	2	2	2	2	2	2	2	2
93	124	96	106	149	135	132	123	124	137	2	2	2	2	2	2	2	2	2	2
154	181	173	154	137	154	147	147	154	192	2	2	2	2	2	2	2	2	2	2
196	197	124	116	121	170	179	169	151	138	2	2	2	2	2	2	2	2	2	2
154	185	131	105	162	178	191	173	143	136	2	2	2	2	2	2	2	2	2	2
138	122	183	200	156	151	181	152	125	124	2	2	2	2	2	2	2	2	2	2
141	106	115	105	129	155	113	132	147	154	2	2	2	2	2	2	2	2	2	2
103	143	173	119	150	209	199	154	171	202	2	2	2	2	2	2	2	2	2	2
176	181	205	208	190	179	210	253	192	169	2	2	2	2	2	2	2	2	2	2
177	220	206	183	185	158	142	143	133	119	2	2	2	2	2	2	2	2	2	2
122	135	128	126	153	156	155	163	140	168	2	2	2	2	2	2	2	2	2	2
136	113	121	110	113	177	198	149	171	147	2	2	2	2	2	2	1	1	1	1
156	153	121	152	140	171	145	188	133	140	1	1	1	1	1	1	1	1	1	1
158	156	159	157	137						1	1	1	1	1					

WMNSTR11 (AD 1031–1265): Deep Chest, Muniment Room – German oak
5-timber mean of **wal21 + wal22 + wal24 + wal25 + wal27**
235 rings, starting date AD 1031

ring widths (0.01mm)										number of samples in master									
140	120	170	140	140	110	110	140	130	170	1	1	1	1	1	1	1	1	1	1
200	150	170	150	130	154	140	165	211	185	1	1	1	1	1	2	2	2	2	2
201	185	202	157	162	201	170	187	169	161	2	2	2	2	2	2	2	2	2	2
145	111	102	99	114	168	164	188	187	175	2	2	2	2	2	2	2	2	2	2
119	163	186	181	177	159	143	145	154	167	2	2	2	2	2	2	2	2	2	2
178	199	202	189	183	153	140	145	183	159	2	2	2	2	2	2	3	3	3	3
164	174	171	179	179	180	150	158	134	192	3	3	3	3	3	3	3	3	3	3
139	146	153	150	143	150	116	107	159	173	3	3	3	3	3	3	3	3	3	3
166	182	181	188	146	157	157	201	156	163	3	3	4	4	4	4	4	4	5	5
144	218	229	179	136	105	142	172	121	124	5	5	5	5	5	5	5	5	5	5
137	182	130	155	166	146	153	162	139	154	5	5	5	5	5	5	5	5	5	5
223	151	161	162	185	141	157	146	167	170	5	5	5	5	5	5	5	5	5	5
139	150	202	155	170	155	142	139	153	186	5	5	5	5	5	5	5	5	5	5
142	145	126	180	153	127	140	145	119	104	5	5	5	5	5	5	5	5	5	5
128	127	136	96	100	101	87	90	114	107	5	5	5	5	5	5	5	5	5	5
105	113	138	140	113	171	188	132	102	158	5	5	5	5	5	5	5	5	5	5
165	122	105	125	141	131	133	146	139	135	5	5	5	5	5	5	5	5	5	5
147	141	189	134	117	97	111	102	97	104	5	5	5	5	5	5	5	5	5	5
102	111	107	117	121	125	131	127	141	120	5	5	5	5	5	5	5	5	5	5
128	133	123	119	118	104	111	142	112	120	5	5	5	5	5	5	5	5	5	5
97	108	99	111	116	104	152	148	168	115	5	5	5	5	5	5	4	4	4	3
112	126	122	133	144	113	122	104	124	124	3	3	3	3	3	3	3	3	3	3
147	105	110	112	115	106	113	93	110	91	3	3	3	3	3	3	3	3	3	3
88	122	130	122	147						3	2	2	2	1					

Table 4 (cont): *Ring-width data for site master curves and dated individuals*

WMNSTR12 (AD 1040–1263): Lesser Treaty Chest, Pyx Chamber – German oak
2-timber mean of **wal31 + wal37**
224 rings, starting date AD 1040

ring widths (0.01mm)										number of samples in master									
150	200	160	90	130	150	150	170	150	260	1	1	1	1	1	1	1	1	1	1
260	220	320	250	240	210	300	260	130	140	1	1	1	1	1	1	1	1	1	1
200	240	160	260	150	120	200	280	300	190	1	1	1	1	1	1	1	1	1	1
160	260	220	190	160	180	230	190	150	235	1	1	2	2	2	2	2	2	2	2
230	180	310	225	255	235	165	135	180	145	2	2	2	2	2	2	2	2	2	2
240	200	220	290	200	210	250	195	255	210	2	2	2	2	2	2	2	2	2	2
340	230	150	170	315	305	370	270	215	235	2	2	2	2	2	2	2	2	2	2
225	205	230	175	190	170	250	350	385	210	2	2	2	2	2	2	2	2	2	2
220	199	274	348	244	197	263	236	190	108	2	2	2	2	2	2	2	2	2	2
148	231	224	164	197	172	166	100	105	116	2	2	2	2	2	2	2	2	2	2
146	203	149	272	240	165	199	210	192	200	2	2	2	2	2	2	2	2	2	2
317	240	166	214	197	156	182	161	168	164	2	2	2	2	2	2	2	2	2	2
219	262	193	224	225	227	270	189	269	195	2	2	2	2	2	2	2	2	2	2
207	183	206	268	225	270	246	158	132	204	2	2	2	2	2	2	2	2	2	2
199	219	262	252	265	253	278	234	194	170	2	2	2	2	2	2	2	2	2	2
290	284	221	232	204	275	323	202	280	358	2	2	2	2	2	2	2	2	2	2
240	246	239	265	280	221	180	159	148	200	2	2	2	2	2	2	2	2	2	2
213	242	234	263	283	296	228	229	199	278	2	2	2	2	2	2	2	2	2	2
245	277	245	185	248	324	341	303	344	273	2	2	2	2	2	2	2	2	2	2
302	185	179	220	220	183	183	244	185	230	2	2	2	2	2	2	2	2	2	2
222	171	237	165	137	185	149	181	164	199	2	2	2	2	2	2	2	2	2	2
209	188	150	171	196	228	165	180	144	159	2	2	2	2	2	2	2	2	1	1
158	184	188	153							1	1	1	1						

WMNSTR13 (AD 1113–1346): Greater Treaty Chest, Pyx Chamber – Baltic oak
2-timber mean of **wal44 + wal45**
234 rings, starting date AD 1113

ring widths (0.01mm)										number of samples in master									
158	189	87	136	127	93	93	134	206	141	1	1	1	1	1	1	1	1	1	1
160	149	128	145	169	97	60	95	121	139	1	1	1	1	1	1	1	1	1	1
136	135	167	135	125	134	138	142	198	125	1	1	1	1	1	1	1	1	1	1
190	127	120	163	141	157	140	199	134	93	1	1	1	1	1	1	1	1	1	1
163	140	127	132	102	146	142	186	113	127	1	1	1	1	1	1	1	1	1	1
125	119	96	97	114	136	70	148	103	109	1	1	1	1	1	1	1	1	1	1
148	126	106	102	116	167	131	161	177	218	1	1	1	1	1	1	1	1	1	1
230	174	149	203	240	210	189	208	202	156	1	2	2	2	2	2	2	2	2	2
135	149	192	184	215	180	185	241	207	103	2	2	2	2	2	2	2	2	2	2
156	186	161	154	133	148	144	140	139	148	2	2	2	2	2	2	2	2	2	2
113	144	82	91	127	98	112	110	85	93	2	2	2	2	2	2	2	2	2	2
74	94	102	78	77	89	118	154	98	112	2	2	2	2	2	2	2	2	2	2
114	101	113	109	177	167	163	118	96	107	2	2	2	2	2	2	2	2	2	2
135	123	133	140	151	121	114	141	142	151	2	2	2	2	2	2	2	2	2	2
168	150	185	140	134	108	140	96	97	103	2	2	2	2	2	2	2	2	2	2
106	125	97	134	116	130	132	187	178	185	2	2	2	2	2	2	2	2	2	2
131	171	139	113	111	105	125	123	129	116	2	2	2	2	2	2	2	2	2	2
104	117	133	125	106	126	124	131	117	116	2	2	2	2	2	2	2	2	2	2
126	155	142	157	133	135	137	110	105	125	2	2	2	2	2	2	2	2	2	2
105	87	82	106	124	100	99	104	105	101	2	2	2	2	2	2	2	2	2	2
112	113	106	129	93	112	93	126	122	140	2	2	2	2	2	2	2	2	2	2
113	94	104	93	107	107	98	114	102	101	2	2	2	2	2	2	2	2	2	2
88	118	108	125	123	103	133	115	106	107	2	2	2	2	2	2	2	2	2	1
120	75	114	121							1	1	1	1						

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Table 4 (cont): Ring-width data for site master curves and dated individuals

WMNSTR14 (AD 1137–1375): Greater Treaty Chest, Pyx Chamber – Baltic oak
2-timber mean of **wal47 + wal41269**
239 rings, starting date AD 1137

ring widths (0.01mm)										number of samples in master									
135	145	125	121	177	93	117	117	184	152	1	1	1	1	1	1	1	1	1	1
134	158	164	136	121	83	135	118	166	150	1	1	1	1	1	1	1	1	1	1
130	130	95	129	83	97	108	92	75	85	1	1	1	1	1	1	1	1	1	1
101	136	90	118	142	120	118	130	109	99	1	1	1	1	1	1	1	1	1	1
93	93	59	82	121	102	148	127	118	124	1	1	1	2	2	2	2	2	2	2
136	134	100	143	131	87	108	129	117	106	2	2	2	2	2	2	2	2	2	2
102	134	111	119	118	76	113	95	101	120	2	2	2	2	2	2	2	2	2	2
120	126	91	99	129	119	92	117	107	114	2	2	2	2	2	2	2	2	2	2
94	84	92	85	106	121	96	98	122	93	2	2	2	2	2	2	2	2	2	2
101	112	90	110	121	112	123	113	95	72	2	2	2	2	2	2	2	2	2	2
87	67	97	111	105	117	103	133	143	136	2	2	2	2	2	2	2	2	2	2
124	112	130	157	134	115	139	125	125	113	2	2	2	2	2	2	2	2	2	2
99	105	111	96	84	115	107	123	102	89	2	2	2	2	2	2	2	2	2	2
91	92	103	103	137	132	113	130	130	104	2	2	2	2	2	2	2	2	2	2
103	94	92	94	114	98	119	105	106	130	2	2	2	2	2	2	2	2	2	2
135	126	135	115	104	84	96	92	101	121	2	2	2	2	2	2	2	2	2	2
114	145	127	123	147	142	156	120	115	106	2	2	2	2	2	2	2	2	2	2
97	123	142	134	160	203	198	153	144	170	2	2	2	2	2	2	2	2	2	2
168	130	129	138	155	154	137	129	145	134	2	2	2	2	2	2	2	2	2	2
100	109	101	114	103	109	85	107	107	137	2	2	2	2	2	2	2	2	2	2
102	104	121	122	146	112	98	97	125	102	2	2	2	2	2	2	2	2	2	2
92	93	120	140	150	119	115	135	96	96	2	2	2	2	2	2	2	2	2	2
67	86	101	130	110	118	126	143	127	159	2	2	2	2	2	2	1	1	1	1
150	149	115	77	90	91	102	94	122		1	1	1	1	1	1	1	1	1	

wal48 (AD 1146–1365): Greater Treaty Chest, Pyx Chamber – Baltic oak
220 rings, starting date AD 1146

ring widths (0.01mm)

160	140	180	140	120	100	130	150	130	110
100	120	160	160	220	120	120	100	160	140
110	120	120	110	110	090	120	120	160	120
110	110	120	150	130	150	120	120	130	150
150	180	120	100	160	180	110	130	120	150
160	190	210	180	190	150	100	110	110	110
100	130	150	120	160	140	110	150	160	120
130	140	130	230	160	120	130	220	120	150
130	200	160	180	190	140	190	140	150	130
110	230	140	110	080	070	080	110	080	120
140	130	120	130	140	150	160	170	130	190
180	180	110	120	110	120	130	120	120	130
150	130	150	140	140	200	180	190	180	180
140	150	100	130	140	150	150	140	120	140
120	110	120	100	100	110	130	110	150	120
140	120	140	140	110	090	160	040	100	120
110	100	120	130	130	120	140	160	150	170
190	130	110	170	140	130	180	120	080	130
130	120	100	120	130	090	110	100	090	100
100	110	120	140	100	090	080	070	060	080
090	080	080	070	090	070	070	070	080	070
070	080	090	100	110	080	100	110	110	130

