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Summary

Six doors were sampled as part of a programme of reassessing the historic medieval timberwork of the Abbey. Some of these doors were initially sampled by Dr John Fletcher in the 1970s. The present analysis resulted in all the doors being dated.

The dating has identified the door called 'Pyx', reused in the Chapter House vestibule, as having originated from the Saxon abbey constructed by Edward the Confessor, and constructed between AD 1032-64, making it the oldest scientifically-dated door in Britain. The present Pyx doors from the cloister were likely inserted as a consequence of the AD 1303 robbery of the Royal Treasury from the Chapter House undercroft. A door leading to the stair-vice from the north transept is shown to be original to the mid-thirteenth century reconstruction by Henry III, and that in the south transept at Poet's Corner as a mid-fourteenth century replacement. Finally, a door reused in the passage leading to the Chapter House undercroft is shown to be of similar age to the Chapter House and middle section of the church. Apart from the 'Pyx' door and the Chapter House undercroft door, all the dated material was found to be of either Baltic or German provenance.

Keywords

Dendrochronology
Standing Building

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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, although no real details exist of what the pre-AD 1000 church looked like.

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. He started with the choir, and the new church eventually covered much of the area under the present Abbey (Lethaby 1906, 102). 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 the 28th of December AD 1065. Fabric surviving from this Saxon church includes the Rere-Dorter, Chapel of the Pyx and adjoining undercroft, and the Frater. All of this is stone, but there also survives a single timber relic, the cut-down door on the south side of the Chapter House Vestibule, known simply as 'Pyx'. Recently, this door has thought to have been reused from the original doorway to the Pyx Chapel of Edward the Confessor (Hewett 1985). Later in AD 1066, Edward's successor Harold was defeated by William the Conqueror, and the Saxon period came to a close.

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 (Fig 2). This report summarises the study and analysis of six of these doors, the attempt to phase and provenance the timber used in their construction, and their relationship to the perceived sequence of building at the Abbey.

Description of the Doors:

Altogether six doors were studied. The oldest was thought to be the door on the south side of the Chapter House Vestibule, known as the 'Pyx', but other doors were studied from the Pyx Chamber itself (Fig 3), the north and south transepts, and the passage leading down to the Chapter House undercroft (Fig 4). Most of the doors are of different sizes and forms of construction. Indeed, some are older doors presumably reused from other parts of the Abbey. Each door has been dealt with separately below as well as in the analysis and discussion stages.

The Door called 'Pyx', Chapter House Vestibule

The door from the Chapter House Vestibule into the under-stairs cupboard on the south side has historically been called the 'Pyx' door, although it does not now lead into the Pyx chamber, as it formally did. It is not to be confused with the two large doors from the cloister into the Pyx chamber or treasury itself, or the door to the Chapter House undercroft. The door is described by Hewett (1985), who was one of the first to appreciate its significance. At present the door is just over 4ft (1270mm) in width and 6ft-6in (1980mm) in height (Fig 5). It is constructed of five boards about 1½in (40mm) thick and ranging in width from 9in (225mm) to 15½in (390mm). The boards are rebated, without stops, half the thickness of the boards by 1⅜in (35mm). Although Hewett (1985, 155-6) stated that the boards were riven, closer inspection found that in fact they were all converted tangentially by sawing through and through. Nevertheless, the

boards were fully seasoned before jointing, as the deformation typical with through-and-through conversion was not evident here (Miles 1997).

The boards are connected by three flush, inset ledges in the shape of two opposed dovetails, the edges cut slightly concave and secured by pegs. There are also about three edge-dowels ½in in diameter per joint which pass through the centreline of the rebate. Two ledges were placed top and bottom on the back, and in the middle on the front. There still remains a central strap with a split curl surviving on the original front, which is now the back (Fig 6). There is also the impression of a Romanesque C and strap hinge with split-curl terminals at the top of the door (Geddes 1999, 344; Rodwell, 2002, 7). The original front of the door was originally covered with animal skin, of which some fragments still survive beneath the central iron strap. This skin had been reputed to have been human, but recent analysis has shown that it is actually non-human (Rodwell *pers comm*).

The door has been reduced by about 4in (100mm) on all sides and inserted in its present position back to front on the south side of the Chapter House vestibule when it was reconstructed together with the Chapter House *c* AD 1250. It is not known where in the Abbey the door would have originally been located, although Hewett suggests it may have originated from the Saxon Pyx Chapel.