Table 4 (cont): Ring-width data for site master curves and dated individuals

WMNSTR15 (AD 827–1148): Shelf or Canopy Boards, Pyx Chamber – English oak
3-timber mean of wal53 + wal55 + wal56
322 rings, starting date AD 827

ring widths (0.01mm)										number of samples in master									
110	115	145	105	120	150	170	160	200	100	1	1	1	1	1	1	1	1	1	1
95	170	95	60	45	105	110	150	120	170	1	1	1	1	1	1	1	1	1	2
130	113	120	115	160	123	163	150	123	110	2	2	2	2	2	2	2	2	2	2
110	123	118	143	115	88	112	105	121	125	2	2	2	2	2	3	3	3	3	3
113	122	142	150	125	90	80	76	90	107	3	3	3	3	3	3	3	3	3	3
113	96	88	105	125	119	88	73	55	66	3	3	3	3	3	3	3	3	3	3
82	83	78	98	91	96	103	101	105	81	3	3	3	3	3	3	3	3	3	3
74	66	58	65	65	66	58	65	63	55	3	3	3	3	3	3	3	3	3	3
82	88	80	93	108	129	123	98	82	77	3	3	3	3	3	3	3	3	3	3
79	75	66	73	73	68	74	84	88	99	3	3	3	3	3	3	3	3	3	3
83	87	83	73	63	59	47	48	51	53	3	3	3	3	3	3	3	3	3	3
67	67	68	67	68	48	33	35	56	55	3	3	3	3	3	3	3	3	3	3
57	53	48	49	53	58	60	68	67	55	3	3	3	3	3	3	3	3	3	3
43	41	60	63	78	74	78	88	71	61	3	3	3	3	3	3	3	3	3	3
68	79	82	65	62	59	68	62	71	68	3	3	3	3	3	3	3	3	3	3
85	69	82	97	84	90	84	58	93	83	3	3	3	3	3	3	3	3	3	3
92	73	128	88	117	138	108	121	113	100	3	3	3	3	3	3	3	3	3	3
98	112	140	97	93	93	75	119	85	75	3	3	3	3	3	3	3	3	3	3
77	126	137	115	118	124	118	100	105	98	3	3	3	3	3	3	3	3	3	3
107	74	60	65	73	84	92	88	80	108	3	3	3	3	3	3	3	3	3	3
106	90	82	105	80	66	58	70	73	92	3	3	3	3	3	3	3	3	3	3
99	92	82	72	97	90	100	88	87	107	3	3	3	3	3	3	3	3	3	3
106	93	61	70	54	66	63	72	93	87	3	3	3	3	3	3	3	3	3	3
59	101	110	121	114	100	123	114	88	112	3	3	3	3	3	3	3	3	3	3
191	149	136	119	133	111	108	128	122	134	3	3	3	3	3	3	3	3	3	3
125	124	133	147	108	146	125	99	106	114	3	3	3	3	3	3	3	3	3	3
117	162	145	93	87	96	91	89	74	73	3	3	3	3	3	3	3	3	3	3
87	102	94	106	82	68	93	103	75	68	3	3	3	3	3	3	3	3	3	3
85	88	79	64	72	71	78	88	115	120	3	3	3	3	3	3	3	3	3	2
98	103	79	64	57	67	90	108	92	98	2	2	2	2	2	2	2	2	2	2
95	98	90	105	119	113	105	95	105	110	2	2	2	2	2	2	1	1	1	1
73	70	65	100	80	70	75	60	50	45	1	1	1	1	1	1	1	1	1	1
55	60									1	1								

WMNSTR16 (AD 1007–1143): Shelf or Canopy Boards, Pyx Chamber – English oak
2-timber mean of wal51 + wal54
137 rings, starting date AD 1007

ring widths (0.01mm)										number of samples in master									
350	415	365	275	235	215	170	170	153	175	1	1	1	1	1	1	1	1	1	1
153	180	178	145	145	158	200	170	205	250	1	1	1	1	1	1	1	1	1	1
205	205	158	175	193	123	120	90	120	155	1	1	2	2	2	2	2	2	2	2
175	170	165	200	198	234	172	128	100	110	2	2	2	2	2	2	2	2	2	2
120	93	120	110	95	149	148	132	170	169	2	2	2	2	2	2	2	2	2	2
158	278	350	380	208	238	197	209	234	238	2	2	2	2	2	2	2	2	2	2
173	200	153	145	150	185	182	173	173	148	2	2	2	2	2	2	2	2	2	2
158	222	215	198	164	163	188	189	173	203	2	2	2	2	2	2	2	2	2	2
125	125	144	102	124	143	175	154	128	142	2	2	2	2	2	2	2	2	2	2
147	169	142	145	113	118	150	133	133	180	2	2	2	2	2	2	2	2	2	2
155	198	170	150	128	153	163	195	190	140	2	2	2	2	2	2	2	2	2	2
130	103	138	130	90	165	150	160	150	143	2	2	2	2	2	2	2	2	2	2
115	153	145	175	158	178	110	120	90	80	2	2	2	2	2	2	1	1	1	1
120	140	100	170	110	65	80				1	1	1	1	1	1	1			

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wa157 (AD 970–1090): Shelf or Canopy Boards, Pyx Chamber – English oak
121 rings, starting date AD 970

ring widths (0.01mm)
```
300 200 160 150 150 130 210 215 190 295
170 165 225 310 200 325 270 150 210 200
175 170 190 250 200 200 225 210 240 340
280 250 195 180 170 155 180 280 250 215
200 210 330 220 140 120 090 085 130 130
160 200 210 190 200 230 200 260 270 250
165 250 155 170 190 240 260 280 290 200
270 250 310 250 225 325 220 200 160 130
110 170 250 250 240 340 310 200 390 350
310 280 320 335 350 225 260 300 275 190
190 140 240 270 280 270 290 215 215 275
260 170 325 320 200 350 340 200 250 220
170
```

WMNSTR17 (AD 1124–1228): Chest 1 in Lapidarium – English oak
2-timber mean of **wa164** + **wa165;** 105 rings, starting date AD 1124

ring widths (0.01mm)											number of samples in master									
287	281	235	299	299	212	268	281	396	310		1	1	1	1	1	1	1	1	1	1
338	375	354	245	299	174	272	191	177	206		1	1	1	1	1	1	2	2	2	2
284	307	225	171	202	229	195	194	182	311		2	2	2	2	2	2	2	2	2	2
240	219	194	287	245	299	271	228	232	182		2	2	2	2	2	2	2	2	2	2
197	256	260	271	276	270	245	274	265	258		2	2	2	2	2	2	2	2	2	2
329	260	261	177	202	269	175	180	160	128		2	2	2	2	2	2	2	2	2	2
114	121	169	219	146	185	183	134	135	236		2	2	2	2	2	2	2	2	2	2
192	186	183	194	151	130	151	207	184	203		2	2	2	2	2	2	2	2	2	2
170	202	155	131	171	176	231	168	166	186		2	2	2	2	2	2	2	2	2	2
163	171	188	147	165	159	195	308	266	371		2	2	2	2	2	2	2	1	1	1
383	272	488	291	329							1	1	1	1	1					

WMNSTR18 (AD 1200–1402): Chest 2 in Lapidarium – Baltic oak
6-timber mean of **wal71** + **wal72** + **wal73** + **wal74** + **wal75** + **wal76**; 203 rings, starting date AD 1200

ring widths (0.01mm)

```
 74  91  52 111 118 107  79  63  97 117
103 103 110  82 118 103  83  63  73  78
 59  48  61  56  50  66  47  49  41  71
 60  67  70  57  63  52  65  87  63  80
 94  79  75  99 133  97 118  83  95 112
 89  80  88  89 120  98  89  75 108  99
 76  90 112 160 119 172 128 119 129 101
112 158 172 125 131 134 118 122 105 110
135 141 118 118 141 106  81  63  65  77
 93  89  80  67  85 106 143 113 142 177
158 156 173 139  88  84 119 149 203 225
166 163 195 253 193 198 240 147 140 129
147 183 202 144 156 179 142 188 220 185
178 134 130 117 195 158 174 155 161 192
211 182 164 175 174 218 168 159 213 185
240 265 212 196 158 162 156 190 181 225
217 143 190 230 165 194 190 215 231 199
166 164 170 140 156 200 152 156 248 198
212 206 158 184 217 268 223 269 203 240
269 200 220 212 253 229 280 192 202 165
148 213 255
```

number of samples in master

```
1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1
2 2 2 2 2 2 2 2 2 2
2 2 2 2 2 2 2 2 2 2
2 2 2 2 2 2 2 2 2 2
2 2 2 2 3 3 3 3 3 3
3 3 3 3 3 3 3 3 3 3
3 3 3 3 3 3 3 3 3 3
3 3 3 3 3 3 3 3 4 5
5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5
6 6 6 6 6 6 6 6 6 6
6 6 6 6 6 6 6 6 6 6
6 6 6 6 6 6 6 6 6 6
6 6 6 6 6 6 6 6 6 6
6 6 6 6 6 5 4 4 4 4
3 3 3 3 3 3 2 1 1 1
1 1 1
```

WMNSTR19 (AD 1146–1345): Panels from demolished partition in Muniment Room, now in Lapidarium, Westminster Abbey – Baltic oak
5-timber mean of **wal81** + **wal82** + **wal83** + **wal84** + **wal85**
200 rings, starting date AD 1146

ring widths (0.01mm)

```
 99 129  99 121 151  78  52 144 122 145
 83  78 101 106 115  71 104  85 126  54
 88  46  79  48  52  73  93  71  79  46
 68  40  47  36  67  69  52 113  97 129
148 153 139  84 126 117  67  77 117 186
158 123 239 188 187 166 118 146 111 128
106  93 115 111 126 125 146  98 119 125
117  86  67 116 113  86  97  65  63  86
 75  99 113 162 142  94 107 116 111 131
110 136  78 127 117 100 125 124 109 104
 94 120  97 108 136 128 122 114  96 113
179 124  92 123 109  72 115  90 130  80
126 107 107 104  93 115 107 132 137 145
138 114  95 127 136 133 118 119  98 116
128  76 113 101  88  97  74  93  90 104
141 125 134 125 127 117 145 148  87  91
 65  69  91  92  83 100 128 160 101 126
146  82 115 107 114  92  87  75  81  97
104 135 115  89  94  90  98  86 114  93
146 118 111 104  67  85 104 112  69 103
```

number of samples in master

```
1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 2
2 2 2 2 2 2 2 2 2 2
2 2 2 2 2 2 2 2 2 3
3 3 3 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 4
5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 4 4 4
4 4 4 4 4 4 4 4 4 4
4 4 4 4 4 4 4 4 4 3
3 3 3 3 2 2 1 1 1 1
```

WMNSTR20 (AD 1151–1369): Cupboard in Muniment Room – Baltic oak
4-timber mean of **wa192 + wa193 + wa194 + wa195**
219 rings, starting date AD 1151

ring widths (0.01mm)										number of samples in master									
160	137	134	140	122	152	107	152	184	182	1	1	1	1	1	1	1	1	1	1
215	152	154	122	167	161	150	136	173	135	1	1	1	1	1	1	1	1	1	1
142	137	141	143	150	158	129	167	143	164	1	1	1	1	1	1	1	1	1	1
144	189	119	180	99	146	146	151	100	125	1	1	1	1	2	2	2	2	2	2
163	135	114	127	159	162	162	173	188	172	2	2	2	2	2	2	2	2	2	2
147	128	134	101	136	111	127	153	131	166	2	2	2	2	2	2	2	2	2	2
145	137	105	145	88	99	97	94	141	106	2	2	2	2	2	2	2	2	2	2
103	113	107	104	117	86	118	130	126	156	3	3	3	3	3	3	3	3	4	4
129	125	123	133	87	102	168	132	119	101	4	4	4	4	4	4	4	4	4	4
78	73	78	86	83	85	98	129	110	123	4	4	4	4	4	4	4	4	4	4
111	130	146	127	149	162	148	85	134	102	4	4	4	4	4	4	4	4	4	4
90	111	119	141	119	142	119	136	151	140	4	4	4	4	4	4	4	4	4	4
138	143	154	136	147	121	132	101	134	141	4	4	4	4	4	4	4	4	4	4
142	139	126	112	124	129	95	110	101	118	4	4	4	4	4	4	4	4	4	4
117	106	127	142	119	131	112	115	143	125	4	4	4	4	4	4	4	4	4	4
125	129	121	99	86	100	97	101	113	107	4	4	4	4	4	4	4	4	4	4
112	129	149	124	121	168	105	107	121	107	4	4	4	4	4	4	4	4	4	4
128	115	108	85	100	92	100	112	95	98	4	4	4	4	4	4	4	4	4	4
84	88	91	93	90	104	92	115	146	102	3	3	3	3	3	3	3	3	3	3
109	97	100	93	97	125	119	96	113	105	3	3	2	2	2	2	2	2	2	2
114	133	129	119	110	103	98	82	128	148	2	2	2	2	2	2	2	2	2	2
109	123	146	93	197	179	154	136	132		2	2	2	2	1	1	1	1	1	