Outer and Inner Doors, Pyx Chamber

A pair of doors lead from the east cloister range, just south of the Chapter House vestibule, into the Pyx Chapel (Figs 3 and 7). They are reputed to have replaced doors damaged in the burglary of AD 1303, as the Pyx Chamber evidently served for a time as the King's treasury. These are very substantial in nature, clearly constructed at the same time, and are composed of a series of 5½in (138mm) boards slotted in between vertical muntins, rather than between two sets of ledges as suggested by Hewett (1985, 174). Overall, they measure 4ft-2in (1270mm) wide for the outer door (Fig 8), and 3ft-9½in (1155mm) wide for the inner door (Fig 9). Both doors measure about 7ft-8in (2340mm) high and the heads are two-centred in shape.

There are five muntins measuring 3¼in (82mm) square with a ⅝in (16mm) groove ⅞in (22mm) deep which, together with the 7in wide durns, or jambs, accommodated six boards (Fig 10). Each door has 10 ledges measuring 3¼in (82mm) by 1¼in (32mm) deep, let into the outer face of both doors, as well as the inside face of the inner door, the intersections being riveted together with square roves. The ends of the ledges are jointed to the door jambs with re-entrant shouldered barefaced lap-dovetails. The ledges on the inside of the outer door are set diagonally in tension, the width of these scaled down to match the ledges in vertical section.

Each of the doors has three large wooden stock-locks bolted to the inside. The outer door is further protected by an iron bar and hasp, which when locked covers all three keyholes, and the inner door has an iron bolt to allow the door to be locked from the inside. Disused keyholes in both doors show that the doors have had earlier locks, since replaced. Each door is hung on large band-hinges with corresponding bands on the inside and riveted through with the ledges.

North-East Stair Vice, North Transept

In the north transept, the small door at the bottom of the north-east vice consists of four boards with V-edge joints (Figs 2 and 11). There were originally five chamfered ledges on the back, but only the lower two are replacements, as is the lower two thirds of the left-hand board. The cross-boards on the back of the door have also been applied later. The door measures 3ft (900mm) wide and 7ft-3in (2210mm) high with a two-centred head. The boards measure ⅞in (22mm) at the thick end, tapering to ⅝in (16mm) at the start of the V-joint (Fig 12). The

original surviving ledges measure approximately 1¼in (32mm) by 2in (50mm) and are bevelled, not half-round as stated in Geddes (1999, 344).

Decorative ironwork includes two strap hinges with two pairs of tendrils and pointed lobe, and a raised bar over the weld (Geddes 1999, 344). The north transept is thought to have been completed by AD 1253 when the north porch adjacent was being leaded, and is basically contemporary with the Chapter House. There is no reason to think that the door was not made for its present situation, and is most likely to be primary mid-thirteenth century fabric.

South-East Passage Door, South Transept (Poets' Corner)

The corresponding door in the south-east corner of the south transept is very different in construction (Figs 3 and 13). This door, as seen from the main body of the Abbey, has a series of seven vertical square-edged boards, clench-nailed in a square pattern to 12 horizontal boards on the back, of which one is a replacement. It is slightly wider than its north transept counterpart, being 3ft-9in (1m) wide, and 7ft (2130mm) high, again with a two-centred head. The boards measure between 6in (150mm) and 7in (175mm) in width and are ¾in in thickness (Fig 14). The two layers of boards are nailed together by clenched nails in a 3in (75mm) grid, some of which accidentally align with the joints in the boards.

Door to Chapter House Undercroft

The passage entered from the south transept door described above leads to the stair vice leading to the triforium level, as well as continuing downwards to the Chapter House undercroft (Fig 4). At the bottom of the first flight of steps leading to the undercroft is a large door which has been cut-down and reused from elsewhere. It measures 4ft (1213 mm) wide by 6ft 4in (1930mm) high with a square top. The outer face consists of four old planks abutting a replacement hanging stile, probably repaired by Sir Gilbert Scott in the nineteenth century (Fig 15). Indeed, it is thought that he probably inserted this door in its present position around AD 1865 when he was restoring the north transept. The planks are about 1⅛in (30mm) in thickness tapering to ¾in (20mm) and have 2in (50mm) deep V-edged joints. The inside face of the door consists of a 5in (130mm) by 1¾in (45mm) thick locking stile, a bottom rail slightly thinner and wider, and braces averaging 1½in (38mm) and 1¾in (45mm) in thickness. The boards are fixed to the framing by large 1in (25mm) diameter flat-headed clout nails. The bottom rail is dovetail-lap jointed into the stile. A significant feature of this door is the diagonal braces / ledges which are set at different angles (Figs 15 and 16).

The undercroft to the Chapter House was used at some point as a treasury, and although the documented AD 1303 burglary is generally thought to relate to the Pyx Chamber, recent research suggests that it was actually in the undercroft, and that the burglary took place through a window. Whilst there was probably no door at the present position of the undercroft door, there is evidence for a 'pit-fall' beyond, with a section of wooden steps which might have served as a type of draw-bridge to secure the undercroft from inside (Rodwell *pers comm*).