WMNSTR21 (AD 1169–1360): Cope Chest, Pyx Chamber – Baltic oak
4-timber mean of **wa202 + wa203a2 + wa204 + wa212**
192 rings, starting date AD 1169

ring widths (0.01mm)										number of samples in master									
151	217	168	138	146	164	109	133	114	104	1	1	2	2	2	2	2	2	2	2
107	110	137	164	202	143	170	189	207	183	2	2	2	2	2	2	2	2	2	2
148	151	156	145	156	193	203	144	167	160	2	2	2	2	2	2	2	2	2	2
179	156	146	170	166	136	171	149	121	157	2	2	2	2	2	2	2	2	4	4
142	145	138	129	135	162	149	140	149	128	4	4	4	4	4	4	4	4	4	4
161	129	95	113	106	114	143	109	100	144	4	4	4	4	4	4	4	4	4	4
159	151	120	131	102	114	84	109	116	118	4	4	4	4	4	4	4	4	4	4
106	101	96	92	98	81	91	93	113	103	4	4	4	4	4	4	4	4	4	4
107	121	143	134	111	103	155	115	138	115	4	4	4	4	4	4	4	4	4	4
137	111	95	127	133	147	138	147	125	121	4	4	4	4	4	4	4	4	4	4
102	88	119	124	124	117	128	98	109	103	4	4	4	4	4	4	4	4	4	4
109	111	128	114	111	107	121	106	81	101	4	4	4	4	4	4	4	4	4	4
102	106	122	113	107	104	113	113	102	82	4	4	4	4	4	4	4	4	4	4
73	67	77	99	115	93	96	100	107	113	4	4	4	4	4	4	4	4	4	4
124	113	128	108	112	105	116	130	113	112	4	4	4	4	4	4	4	4	4	4
115	98	100	92	79	74	94	90	85	98	4	4	4	4	4	4	4	4	4	4
90	91	98	97	88	114	115	101	112	97	4	4	4	4	4	4	4	4	4	4
110	99	100	100	94	95	95	87	74	81	4	4	4	4	4	4	4	4	4	4
85	99	106	107	100	133	111	103	100	115	3	3	3	3	3	1	1	1	1	1
141	124									1	1								

Table 5: Dating evidence for the site sequence **WMNSTR9** *(AD 850–1161). Regional multi-site chronologies are in* **BOLD**

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
London	Merton Priory	(Tyers 1988a)	MPY_T7	922–1176	255	13.9
London	Guildhall, City	(Tyers 2001b)	GYEM_T98	498–1212	312	13.4
London	Fennings Wharf, Southwark	(Tyers 2001b)	FW_W99	802–1435	312	12.6
Southern England	South Master Chronology	(Hillam and Groves 1994)	**SOUTH**	406–1594	312	10.5
London	Fleet Valley, City	(Tyers and Hibberd 1993)	VAL_W89	745–1316	312	10.4
Hampshire	Hampshire Master Chronology	(Miles 2003)	**HANTS02**	443–1972	312	10.3
London	Billingsgate, City	(Tyers unpubl)	BIG_W280	611–1243	312	10.2
Wales	Welsh Master Chronology	(Miles 1997)	**WALES97**	404–1981	312	9.7
London	Thames Exchange, City	(Nayling 1991)	TEX_W70	645–1239	312	9.4

Table 6: Dating evidence for the site sequence **WMNSTR10** *(AD 959–1227). Regional multi-site chronologies are in* **BOLD**

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
Germany	Niedersachsen Nord	(Leuschner unpubl)	**GER_NORD**	915–1873	269	11.9
Germany	Peterborough Cathedral	(Tyers and Tyers 2007)	PCBN_T69	944–1230	269	10.6
Germany	Hollstein Master Chronology	(Hollstein 1980)	**HOLLST**	1101–1975	269	7.3
Germany	Westminster Abbey	(Miles and Bridge 2005)	WMNSTR4	1004–1219	216	6.5
Baltic	Baltic early group	(Tyers unpubl)	**BALO_T86**	1052–1420	176	6.3
Baltic	Hull Magistrates Court	(Tyers 1998)	HMC_T165	1078–1369	150	5.9
Germany	Southern Germany	(Becker 1981)	**GER_BEC**	370BC–1950	269	5.8
Eastern Baltic	Southwark ship	(Tyers 1990)	GAS-SHIP	1052–1370	176	5.4
Eastern Baltic	Magdalen College, Oxford	(Miles and Worthington 2000)	MAGDALN2	1080–1416	148	5.2

Table 7: Dating evidence for the sequence **wa1156** (AD 998–1212)

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
London	Merton Priory	(Tyers 1988a)	MPY_T7	922–1176	179	6.3
London	Millennium Bridge, City	(Tyers 1999)	MBC_T35	999–1389	214	5.8
Wiltshire	Salisbury Cathedral	(Miles and Worthington 2001)	SARUM3	1054–1248	159	5.7
Cheshire	Nantwich	(Leggett *et al* 1982)	NANTWICH	930–1330	215	5.7

Table 8: Dating evidence for the sequence **wa118** (AD 1127–1200). Regional multi-site chronologies are in **BOLD**

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
London	London Master Chronology	(Tyers pers comm)	**LONDON**	413–1728	74	8.3
Hampshire	Winchester Round Table	(Barefoot and Haddon-Reece unpubl)	TABLE	1041–1211	74	8.0
Essex	Cressing Temple Barns	(Tyers and Hibberd 1993)	CRBCR1	1120–96	70	7.0
Hampshire	Hampshire Master Chronology	(Miles 2003)	**HANTS02**	443–1972	74	6.0

Table 9: Dating evidence for the sequence **wa121** (AD 1031–1265). Regional multi-site chronologies are in **BOLD**

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
Germany	Peterborough Cathedral	(Tyers and Tyers 2007)	PCBN_T69	944–1230	200	8.8
West Denmark	West Denmark	(Bonde unpubl)	**DENM_W2**	109BC–1986	235	6.5
Germany	Westminster Abbey	(Miles and Bridge 2005)	WMNSTR4	1004–1219	189	6.3
Germany	Niedersachsen Nord	(Leuschner unpubl)	**GER_NORD**	915–1873	235	6.3

Table 10: *Dating evidence for the sequence* **wa122** *(AD 1046–1261). Regional multi-site chronologies are in* **BOLD**

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
Germany	Peterborough Cathedral	(Tyers and Tyers 2007)	PCBN_T69	944–1230	185	6.1
Baltic	Chapel Lane, Hull	(Tyers 2000)	CLS2000	1110–1393	152	5.7
Eastern Baltic	Magdalen College, Oxford	(Miles and Worthington 2000)	MAGDALN2	1080–1416	182	5.2
West Denmark	West Denmark	(Bonde unpubl)	**DENM_W2**	109BC–1986	216	5.1

Table 11: *Dating evidence for the sequence* **wa124** *(AD 1119–1264). Regional multi-site chronologies are in* **BOLD**

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
Baltic	Baltic early group	(Tyers unpubl)	**BALO_T86**	1052–1420	147	5.9
Baltic	Chapel Lane, Hull	(Tyers 2000)	CLS2000	1110–1393	147	5.7
Baltic	Westminster Abbey	(Miles and Bridge 2005)	WMNSTR3	1137–1275	128	5.3
Eastern Baltic	Magdalen College, Oxford	(Miles and Worthington 2000)	MAGDALN2	1080–1416	147	4.9

Table 12: *Dating evidence for the sequence* **wa125** *(AD 1113–1236). Regional multi-site chronologies are in* **BOLD**

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
Germany	Niedersachsen Nord	(Leuschner unpubl)	**GER_NORD**	915–1873	124	5.7
Germany	Peterborough Cathedral	(Tyers and Tyers 2007)	PCBN_T69	944–1230	118	4.7
Eastern Baltic	Southwark ship	(Tyers 1996)	GAS-SHIP	1052–1370	124	4.7
Germany	Westminster Abbey	(Miles and Bridge 2005)	WMNSTR4	1004–1219	107	4.6

Table 13: Dating evidence for the sequence **wa127** (AD 1087–1239). Regional multi-site chronologies are in **BOLD**

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
Germany	Niedersachsen Nord	(Leuschner unpubl)	**GER_NORD**	915–1873	153	6.8
Germany	Westminster Abbey	(Miles and Bridge 2005)	WMNSTR4	1004–1219	133	6.5
West Denmark	West Denmark	(Bonde unpubl)	**DENM_W2**	109BC–1986	153	6.4
Germany	Peterborough Cathedral	(Tyers and Tyers 2007)	PCBN_T69	944–1230	144	6.3

Table 14: Dating evidence for the site sequence **WMNSTR11** (AD 1031–1265). Regional multi-site chronologies are in **BOLD**

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
Germany	Peterborough Cathedral	(Tyers and Tyers 2007)	PCBN_T69	944–1230	200	9.7
Germany	Niedersachsen Nord	(Leuschner unpubl)	**GER_NORD**	915–1873	235	8.8
Germany	Westminster Abbey	(Miles and Bridge 2005)	WMNSTR4	1004–1219	189	8.0
West Denmark	West Denmark	(Bonde unpubl)	**DENM_W2**	109BC–1986	235	7.5
unknown	Boat planks	(Tyers pers comm)	SYM-T9	1133–1333	133	6.8
Baltic	Chapel Lane, Hull	(Tyers 2000)	CLS2000	1110–1393	156	6.2
Eastern Baltic	Magdalen College, Oxford	(Miles and Worthington 2000)	MAGDALN2	1080–1416	186	6.6
Imported	Vejby, Denmark	(Bonde and Jensen 1995)	**VEJBY_26**	1109–1370	157	6.5
Baltic	Baltic early group	(Tyers unpubl)	**BALO_T86**	1052–1420	214	6.4

Table 15: Dating evidence for the site sequence **WMNSTR12** (AD 1040–1263). Regional multi-site chronologies are in **BOLD**

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
Germany	Niedersachsen Nord	(Leuschner unpubl)	**GER_NORD**	915–1873	224	11.1
Germany	Presbytery Roof, St Albans	(Howard *et al* 2002)	STACSQ01	1050–1264	214	9.1
Germany	Southern Germany	(Becker 1981)	**GER_BEC**	370BC–1950	224	8.2
Germany	Hollstein Master Chronology	(Hollstein 1980)	**HOLLST**	1101–1975	224	6.9
Germany	Westminster Abbey	(Miles and Bridge 2005)	WMNSTR4	1004–1219	180	6.7
Germany	Peterborough Cathedral	(Tyers and Tyers 2007)	PCBN_T69	944–1230	191	6.5
Baltic	Gdansk regional chronology	(Wazny pers comm)	**GDANSK**	996–1985	224	6.4
Baltic	Thornham Parva Retable	(Tyers 2002b)	OS071	1053–1309	211	6.3
Germany	Huber Master Chronology	(Huber and Giertz-Siebenlist 1978)	**HUBER**	1101–1790	163	6.1

Table 16: Dating evidence for the site sequence **WMNSTR13** (AD 1113–1346). Regional multi-site chronologies are in **BOLD**

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
Baltic	Hull Magistrates Court	(Tyers 1998)	HMC_T165	1078–1369	234	9.6
Baltic	Copper Wreck 4	(Bonde and Wazny unpubl)	COP4_T9	1011–1395	234	9.4
Baltic	Barton on Humber church door	(Tyers 2001a)	BHSPND26	1144–1358	203	9.1
Baltic	Abbotts Lane, Southwark	(Tyers 1994)	ABB_DOOR	1165–1386	182	9.0
Baltic	Chapel Lane, Hull	(Tyers 2000)	CLS2000	1110–1393	234	8.0
Baltic	Copper Wreck 1	(Bonde and Wazny unpubl)	COP1_T29	1094–1402	234	7.4
Baltic	Baltic early group	(Tyers unpubl)	**BALO_T86**	1052–1420	234	7.2
Eastern Baltic	Magdalen College, Oxford	(Miles and Worthington 2000)	MAGDALN2	1080–1416	234	6.2
Eastern Baltic	Bishop's Palace, Salisbury	(Miles and Worthington 2000)	SARUMBP3	1088–1400	234	6.1