Objectives of dating:

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

- to ascertain whether the door on the south side of the Chapter House vestibule, generally known as the 'Pyx' door, is an eleventh century door, and if so, whether it derives from the period of Edward the Confessor or later

- to determine whether the inner and outer doors of the Pyx Chamber are contemporaneous, and if one or both of them pre- or post- date the AD 1303 burglary

- to establish the date of the door in the north transept leading to the north-east stair vice, and confirm that it is an original mid-thirteenth century door

- to try and determine the date of the door in the south transept leading to the south-east stair vice, and to try and determine how the date relates to the sub-crypt door in the White Tower, Tower of London, which is of the mid-fourteenth century and closely resembles the south transept door at Westminster

- to ascertain the date of the door leading to the Chapter House undercroft, and confirm that it is an earlier reused door, and if so, where in the Abbey the door might have originated

- to determine through dendrochronology whether the timber used in the doors was English, or imported

- to determine whether, in the absence of sapwood and hence precise felling dates, the doors could be linked to any of the other building phases currently through the known building history

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

Assessment:

The doors were initially assessed during March 2001 with the then Clerk of Works, George Burroughs. However, one exception was the door called 'Pyx' in the Chapter House vestibule. In the 1970s, Dr John Fletcher of the Archaeology Research Laboratory at Oxford studied this door with Cecil Hewett and attempted to date two planks.

Of all the doors assessed, this door had the least promising chances of success. Although the rings were reasonably narrow, there was a band of very narrow rings which might cause problems in dating. Also, as the planks were tangentially cut, the number of rings in each of the planks would not be as many had they been radially cut. However, a major redeeming feature of this door was the presence of sapwood rings on at least two of the boards which, if dated, should produce a felling date range which is obviously vital for a door of such importance. The door planks were of sufficient thickness to allow the use of micro-boring. However, the top and bottom edges were too damaged to allow clear *in situ* measurements or impressions to be taken, although Dr John Fletcher did manage to take measurements from two of the boards in the late 1970s.

The Pyx Chamber doors from the cloister leading to the old Pyx Chamber are very substantial in nature, clearly constructed at the same time. The framing material is all too fast grown and small-sectioned to be worth sampling, but the boards in between were all found to be very slow grown and as such would be excellent for dating. To sample these doors, it appeared to be possible to drill in from the edge of the door through each board and muntin in succession, giving access to a number of boards from a single hole. It is very unlikely that any sapwood would be found, but the comparison of last heartwood ring dates from a number of boards should provide an indication of likely felling period.

The middle lock on the inner door retained some sapwood, and was considered worth sampling.

Both the doors leading to the stair vices in the north and south transepts were assessed. The north transept door consisted of V-edged boards with excellent ring counts, although access would be difficult to get a straight approach for the micro-boring jig. Also, the thickness of the door would require extremely careful setting up to ensure the alignment was perfectly central.

The door at the south-east corner of the south transept was constructed of a series of boards that are all slow-grown and are extremely suitable for dendrochronology, and at least one has a clear heartwood/sapwood boundary which would enable a clear felling date range to be produced. This door could be sampled using a long micro-borer through the front vertical boards.

The final door to be assessed was at the bottom of the steps leading into the Chapter House undercroft. Both the V-edged planks as well as the framing members were very slow-grown, and two of these timbers retained clear heartwood/sapwood transitions. The thickness of the members made this door ideal for coring using the micro-borer.

Apart from the 'Pyx' door in the Chapter House vestibule, all of the boards used in the various doors were slow-grown, suggesting that many of them might be imported from the Baltic region, or from other sources.

Sampling strategy:

Sampling was limited to boards and ledges which could be drilled from the edge. The bottoms of the boards were all too eroded to allow the ring boundaries to be clearly defined, and to clean these sufficiently to allow good samples to be taken through photography or impression would have resulted in unacceptable damage to the historic appearance of the doors. Most of the doors would have to be sampled *in situ* as their weight would preclude their being lifted off their pintles; the doors to the Pyx Chamber weighing almost ¼ tonne each. However, the 'Pyx' door in the Chapter House vestibule was easily lifted off its hinge pins and set on trestles immediately outside.

Samples from the 'Pyx' door in the Chapter House vestibule were numbered using the prefix **wa** followed by numbers **41** - **44**, with multiple samples from the same timber being labelled **a**, **b**, etc (Fig 6). Segments of cores which had broken during drilling were labelled **a1**, **a2**, etc. The doors to the Pyx Chamber were numbered **51** – **55** for the outer door (Fig 8), and **61** – **65** for the inner door (Fig 9). The north transept door samples were numbered **71** – **74** (Fig 11), the south transept door **81** – **85** (Fig 13), and the door to the Chapter House undercroft **91** – **97** (Fig 15).