Table 17: Dating evidence for the site sequence **WMNSTR14** *(AD 1137–1375). Regional multi-site chronologies are in* **BOLD**

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
Baltic	Salisbury Cathedral	(Miles *et al* 2004)	SARUM15	1117–1354	218	8.2
Baltic	Exeter Bowhill	(Groves 2002)	BOWHILLB	1161–1483	215	8.2
East Baltic	Baltic Master Chronology	(Hillam and Tyers 1995)	**BALTIC1**	1156–1597	220	7.3
Baltic	Hull Magistrates Court	(Tyers 1998)	HMC_T165	1078–1369	233	7.2
Baltic	Copper Wreck 1	(Bonde and Wazny unpubl)	COP1_T29	1094–1402	239	6.6
Baltic	Baltic early group	(Tyers unpubl)	**BAL0_T86**	1052–1420	239	6.3
Imported	Vejby, Denmark	(Bonde and Jensen 1995)	**VEJBY_26**	1109–1370	239	6.1
Baltic	Gdansk regional chronology	(Wazny pers comm)	**GDANSK**	996–1985	239	5.7
Eastern Baltic	Hull Blaydes Staithe	(Hillam 1991)	HULLBLDS	1148–1464	228	5.6

Table 18: Dating evidence for the sequence **wa147** *(AD 1180–1362)*

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
Baltic	Salisbury Cathedral	(Miles *et al* 2004)	SARUM15	1117-1354	175	6.3
Baltic	Hull Magistrates Court	(Tyers 1998)	HMC_T165	1078–1369	183	5.5
Baltic	Copper Wreck 1	(Bonde and Wazny unpubl)	COP1_T29	1094–1402	183	5.4
Baltic	Exeter Bowhill	(Groves 2002)	BOWHILLB	1161–1483	183	4.4

Table 19: Dating evidence for the sequence **wa141269** (AD 1137–1375)

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
Baltic	Exeter Bowhill	(Groves 2002)	BOWHILLB	1161–1483	115	8.0
Baltic	Salisbury Cathedral	(Miles *et al* 2004)	SARUM15	1117–1354	218	6.5
Baltic	Hull Magistrates Court	(Tyers 1998)	HMC_T165	1078–1369	233	5.9
Baltic	Copper Wreck 1	(Bonde and Wazny unpubl)	COP1_T29	1094–1402	239	5.4

Table 20: Dating evidence for the sequence **wa148** (AD 1146–1365). Regional multi-site chronologies are in **BOLD**

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
Eastern Baltic	Magdalen College, Oxford	(Miles and Worthington 2000)	MAGDALN2	1080–1416	220	9.2
Baltic	Baltic early group	(Tyers unpubl)	**BALO_T86**	1052–1420	220	8.6
Baltic	Copper Wreck 4	(Bonde and Wazny unpubl)	COP4_T9	1011–1395	220	8.5
Baltic	Chapel Lane, Hull	(Tyers 2000)	CLS2000	1110–1393	220	8.0

Table 21: Dating evidence for the site sequence **WMNSTR15** (AD 827–1148). Regional multi-site chronologies are in **BOLD**

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
London	Turks Boatyard, Kingston	(Tyers 1995)	TUR63	906–1123	218	7.5
Shropshire	Shropshire Master Chronology	(Miles 1995)	**SALOP95**	881–1745	268	6.8
Hampshire	Winchester Round Table	(Barefoot and Haddon-Reece unpubl)	TABLE	1041–1211	108	6.8
Hertfordshire	Westwick Cottage	(Howard *et al* 1997)	WESTWICK	940–1179	209	6.6
London	Guildhall, City	(Tyers 2001b)	GYEM_T98	498–1212	322	6.6
London	Swan Lane, City	(Groves and Hillam 1987)	SWANMED	938–1192	211	6.5
London	Horsefair, Kingston	(Tyers 1991)	HOR_T27	904–1287	322	6.5
London	Merton Priory	(Tyers 1988a)	MPY_T7	922–1176	322	6.4
London	Thames Exchange, City	(Nayling 1991)	TEX_W70	645–1239	322	6.3

Table 22: Dating evidence for the site sequence **WMNSTR16** (AD 1007–1143)

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
London	Thames Exchange, City	(Nayling 1991)	TEX_W70	645–1239	137	7.2
London	Guildhall, City	(Tyers 2001b)	GYEM_T98	498–1212	137	6.7
London	Fennings Wharf, Southwark	(Tyers 2001b)	FW_W99	802–1435	137	6.3
London	Fleet Valley, City	(Tyers and Hibberd 1993)	VAL_W89	745–1316	137	6.2

Table 23: Dating evidence for the sequence **wa157** (AD 970–1090)

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
London	Guildhall, City	(Tyers 2001b)	GYEM_T98	498–1212	121	7.9
London	Fennings Wharf, Southwark	(Tyers 2001b)	FW_W99	802–1435	121	7.7
London	Billingsgate, City	(Tyers unpubl)	BIG_W280	611–1243	121	7.6
London	Thames Exchange, City	(Nayling 1991)	TEX_W70	645–1239	121	7.2

Table 24: Dating evidence for the site sequence **WMNSTR17** (AD 1124–1228). Regional multi-site chronologies are in **BOLD**

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
London	Millennium Bridge, City	(Tyers 1999)	MBC_T35	999–1389	105	9.1
London	Fleet Valley, City	(Tyers and Hibberd 1993)	VAL_W89	745–1316	105	8.8
Hampshire	Hampshire Master Chronology	(Miles 2003)	**HANTS02**	443–1972	105	8.4
Southern England	South Master Chronology	(Hillam and Groves 1994)	**SOUTH**	406–1594	105	8.1
Somerset	Abbey Barn, Glastonbury	(Bridge 1983)	GLAST	1095–1334	105	8.0
London	Billingsgate, City	(Tyers unpubl)	BIG_W280	611–1243	105	7.9
Somerset	Somerset Master Chronology	(Miles 2004)	**SOMRST04**	770–1979	105	7.8
Southern England	Southern England Master	(Bridge 1988)	**SENGLAND**	1083–1589	105	7.7
London	Horsefair, Kingston	(Tyers 1991)	HOR_T27	904–1287	105	6.7

Table 25: Dating evidence for the sequence **wa164** (AD 1124–1220). Regional multi-site chronologies are in **BOLD**

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
Southern England	South Master Chronology	(Hillam and Groves 1994)	**SOUTH**	406–1594	97	9.6
Hampshire	Hampshire Master Chronology	(Miles 2003)	**HANTS02**	443–1972	97	9.2
Gloucestershire	Gloucester Blackfriars	(Hillam and Groves 1993)	GLOUCBLF	1076–1219	96	8.5
Wiltshire	Salisbury Cathedral	(Miles *et al* 2004)	SARUM14	1053–1241	97	8.3

Table 26: Dating evidence for the sequence **wa165** (AD 1140–1228). Regional multi-site chronologies are in **BOLD**

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
London	London Master Chronology	(Tyers pers comm)	**LONDON**	413–1728	89	6.0
Somerset	Abbey Barn, Glastonbury	(Bridge 1983)	GLAST	1095–1334	89	5.8
Herefordshire	Dore Abbey	(Tyers and Boswijk 1998)	DORE1	1073–1195	56	5.7
Sussex	Rhenish Helm, Sompting	(Tyers 1988b)	SOMPTING	1182–1292	47	5.7

*Table 27: Dating evidence for the site sequence **WMNSTR18** (AD 1200–1402). Regional multi-site chronologies are in **BOLD***

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
Baltic	Abbots Lane, Southwark	(Tyers 1994)	ABB_BALT	1278–1368	91	12.0
Baltic	Baltic area 2	(Tyers unpubl)	**BAL2_T66**	1257–1615	146	10.2
Baltic	Baltic early group	(Tyers unpubl)	**BALO_T86**	1052–1420	203	8.8
Baltic	Chapel Lane, Hull	(Tyers 2000)	CLS2000	1110–1393	194	7.6
Baltic	Abbotts Lane, Southwark	(Tyers 1994)	ABB_DOOR	1165–1386	187	7.4
Baltic	Copper Wreck 4	(Bonde and Wazny unpubl)	COP4_T9	1011–1395	196	7.3
Baltic	New Baxtergate, Grimsby	(Groves 1992)	GRIMSBY1	1100–1405	203	7.3
Baltic	Hull Magistrates Court	(Tyers 1998)	HMC_T165	1078–1369	203	7.0
Baltic	Millennium Bridge, City	(Tyers 1999)	MBC_BALT	1085–1415	203	6.2

*Table 28: Dating evidence for the site sequence **WMNSTR19** (AD 1146–1345). Regional multi-site chronologies are in **BOLD***

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
Baltic	Hull Magistrates Court	(Tyers 1998)	HMC_T165	1078–1369	200	11.9
Baltic	Salisbury Cathedral	(Miles *et al* 2004)	SARUM15	1117–1354	200	11.6
Baltic	Copper Wreck 1	(Bonde and Wazny unpubl)	COP1_T29	1094–1402	200	11.0
Baltic	Baltic early group	(Tyers unpubl)	**BALO_T86**	1052–1420	200	10.2
Baltic	Gdansk regional chronology	(Wazny pers comm)	**GDANSK**	996–1985	200	8.8
Baltic	Chapel Lane, Hull	(Tyers 2000)	CLS2000	1110–1393	200	8.2
Eastern Baltic	Magdalen College, Oxford	(Miles and Worthington 2000)	MAGDALN2	1080–1416	200	8.0
Baltic	Abbotts Lane, Southwark	(Tyers 1994)	ABB_DOOR	1165–1386	181	7.7
Baltic	New Baxtergate, Grimsby	(Groves 1992)	GRIMSBY1	1100–1405	200	7.3

Table 29: Dating evidence for the site sequence **WMNSTR20** (AD 1151–1369). Regional multi-site chronologies are in **BOLD**

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
Eastern Baltic	Magdalen College, Oxford	(Miles and Worthington 2000)	MAGDALN2	1080–1416	219	8.2
Baltic	Baltic early group	(Tyers unpubl)	**BALO_T86**	1052–1420	219	8.1
Baltic	Copper Wreck 1	(Bonde and Wazny unpubl)	COP1_T29	1094–1402	219	8.1
Baltic	Abbotts Lane, Southwark	(Tyers 1994)	ABB_DOOR	1165–1386	205	7.2
Baltic	Hull Magistrates Court	(Tyers 1998)	HMC_T165	1078–1369	219	7.2
Baltic	New Baxtergate, Grimsby	(Groves 1992)	GRIMSBY1	1100–1405	219	6.7
Eastern Baltic	Southwark ship	(Tyers 1990)	GAS-SHIP	1052–1370	219	6.2
Eastern Baltic	East St Helen's Street, Abingdon	(Miles and Haddon-Reece 1995)	STHELEN2	1216–1416	154	6.0
Baltic	Gdansk regional chronology	(Wazny pers comm)	**GDANSK**	996–1985	219	5.8

Table 30: Dating evidence for the site sequence **WMNSTR21** (AD 1169–1360). Regional multi-site chronologies are in **BOLD**

County or region	Chronology name	Short publication reference	File name	Spanning	Overlap (yrs)	*t*-value
Baltic	Hull Magistrates Court	(Tyers 1998)	HMC_T165	1078–1369	192	9.5
Baltic	Copper Wreck 4	(Bonde and Wazny unpubl)	COP4_T9	1011–1395	192	8.7
Baltic	Chapel Lane, Hull	(Tyers 2000)	CLS2000	1110–1393	192	8.6
Baltic	Abbotts Lane, Southwark	(Tyers 1994)	ABB_DOOR	1165–1386	192	8.0
Baltic	Baltic early group	(Tyers unpubl)	**BALO_T86**	1052–1420	192	7.3
Baltic	New College Oxford, bell tower door	(Miles and Worthington 2006)	NWCOLLG2	1086–1357	189	6.5
Baltic	New Baxtergate, Grimsby	(Groves 1992)	GRIMSBY1	1100–1405	192	6.2
Baltic	Westminster Abbey	(Miles and Bridge 2005)	WMNSTR5	1162–1330	162	5.9
Eastern Baltic	Magdalen College, Oxford	(Miles and Worthington 2000)	MAGDALN2	1080–1416	192	5.8

FIGURES
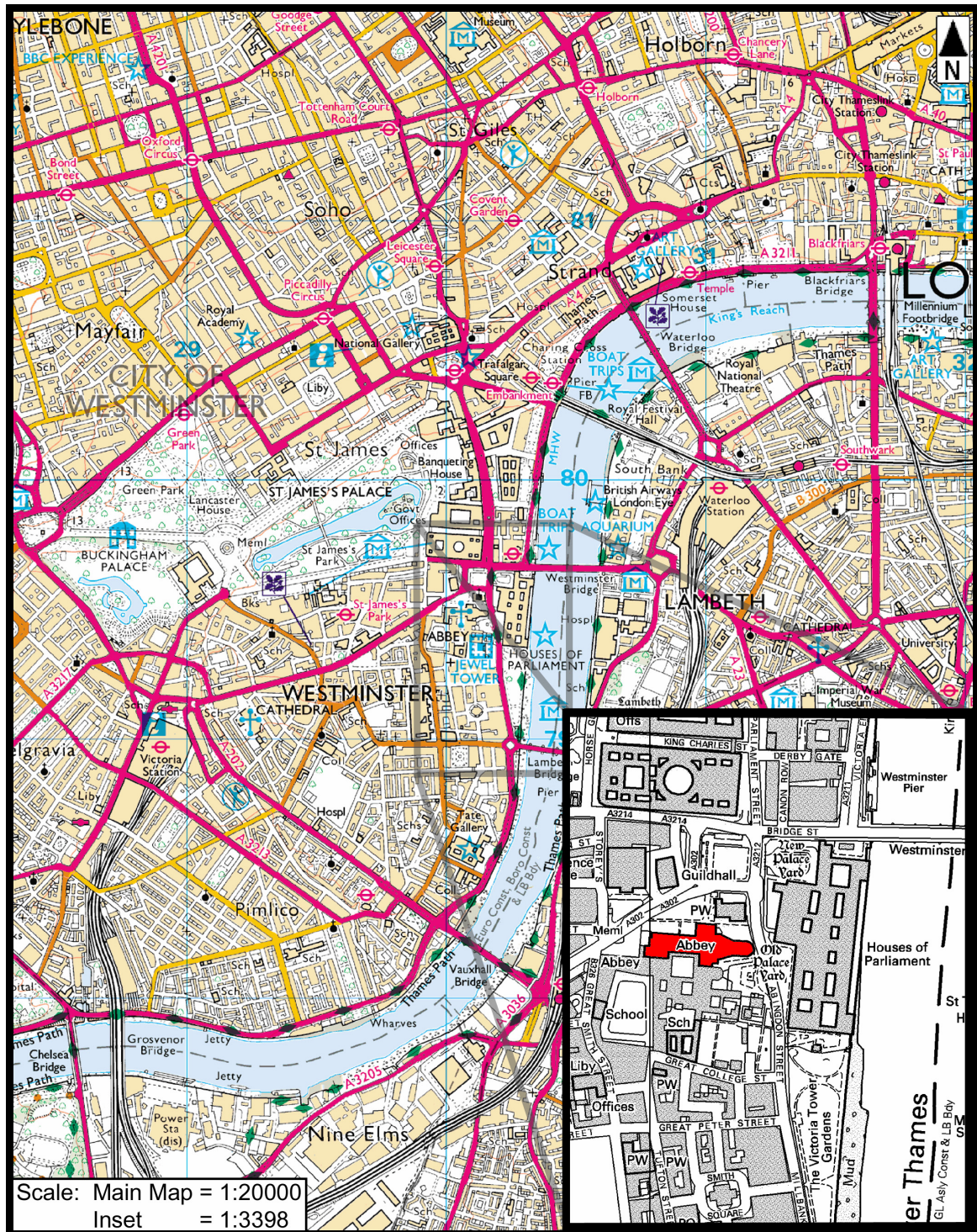
Figure 1: Location of Westminster Abbey, London
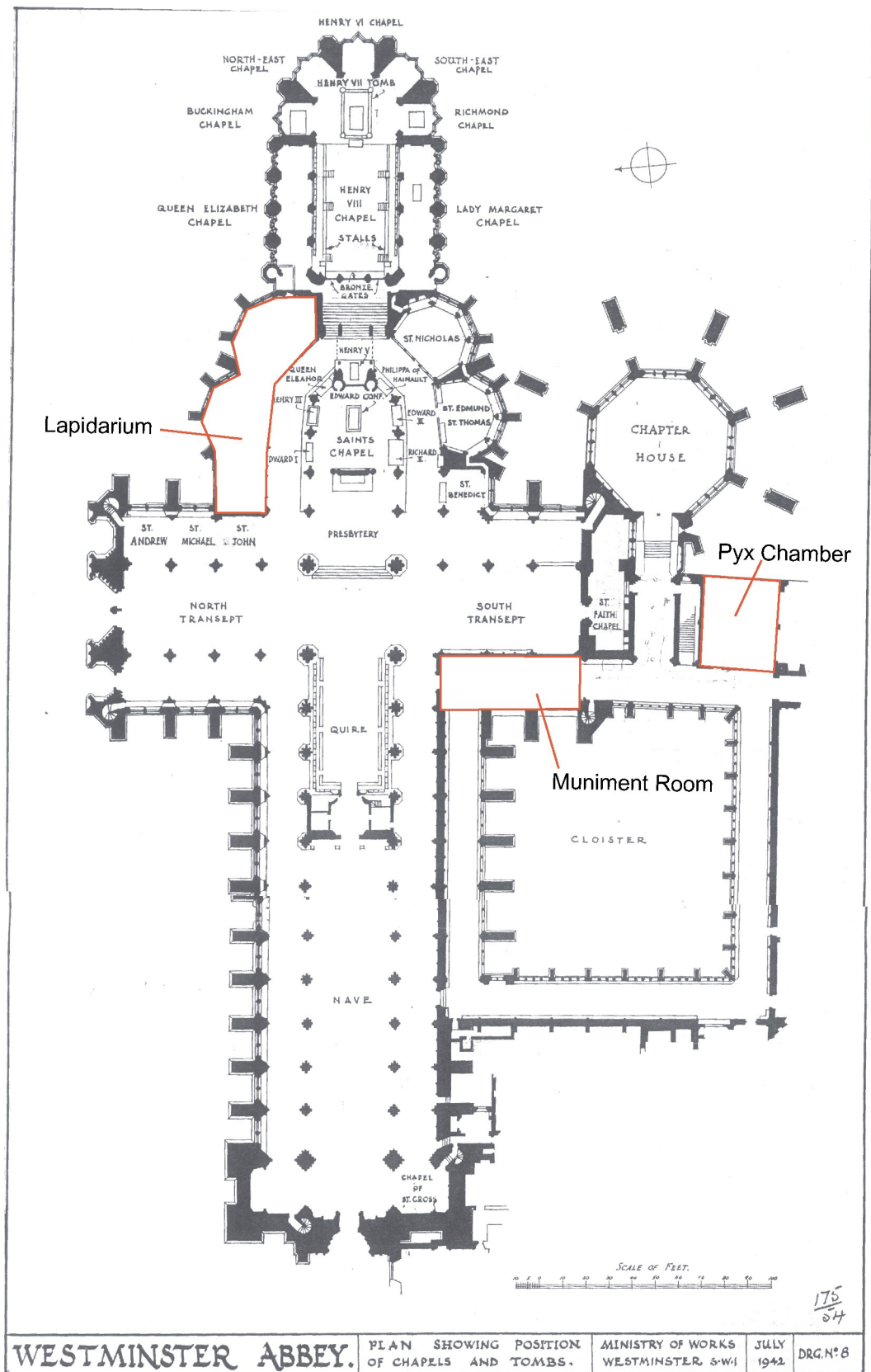
Figure 2: Plan of the Abbey showing the locations, outlined in red, of the Pyx Chamber and (at first-floor level) Muniment Room and Lapidarium

Figure 3: Lesser Treaty Chest (D Miles)
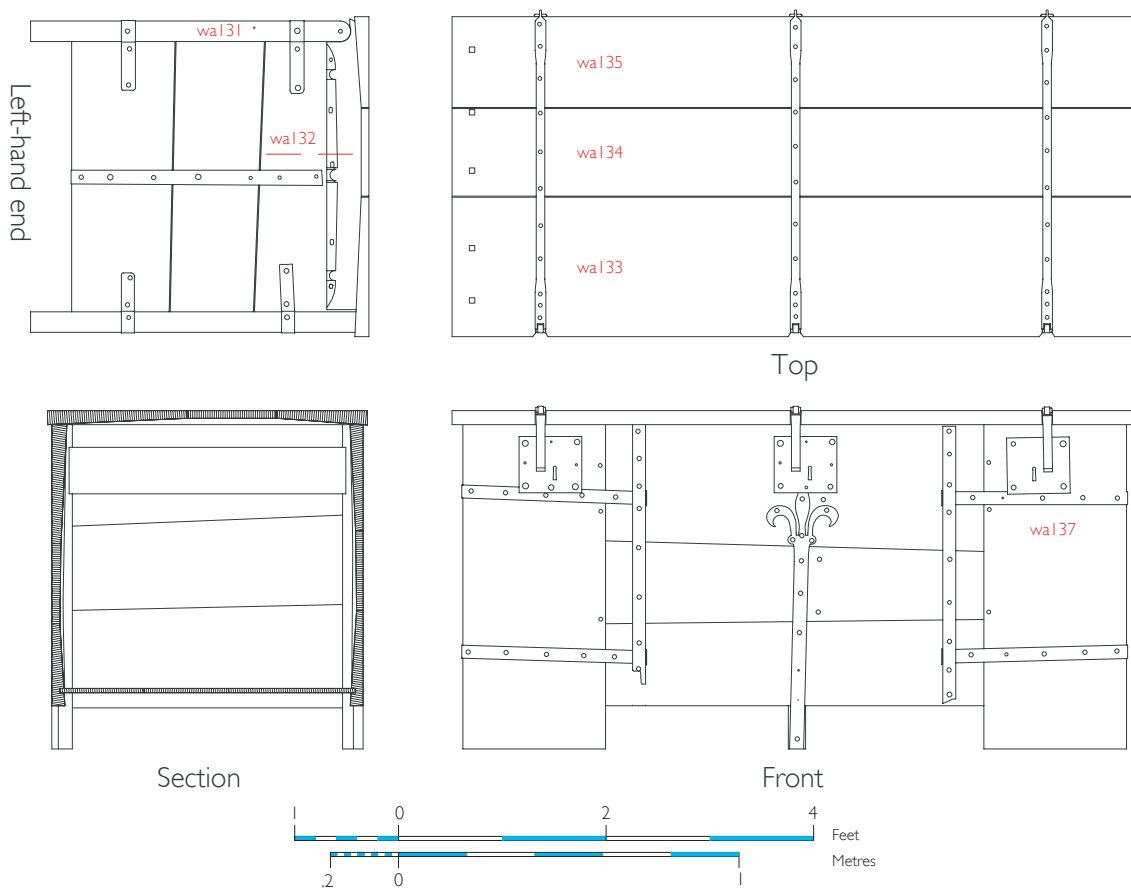
Figure 4: Measured drawings of Lesser Treaty Chest showing sample locations (D Miles)

Figure 5: Detail of hinge on Lesser Treaty Chest (D Miles)

Figure 6: Detail of security chains on back of Lesser Treaty Chest (D Miles)

Figure 7: Dr John Fletcher measuring ring sequences of Greater Treaty Chest (D Haddon-Reece)