Methodology:

All 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 doors 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 surface of the door planks was too abraded or damaged to allow the rings to be accurately measured, and cleaning the surface would cause unacceptable visual damage 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 is 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 door (Fig 18). 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. Thus four of the original 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 x10/x45 variable-focus microscope using a travelling stage electronically displaying displacement to a precision of 0.001mm, rounded to the nearest 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 re-written in Microsoft Visual Basic by M R Allwright and P A Parker.

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, and for Baltic timbers, a 95% sapwood estimate of 8 - 24 rings has been used (Tyers 2001). Coming west from the Baltic region the sapwood range increases to 8-38 rings (Hillam *et al* 1987).

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 under study. However, it is common practice to build timber-framed structures with green or unseasoned timber and that construction usually took place within twelve months of felling (Miles 1997). Given the protracted nature of major building campaigns, more latitude must be given in interpreting construction dates, especially in subsequent phases. However, this can sometimes be mitigated in the light of complimentary documentary evidence.

Cross-matching and site chronologies:

The Door called 'Pyx', Chapter House Vestibule

Efforts to try and date this door through dendrochronology extend back to the 1970s when two boards from the door (**wa41a** and **wa42a**) were initially measured by Dr J M Fletcher. This was commissioned by the Historic Buildings and Monuments Commission, the precursor to English Heritage. Dr Fletcher made two visits to measure the tops of the boards *in situ*, assisted by F S Walker, Margaret Tapper, and Dr Jane Geddes. At the time, these two boards were found to cross-match together, but failed to date reliably enough for publication. As part of this current analysis, the 1970s data was found in punch-card form in the Fletcher archives, confusingly labelled 'Chapter House Undercroft', and were manually keyed in. Now nearly 30 years on, more encouraging matches were found with the reference chronologies, but clearly more material would be needed to bolster the *t*-value matches to acceptable limits.

Therefore, during the 2005 analysis, four out of five boards making up this door were sampled using the micro-borer (**wa41b**, **wa42b**, **wa43**, and **wa44**). The only board not sampled was the middle board which was one of the outer slabs of the tree when converted with only 30 rings. Radial splits in the first two boards required additional core samples to ensure the breaks were covered (**wa41c** and **wa42c**). The three unbroken sequences from the first two boards were found to match each other, as well as with the direct measurements by Fletcher. These were combined to form the same timber means **wa41** and **wa42**. As the matches between samples suggested that they had originated from the same parent tree (Table 2), the five individual sequences were combined to form the 107-ring site master **WMNSTR1** (Table 3). The remaining two samples **wa43** and **wa44** had too few rings to reliably cross-match with the other boards or the site master.

The site master **WMNSTR1** was compared with over 1300 British reference chronologies and was found to date, spanning the years AD 924–1030 (Table 4). The number of chronologies matched was limited, unusual considering the wealth of Norman chronologies for the London area. However, the site master exceptionally matched well with the Greensted Church chronology from Essex and another from a series of boards from the Tower of London. Whilst dendro-provenancing is not realistic from so few chronologies, is does illustrate that the timber used in this door originated from a source near to London, but which was subject to unusual climatic or management trends.

Outer and Inner Doors, Pyx Chamber

Five boards from the outer door, and four from the inner door were sampled. Of these, two distinct groups were formed. Samples **wa53** and **wa54** from the outer door matched together as shown in Table 2, and were combined to form the 103-year site master **WMNSTR2** (Table 3).

From the outer door, sample **wa52** matched with samples **wa61**, **wa62**, **wa63**, and **wa64** from the inner door (Table 2). These were combined to form the 139-year site master **WMNSTR3** (Table 3).

Both of these site masters were compared with the British reference chronologies, but no outstanding matches were found. They were then compared with other European chronologies, both from imported timbers used in British buildings, as well as with chronologies from abroad. The site master **WMNSTR2** was found to match best with chronologies derived from Baltic material, spanning the years AD 1165–1267 (Table 5). The second site master **WMNSTR3** was found to match best with chronologies derived from German material, spanning the years AD 1137–1275 (Table 6).

Two samples from the outer door failed to date, primarily due to the fracturing of the cores into fragments too short to reliably cross-match.

On the inside of the inner door one of the massive wood-cased locks was sampled (**wa65**). A sequence of 152 years was obtained, including seven sapwood rings (Table 3). It was found to match best with English chronologies, spanning the years AD 1442–1593 (Table 7).

North-East Stair Vice, North Transept

All four boards from this door were sampled (**wa71**, **wa72**, **wa73**, and **wa74**), two of the boards having in excess of 200 rings. With the exception of the early half of the second board (**wa72a1**), all four samples matched together (Table 2). These were combined to form the 216-year site master **WMNSTR4** (Table 3). This was compared to both British as well as European chronologies and it was found to match best with chronologies derived from the Germany area material (Table 8). This dated, spanning the years AD 1004–1219.