Figure 8: Greater Treaty Chest (D Miles)
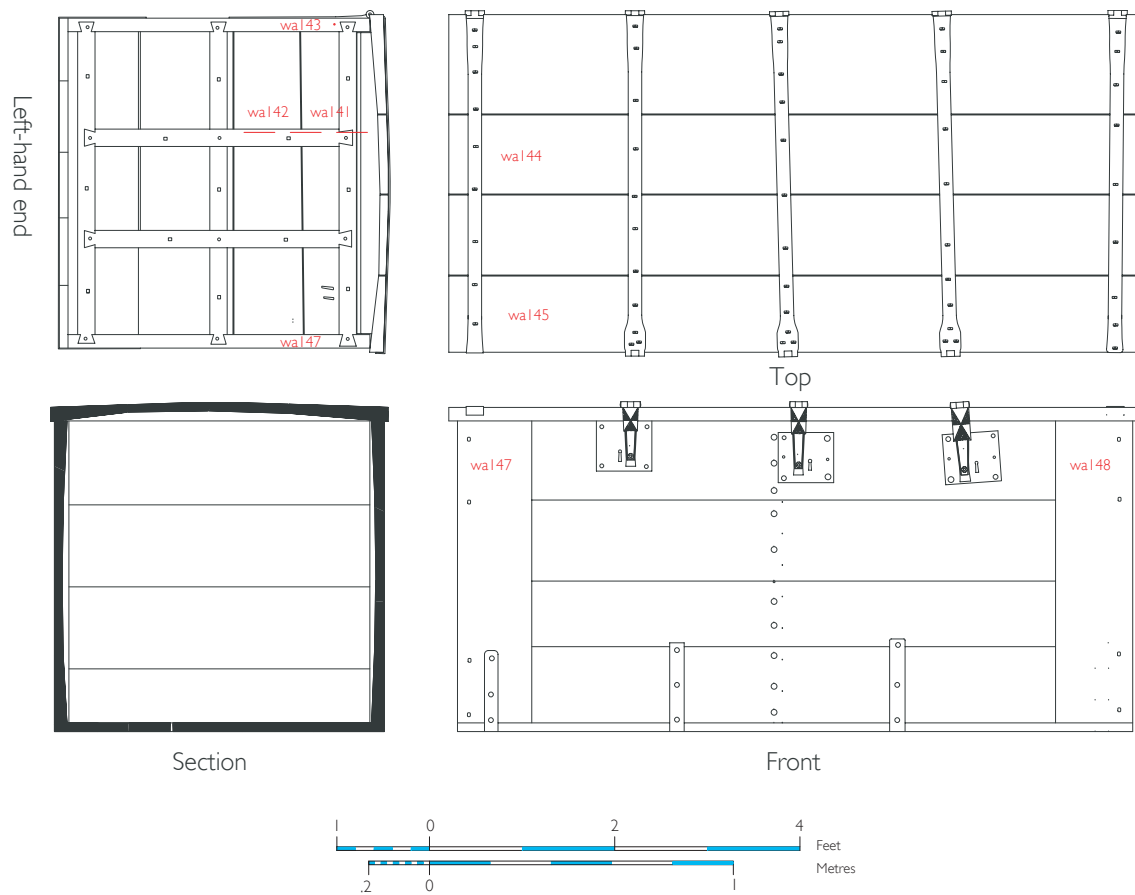
Figure 9: Measured drawings of Greater Treaty Chest showing sample locations (D Miles)

3-2008

Figure 10: Cope Chest (D Miles)

Top

Front

wa201
wa202
wa203
wa204

wa205
wa206
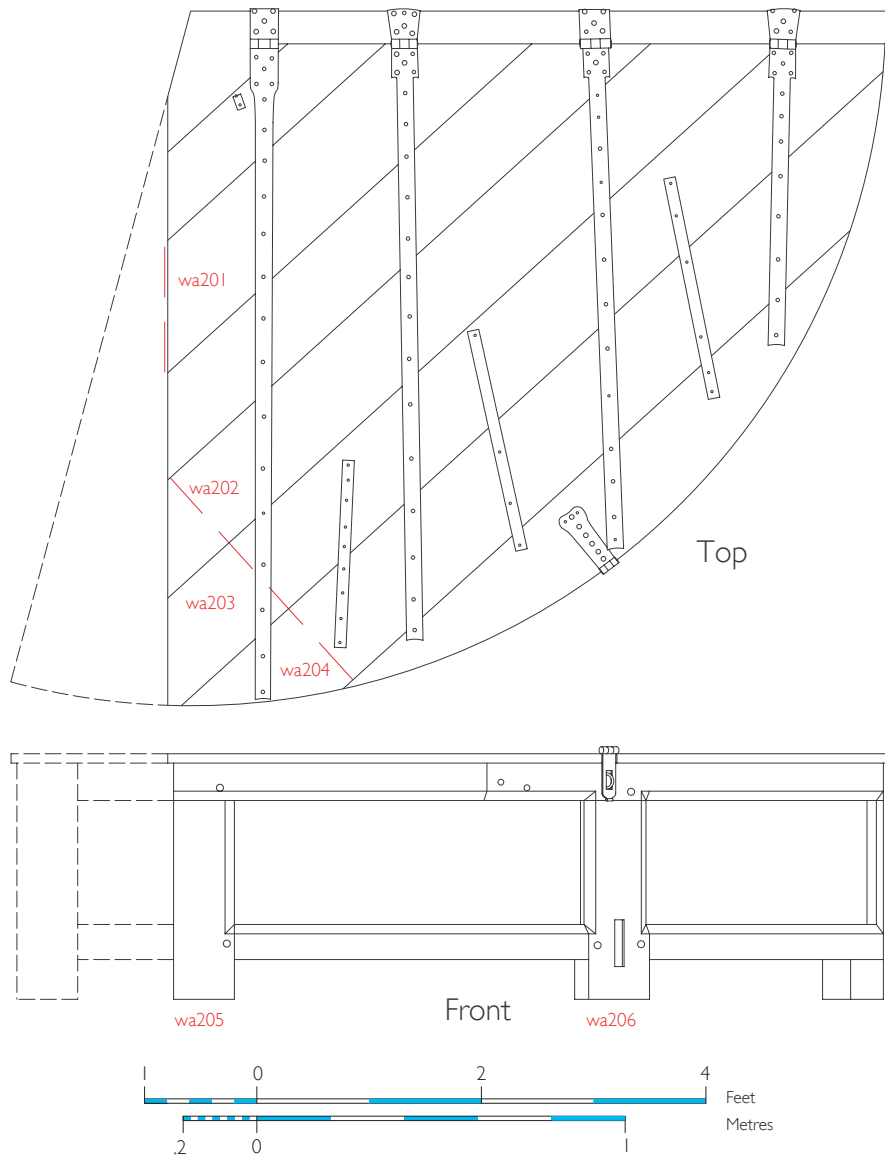
Figure 11: Measured drawings of Cope Chest showing sample locations (D Miles). Dashed lines indicate the original extent of the chest

Figure 12: *Detail of top left front joint of Cope Chest showing chamfer mis-aligning with corner post (D Miles)*

Figure 13: *Detail of altered junction of rear post and top left rail of Cope Chest (D Miles)*
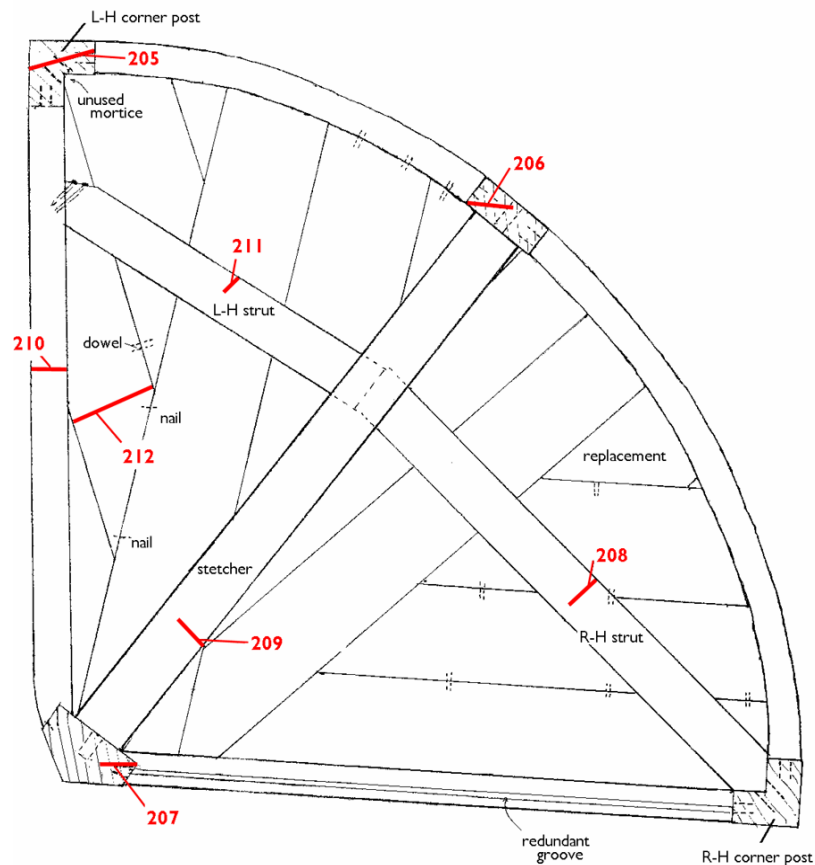
Figure 14: *Plan of underside of Cope Chest, showing sample loctions (after W Rodwell)*

Figure 15: *Shelf or Canopy, Pyx Chamber, looking south-east (D Miles)*
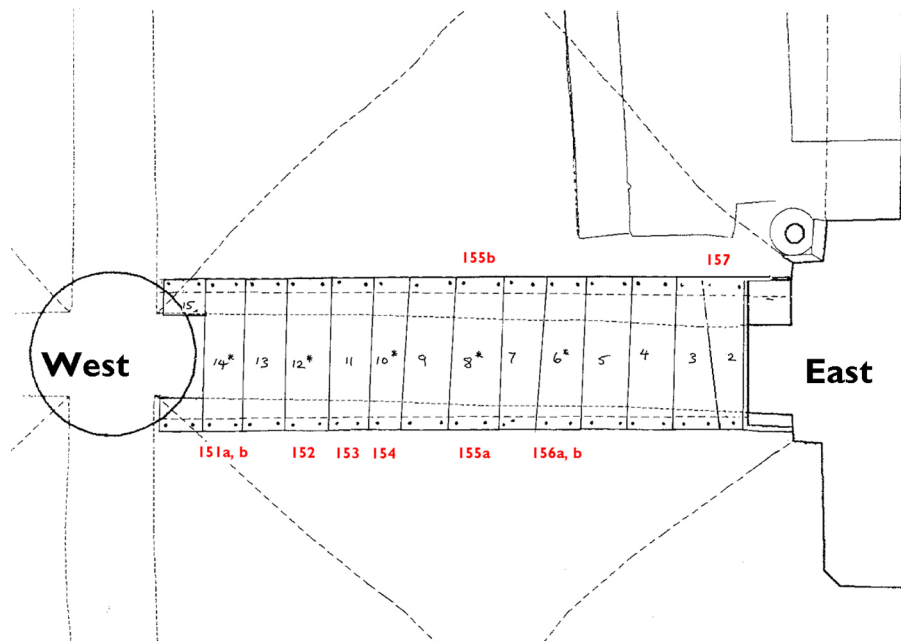
Figure 16: *Sketch drawing of boards making up shelf or canopy, Pyx Chamber, showing sample locations (after W Rodwell)*

Boards from shelf in Pyx Chamber

Bottom panels from Long Chest

0   1

Feet

Metres

0   0.2
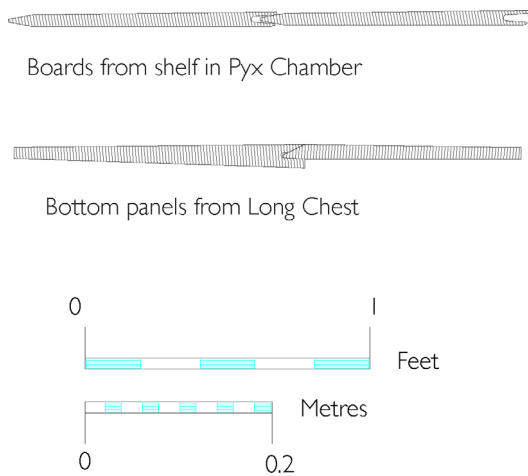
Figure 17: *Comparative sections through typical boards comprising shelf or canopy, Pyx Chamber, and the Long Chest, Muniment Room (D Miles)*

Figure 18: *Scratched assembly marks and nail heads to shelf or canopy boards, Pyx Chamber (D Miles)*

Figure 19: *Photo of underside of shelf or canopy boards, Pyx Chamber, showing painted decoration (P Payne)*

Figure 20: Long Chest, Muniment Room (D Miles)
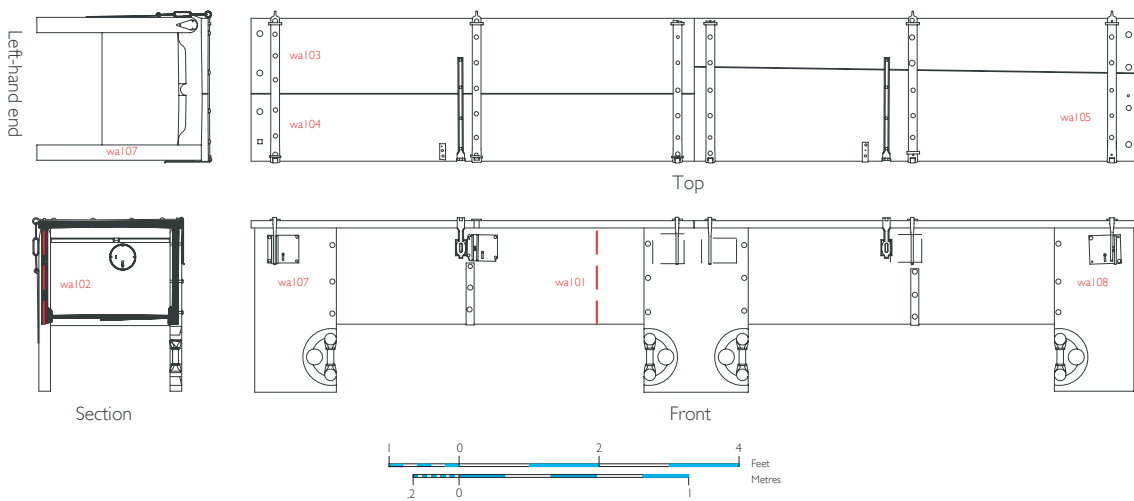
Figure 21: Measured drawings of the Long Chest, Muniment Room, showing sample locations (D Miles)

Figure 22: Detail of foot of Long Chest, Muniment Room (D Miles)

Figure 23: Front left lock plate, Long Chest, Muniment Room (D Miles)
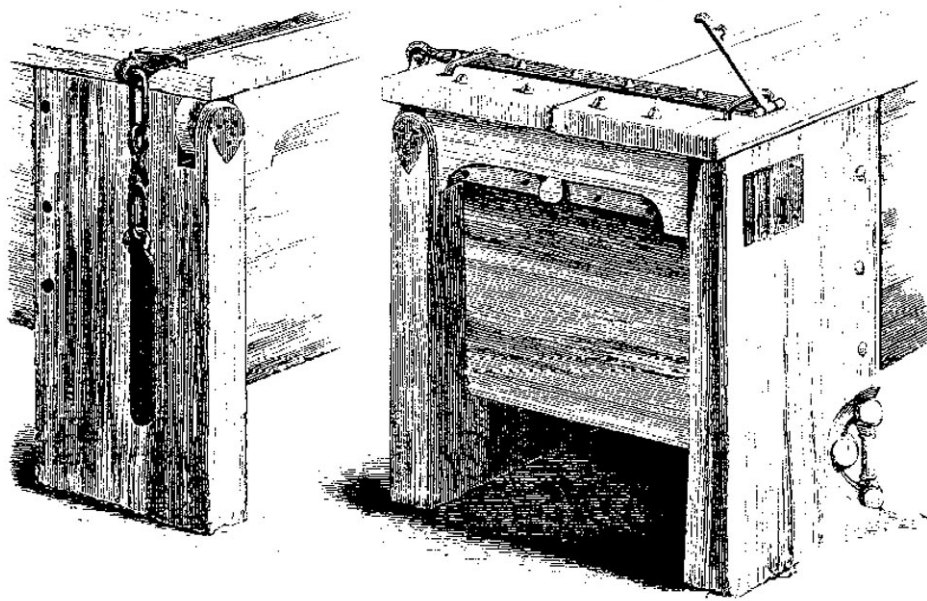
Figure 24: Drawings of left end of Long Chest, Muniment Room (Scott 1863)

Figure 25: Till of Long Chest, Muniment Room (D Miles)

Figure 26: The Large Chest, Muniment Room (J Meadows)
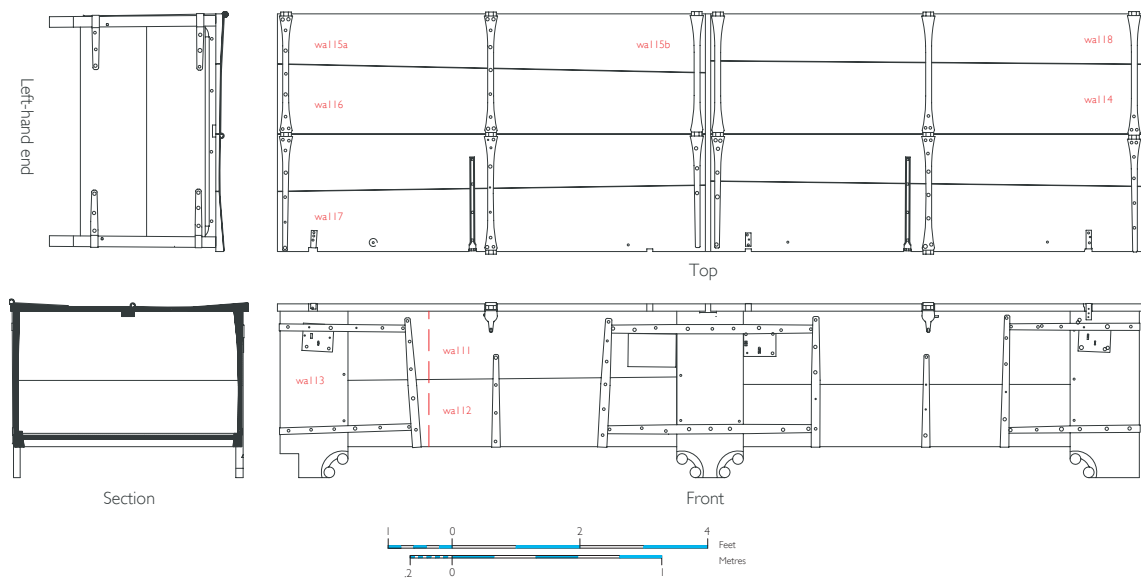
Figure 27: Measured drawings of the Large Chest, Muniment Room, showing sample locations (D Miles)

Figure 28: Top of lid to Large Chest, Muniment Room, showing mark of former movable stud for secret locking device (D Miles)

Figure 29: Top of front board to Large Chest, Muniment Room, showing cut-out for secret locking device (D Miles)

Figure 30: The Deep Chest, Muniment Room (J Meadows)
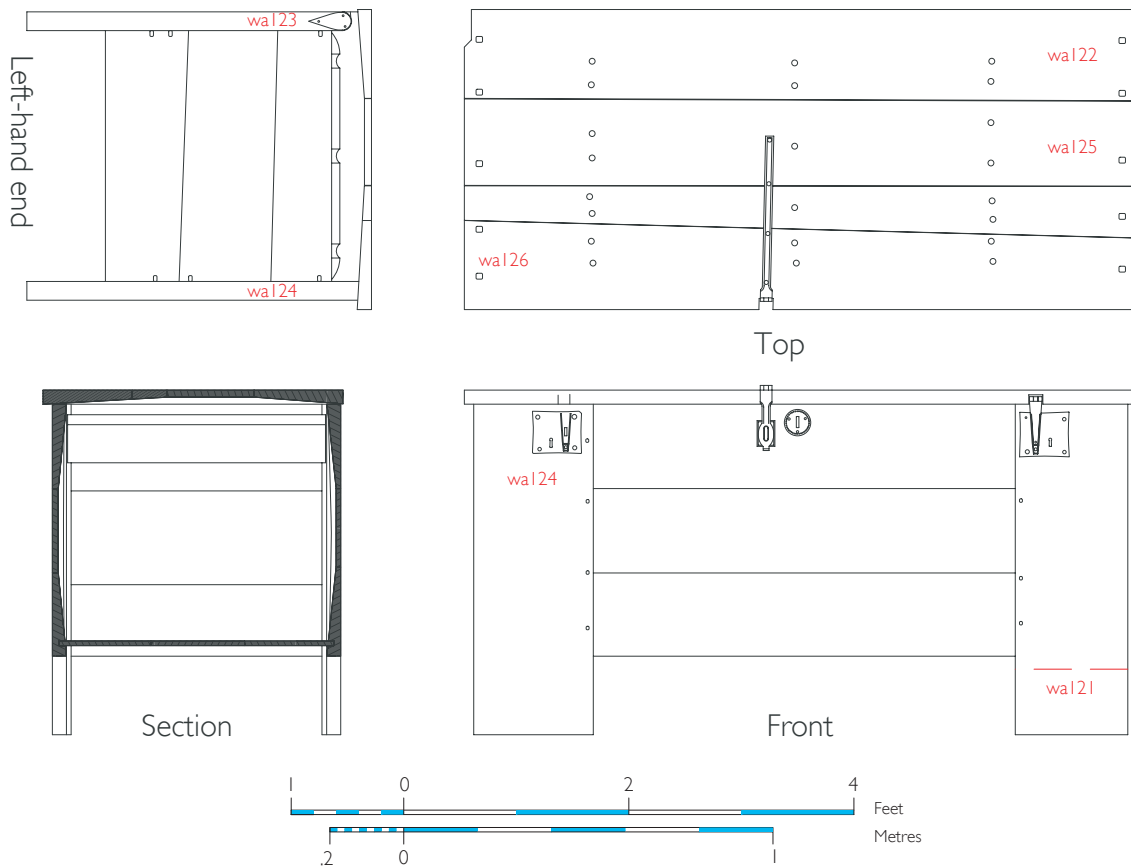
Figure 31: Measured drawings of the Deep Chest, Muniment Room, showing sample locations (D Miles)

Figure 32: Till in the Deep Chest, Muniment Room (D Miles)

Figure 33: The Richard II Cupboard or Armoire, Muniment Room (J Meadows)

Section   Left-hand end   Front
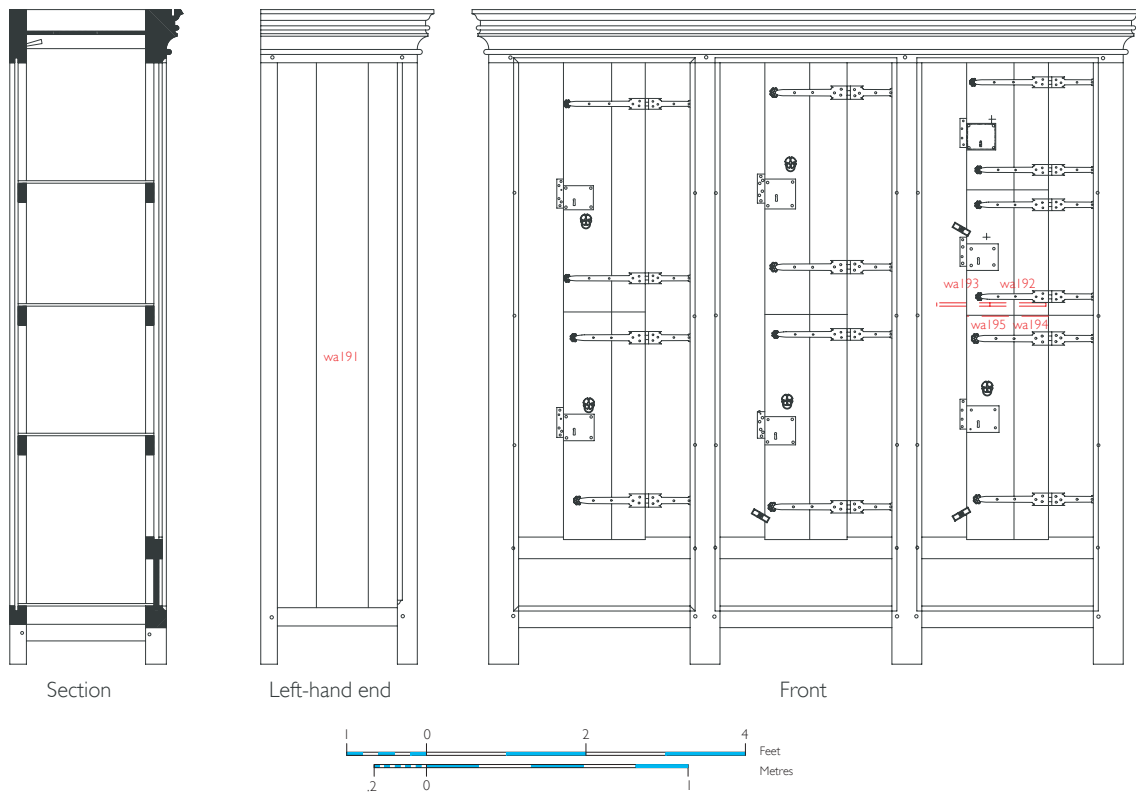
Figure 34: The Richard II Cupboard or Armoire, Muniment Room, showing sample locations (D Miles)