South-East Passage Door, South Transept (Poets' Corner)

Five boards from this door were sampled: **wa81**, **wa82**, **wa83**, **wa84**, and **wa85**. The last sample fractured during coring, particularly regrettable as it retained a heartwood/sapwood boundary. Three of the samples (**wa81**, **wa82**, and **wa84**) matched together as shown in Table 2, and were combined to form the 169-year site master **WMNSTR5** (Table 3). This was compared with the reference chronologies and was found to date, spanning the years AD 1162–1330 (Table 9), matching best with Baltic material chronologies.

One additional sample, (**wa83**), failed to match the other samples of the site master, but did date individually. This also matched with Baltic material chronologies, spanning the years AD 1168–1328 (Table 10). It is likely that this timber came from a slightly different region of the Baltic.

Door to Chapter House Undercroft

Seven timbers were sampled from this door – two planks and five of the framing members. Two cores were taken from two of the braces with heartwood/sapwood boundaries to increase chances of dating, and to bridge over fractures in the cores. Thus samples **wa91a2** and **wa91b** were combined to form the mean **wa91**, and samples **wa92a** and **wa92b** were combined to form the mean **wa92**, The two planks, (**wa96**, and **wa97**) were found to have originated from the same tree (Table 2), and were combined to form the same-tree mean **wa967**.

Once all the individual same-timber and same-tree means were produced, they were compared with each other, and sample **wa967** was found to match **wa91** (Table 2) and these were combined to form the 183-year site master **WMNSTR6** (Table 3). This was compared with the reference chronologies and was found to date, spanning the years AD 1000–1182 (Table 11), matching best with English chronologies.

Two other samples dated individually, but did not match the site master. Sample **wa94** (Table 3) matched best, spanning the years AD 1083–1198 (Table 12), and sample **wa95** (Table 2) matched, spanning the years AD 1097–1181 (Table 13).

Several other samples, despite having between 72 and 91 years growth, failed to match either the other samples or any of the site masters or reference chronologies on their own.

Interpretation and discussion:

The Door called 'Pyx', Chapter House Vestibule

Remarkably, this door retained some sapwood on the two planks dated. Sample **wa41** had a clear heartwood/sapwood boundary at AD 1026, and sample **wa42** had 10 rings of sapwood with a heartwood/sapwood boundary date AD 1020. By taking the average heartwood/ sapwood boundary date of AD 1023, a felling date range of AD 1032–64 has been produced (Fig 20).

This makes this the oldest securely-dated door in Britain, and the earliest example of post-Roman sawn timber boards. As such, it is of Saxon origin, and must have been part of the original Abbey complex built by Edward the Confessor between *c* AD 1050 and 1065. Dendrochronology has shown that the timber was of English origin. The date range produced by this door has pushed back the earliest known examples of square-rebated boards by about half a century (Geddes 1999, 28-9).

Outer and Inner Doors, Pyx Chamber

Three boards from the outer door, and four from the inner door were dated. Although none retained any evidence of a heartwood/sapwood boundary, the clustering of dates between AD 1266 and 1275 for the outer door, and between AD 1263 and 1274 for the inner door, suggests that a minimum number of heartwood rings had been removed with the sapwood, with a felling period somewhere *c* AD 1300. This accords well with the documented burglary of the Royal Treasury in AD 1303 for which these doors are thought to relate (Rodwell 2002, 4). Although the treasury at the time was probably located in the Chapter House undercroft, it is thought that the Pyx Chapel was converted to a new treasury following this break in, the door leading into the Chapter House vestibule blocked up, and a new opening made in the cloister wall for the pair of strong timber doors (Rodwell *pers comm*). These doors are very similar in construction, diagonal ledges are used on the inside of the outer door, whereas the ledges are horizontal on the other faces. Dendrochronology strongly suggests that the doors are coeval, despite the poor dating between the groups of boards (Fig 20). The analysis has shown that some of the boards were imported from the eastern Baltic region. Although not sampled, the fast-grown durns and muntins (Fig 19) seem likely to be of local origin.

The locks on the inside of the two doors are also broadly contemporary with each other, but are clearly later replacements. The middle lock on the inner door retained seven rings of sapwood, and a felling date range of AD 1595–1627 was derived for this lock. The timber was clearly of English origin.

North-East Stair Vice, North Transept

Of the four boards dated, none retained any evidence of a heartwood/sapwood transition. Three of the last measured ring dates cluster between AD 1181 and 1191. However, the line of sampling of these boards was through the V-edge, resulting in the loss of 20 or more rings to the outer extremity of the feather-edge. However, the last board which did not have a V-joint formed on the outer edge produced a last measured ring date of AD 1219, and a *terminus post quem* for felling of after AD 1227, which is entirely consistent with a *c* AD 1250 construction date (Fig 20). The analysis suggests a slightly more western origin than the other imports, perhaps Germany, for the timber.