Figure 35: Knuckle of hinge to the Richard II Cupboard or Armoire, Muniment Room (D Miles)

Figure 36: Termination of hinge to the Richard II Cupboard or Armoire, Muniment Room (D Miles)

Figure 37: The large hutch-type chest, Lapidarium (D Miles)
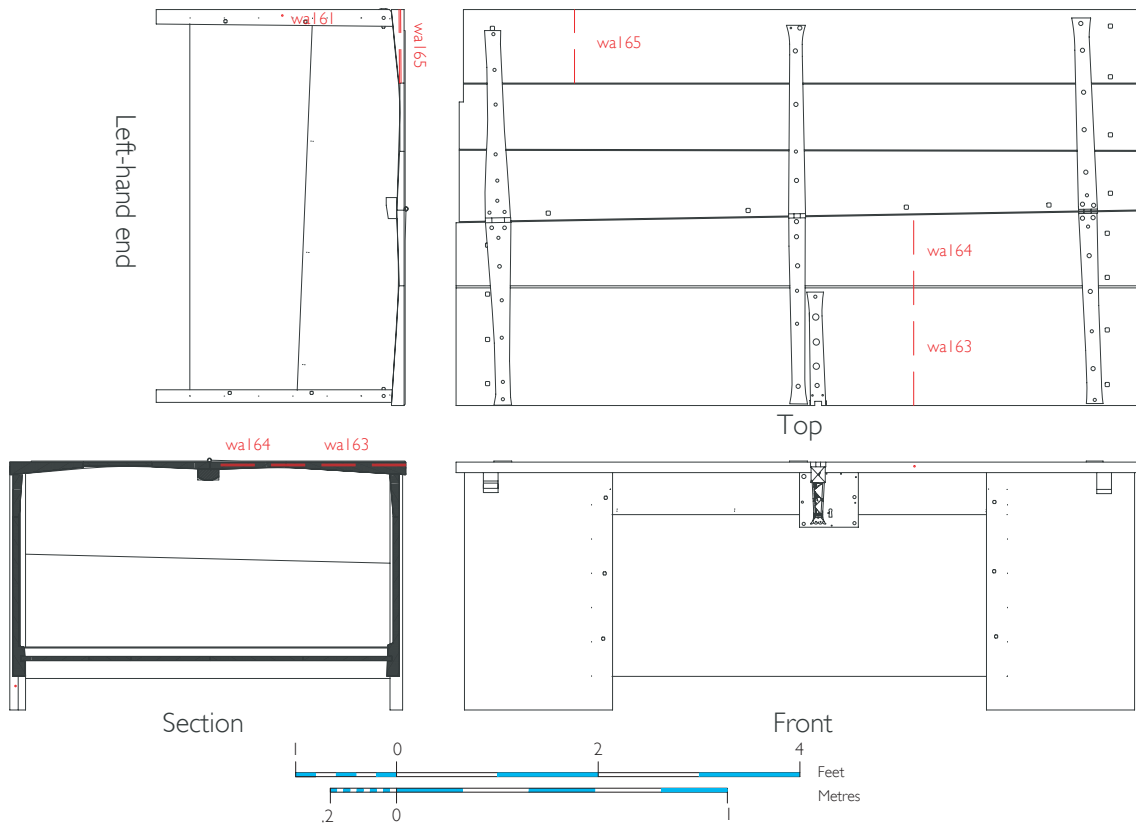
Figure 38: Measured drawings of the large hutch-type chest, Lapidarium, showing sample locations (D Miles)

Figure 39: Photograph of lock plate and hasp to the large hutch-type chest, Lapidarium (D Miles)

Figure 40: *The large panelled chest, Lapidarium (D Miles)*
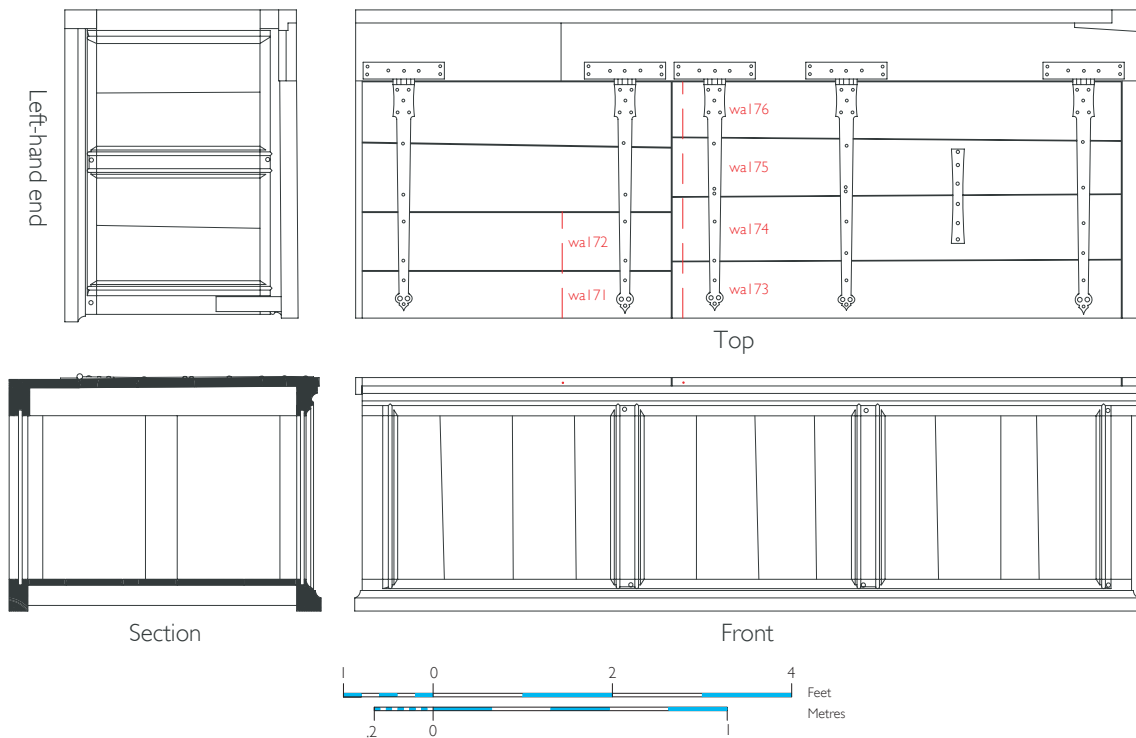
Figure 41: *Measured drawings of the large panelled chest, Lapidarium, showing sample locations (D Miles)*

Figure 42: Details of hinges to the large panelled chest, Lapidarium (D Miles)

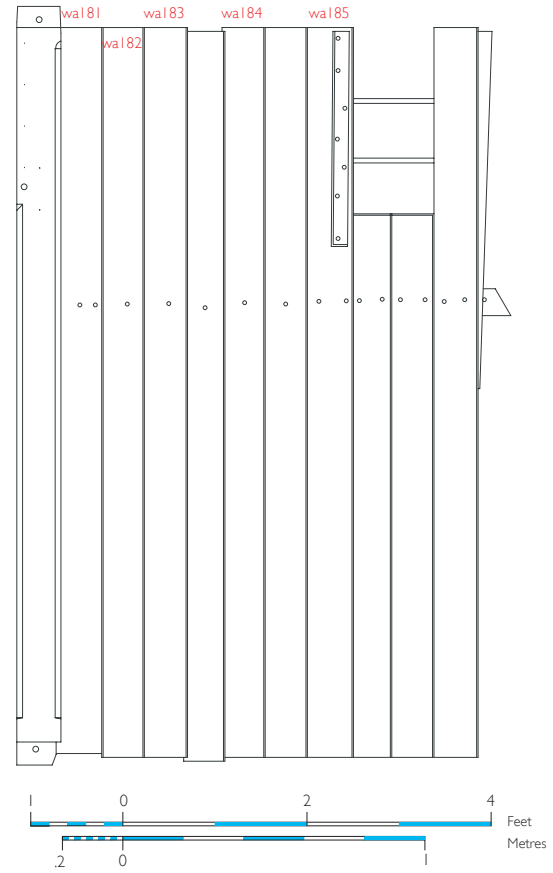*Figure 43:* *Wall panel from Muniment Room, now in Lapidarium (photographer)*

Figure 44: *Measured drawing of the front of section of wall panel from Muniment Room, now in Lapidarium, showing sample locations (D Miles)*

Figure 45: *Drilling the Long Chest with the micro-borer (D Miles)*

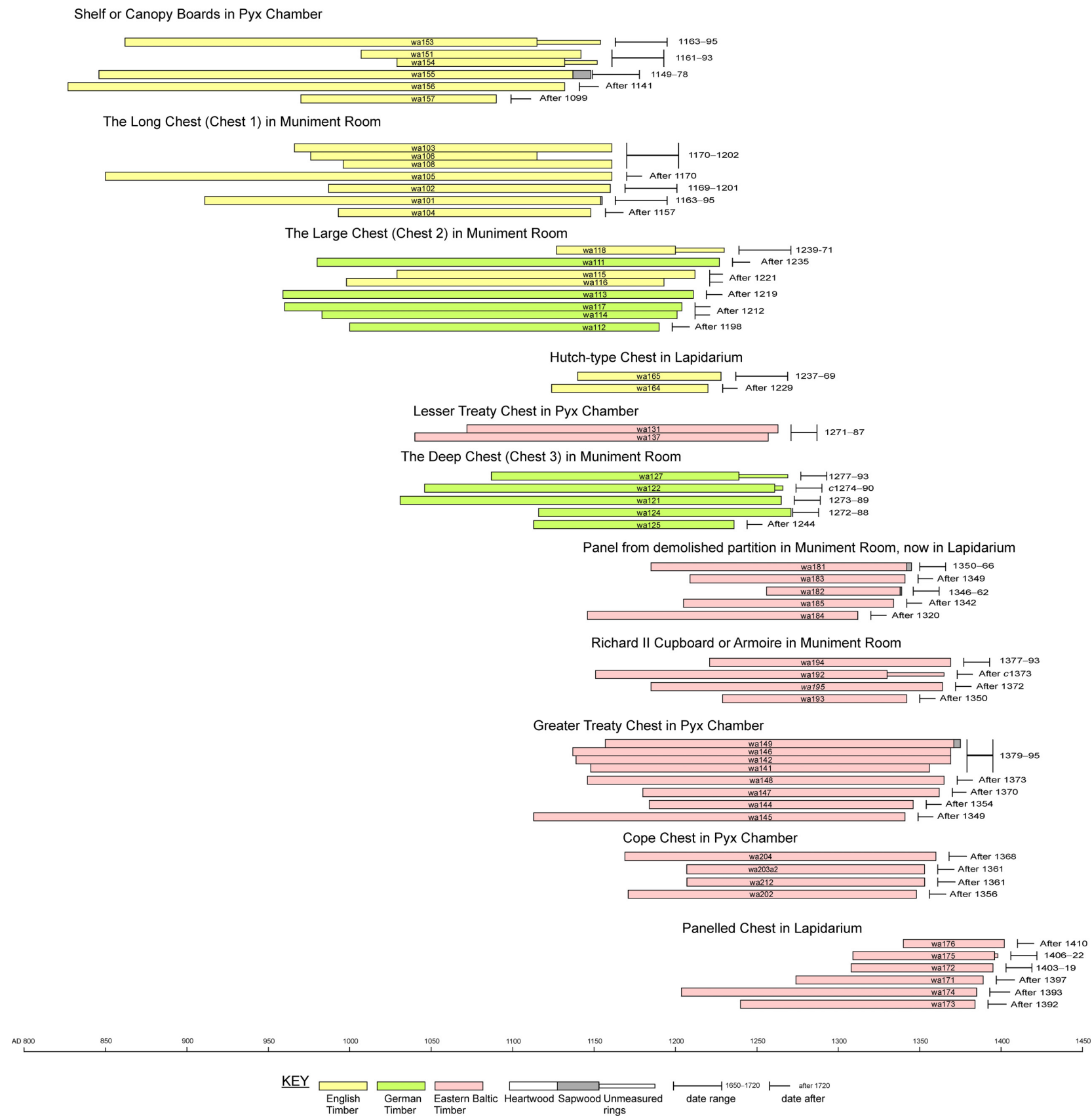**Figure 46:** *Micro-bore hole (8mm diameter) and core (M Bridge)*

Figure 47: Bar diagram showing positions of dated samples