South-East Passage Door, South Transept (Poets' Corner)

Four of the five boards sampled dated, giving last measured ring dates ranging from AD 1314 to 1330. None of the dated boards retained evidence for sapwood, therefore a *terminus post quem* or felled after date of AD 1338 can be given for this door (Fig 20). Stylistically, this door

is very similar to the sub-crypt door in the White Tower at the Tower of London, which produced similar last heartwood-ring dates. Unfortunately a fifth board with some sapwood failed to date. The analysis suggests an eastern Baltic origin for the timber.

Door to Chapter House Undercroft

Five timbers from this door dated. The timbers with the latest heartwood ring dates are the external boards, two of which (**wa96** and **wa97**) were found to originate from the same tree and produced a 'felled after date' or *terminus post quem* of AD 1224, taking into account last unmeasured rings in the V-groove joints. Inspection of the edge of the feather-edge of the V-groove on the inside of board **wa97** lower down from the point of sampling showed clear evidence for the heartwood/sapwood boundary. Although this could not be directly related to the sequence of rings sampled, this confirms that the *terminus post quem* of AD 1224 is probably within 10 years of the actual felling date range. The bottom rail and locking stile produced *termini post quem* or 'felled after dates' of after AD 1190 and after AD 1207 respectively. These four last heartwood ring dates are consistent with each other and would suggest a felling period *c* AD 1250 (Fig 20).

However, one of the braces dated with a clear heartwood/sapwood boundary date of AD 1111. This would give a felling date range of AD 1120–52, which is a full century earlier than the other dated elements of the door. Closer inspection of this brace has shown that there is a peg hole filled with a plug, which suggests that this timber had been reused (Fig 16). Other peg holes in this and some other braces which have not dated may also signify secondhand timber. Dendrochronology shows that the timber is local in origin.

The dating of this door to *c* AD 1250 would suggest that it was subsequently reused from one of the main doors of the central part of the Abbey, rebuilt during the reign of Henry III. The door was recorded, and the line of the cross-braces projected beyond the later hanging style inserted by Scott and the truncated top, producing a reconstruction of the door as originally built. It would have measured approximately 4ft (1200mm) wide and just over 8ft (2400mm) high. All of the existing door openings in the Abbey were then measured, and only one looked like it might have been the original location of the door. This is the side door to the west of the main north transept doors. The opening consisted of two leaves 4ft wide and 12ft high, with a square top. A painting hanging in the Abbey dating to the mid 1700s actually shows the western leaf of this door two-thirds the height of the opening, which is virtually identical in size to the reconstruction of the door (Fig 17). As to whether these were the original thirteenth century doors is somewhat confused by a dark internal view of the same door dating from AD 1812 showing these doors as being panelled internally (Ackermann 1812, plate 57).

However, all is made clear by W R Lethaby (1925, 78) who wrote:

> when the repairs of Wren's time were done, older wooden doors were new cased. In the accounts of Wren's works at the church is an item, under 1700, for 'mending Solomon's Porch doors.' These were broken up and thrown aside in the more thorough restoration of later days. A considerable fragment of one, which re,ained, has recently been adapted as a door to the stair of the Octagonal Crypt [Chapter House undercroft]. It has diagonal framing covered with plain boarding, and such doors are shown at the North Transept in one of the seventeenth-century views of the interior.

Conclusions:

The door in the Chapter House vestibule known as 'Pyx' was confirmed to be Saxon in origin, and most likely part of the original Edward the Confessor's church. As such, it is the oldest scientifically-dated timber door in Britain, and the earliest example of sawn timber since the departure of the Romans in the fifth century AD.

The Pyx Chamber doors were found to be contemporaneous, constructed with timber from at least two Baltic sources. The last measured ring dates of AD 1274 and 1275 suggest that the minimum number of heartwood rings were removed with the sapwood, and that they most likely relate to a new secure set of doors for the Royal treasury, relocated to the Pyx Chamber following the robbery of AD 1303.

The door from the north transept produced a *terminus post quem* of AD 1227, which is entirely consistent with the construction of the surrounding masonry of the north transept, rebuilt by Henry III between AD 1245 and AD 1255. Conversely, the door from the south transept at Poets' Corner has been shown to be a replacement of about 100 years later, with a *terminus post quem* of after AD 1338.

One of the most interesting doors is that leading into the passage to the Chapter House undercroft. The dendrochronology has shown that this is no earlier than AD 1224, and it most likely originated from the western side door to the north transept, reconstructed between AD 1245 and 1255. Its present position is not historic, although it did replace an earlier door as evidenced by the rebates and multiple lock keep positions. It was almost certainly recycled by Scott in the AD 1860s when he was restoring the north transept. One timber from this door produced a felling date a century earlier, but it seem clear that this was a reused timber.

Through dendro-provenancing, the timbers here were found to have originated from several sources. The 'Pyx' door in the Chapter House vestibule, as well as the reused door in the undercroft, are of English oak, whereas the boards used in the two Pyx Chamber doors were imported from the Baltic, as was the south transept door leading from Poets' Corner. Interestingly though, the timbers of the door in the north transept were found to be of a source to the west of the main Baltic regions, perhaps Germany. All this emphasises the vast amount of timber imported into London during the early medieval period from all parts of Europe.

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Table 1: Summary of tree-ring dating

WESTMINSTER ABBEY DOORS

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 seasons and dates/date ranges (AD)
The door called 'Pyx', Chapter House Vestibule									
* **wa41a**	g Board 1 from fore edge (JMF)	*924-1024*			*101*	*1.49*	*0.64*	*0.306*	
* **wa41b**	mc ditto	*951-1026*	*1026*	*H/S*	*76*	*1.59*	*0.64*	*0.263*	
* **wa41c**	mc ditto	*925-996*			*72*	*1.72*	*0.77*	*0.325*	
wa41	Mean of **wa41a** + **wa41b** + **wa41c**	924-1026	1026	H/S	103	1.54	0.66	0.290	
* **wa42a**	g Board 2 from fore edge (JMF)	*938-1030*	*1020*	*10*	*93*	*1.57*	*0.65*	*0.234*	
wa42b1	mc ditto	*949-966*			*18*	*1.40*	*0.83*	*0.346*	
wa42b2	mc ditto	*980-1009*			*30*	*1.67*	*0.35*	*0.150*	
wa42b3	mc ditto	*1013-1029*	*1020*	*9*	*17*	*1.13*	*0.25*	*0.189*	
* **wa42c**	mc ditto	*940-999*			*60*	*1.73*	*0.80*	*0.247*	
wa42	Mean of **wa42a** + **wa42c**	938-1030	1020	10	93	1.57	0.65	0.234	
wa43a1	mc Board 4 from fore edge	-			19	1.09	0.33	0.266	
wa43a2	mc ditto	-			5	1.93	0.42	0.214	
wa43a3	mc ditto	-			6	1.39	0.24	0.187	
wa43a4	mc ditto	-		8	38	1.63	0.61	0.201	
wa44a1	mc Board 5 from fore edge	-			5	2.24	0.45	0.311	
wa44a2	mc ditto	-			28	2.45	0.56	0.201	
* = **WMNSTR1 Site Master (English)**		**924-1030**	**1023**	**Avg. H/S bdy**	**107**	**1.57**	**0.61**	**0.246**	**1032-64**

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 seasons and dates/date ranges (AD)
Pyx Chamber Outer Door									
wa51a1	mc Board 1 from fore edge	-			59	1.45	0.41	0.211	
wa51a2	mc	-			4	0.63	0.36	1.285	
wa51a3	mc	-			9	0.97	0.28	0.286	
wa51a4	mc	-			27	0.98	0.15	0.159	
† **wa52**	mc Board 2 from fore edge	1152-1275			124	1.11	0.32	0.230	After 1283
* **wa53**	mc Board 3 from fore edge	1165-1266			102	1.34	0.42	0.229	After 1274
* **wa54**	mc Board 4 from fore edge	1174-1267			94	1.51	0.40	0.196	After 1275
wa55a1	mc Board 5 from fore edge	-			5	1.47	0.19	0.172	
wa55a2	mc	-			17	1.45	0.31	0.175	
wa55a3	mc	-			38	1.05	0.29	0.171	
* = **WMNSTR2** Site Master (Baltic)		1165-1267			103	1.44	0.38	0.190	After 1283
Pyx Chamber Inner Door									
wa61a1	mc Board 1 from fore edge	1172-1189			18	1.72	0.44	0.192	
wa61a2	mc	1191-1263			73	1.50	0.39	0.218	
wa61b	mc	1165-1258			94	1.51	0.36	0.209	
† **wa61**	Mean of **wa61a1** + **wa61a2** + **wa61b**	1165-1263			99	1.52	0.38	0.212	After 1271
wa62a1	mc Board 2 from fore edge	1137-1213			77	1.01	0.31	0.259	
wa62a2	mc	-			14	0.99	0.18	0.185	
wa62a3	mc	1228-1270			43	1.05	0.31	0.269	
wa62b	mc	1148-1274			127	1.07	0.31	0.226	
† **wa62**	Mean of **wa62a2** + **wa62b**	1137-1274			138	1.05	0.30	0.236	After 1282
† **wa63**	mc Board 3 from fore edge	1189-1274			86	1.59	0.50	0.264	After 1282
† **wa64**	mc Board 4 from fore edge	1162-1273			112	1.23	0.34	0.227	After 1281
wa65	mc Middle lock case (English)	1442-1593	1586	7	152	1.04	0.73	0.203	1595 - 1627
† = **WMNSTR3** Site Master (Baltic)		1137-1275			139	1.23	0.28	0.187	After 1282
North Transept – North-east Vice Door									
* **wa71**	mc Board 1 from fore edge	1010-1219			210	1.11	0.31	0.226	
wa72a1	mc Board 2 from fore edge	-			107	1.02	0.18	0.134	
* **wa72a2**	mc	1074-1181			108	1.11	0.26	0.128	
* **wa73**	mc Board 3 from fore edge	1034-1187			154	1.22	0.20	0.144	
* **wa74**	mc Board 4 from fore edge	1004-1191			188	1.10	0.26	0.223	
* = **WMNSTR4** Site Master (German/Netherlands)		1004-1219			216	1.13	0.20	0.155	After 1227

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 seasons and dates/date ranges (AD)
South Transept Upper Passage Door to Chapter House Undercroft									
* **wa81**	mc Board 1 from fore edge	1162-1314			153	0.99	0.35	0.269	
* **wa82**	mc Board 2 from fore edge	1184-1330			147	1.14	0.30	0.162	
wa83	mc Board 3 from fore edge	1168-1328			161	0.99	0.28	0.157	
* **wa84**	mc Board 4 from fore edge	1172-1322			151	1.15	0.26	0.158	
wa85a1	mc Board 5 from fore edge	-			48	1.98	0.40	0.185	
wa85a2	mc	-		H/S	27	1.74	0.32	0.168	
* = **WMNSTR5** Site Master (Baltic)		1162-1330			169	1.07	0.25	0.135	After 1338
Door to Chapter House Undercroft									
wa91a1	mc Top left brace	-			17	1.31	0.12	0.126	
wa91a2	mc	*1000-1109*			*110*	*1.10*	*0.22*	*0.125*	
wa91b	mc	*1054-1111*	*1111*	*H/S*	*58*	*1.08*	*0.18*	*0.154*	
* **wa91**	Mean of **wa91a2** + **wa91b**	1000-1111	1111	H/S	112	1.09	0.20	0.130	1120 - 52
wa92a	mc Middle left brace	-			*72*	*1.55*	*0.39*	*0.168*	
wa92b	mc	-		*H/S*	*42*	*1.83*	*0.44*	*0.230*	
wa92	Mean of **wa92a** + **wa92b**	-		H/S	78	1.60	0.42	0.174	
wa93a1	mc Middle right brace	-			52	1.04	0.17	0.119	
wa93a2	mc	-			10	0.71	0.14	0.141	
wa93a3	mc	-			13	0.54	0.08	0.146	
wa93a4	mc	-			91	0.72	0.18	0.142	
wa94	mc Locking stile	1083-1198			116	1.09	0.44	0.185	After 1207
wa95	mc Bottom rail	1097-1181			85	1.59	0.59	0.184	After 1190
wa96a1	mc Board 1 from fore edge	-			21	2.11	0.37	0.211	
wa96a2	mc	1056-1165			110+22 NM	1.76	0.38	0.189	(After 1224)
wa97	mc Board 2 from fore edge	1042-1182			141+33 NM	1.79	0.39	0.182	After 1224
* **wa967**	Same tree mean of **wa96a2** + **wa97**	1042-1182			141	1.82	0.37	0.176	
* = **WMNSTR6** Site Master (English)		1000-1182			183+33 NM	1.49	0.35	0.148	After 1224

Key: *, †, = sample included in site-masters; c = core; mc = micro-core; ¼C, ½C, C = bark edge present, partial or complete ring: ¼C = spring (ring not measured), ½C = summer/autumn, 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 9 - 41 used for English timbers (Miles 1997a), 8 - 24 for Baltic oak boards (Tyers 1998)

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).

Table 2: Matrix of *t* -values and overlaps for site masters

Components of **WMNSTR1**

Sample:	**wa41b**	**wa41c**	**wa42c**	**wa42a**
Last ring date AD:	1026	996	999	1030
wa41a	15.87 74	18.15 72	5.94 60	6.04 87
	wa41b	11.43 46	4.06 49	3.91 76
		wa41c	7.10 57	5.79 59
			wa42c	7.64 60

Components of **WMNSTR2**

Sample:	**wa54**
Last ring date AD:	1103
wa53	6.21 93

Components of **WMNSTR3**

Sample:	**wa61**	**wa62**	**wa63**	**wa64**
Last ring date AD:	1263	1274	1274	1273
wa52	3.68 99	3.78 123	1.56 86	5.36 112
	wa61	3.72 99	4.41 75	7.32 99
		wa62	2.05 86	4.88 112
			wa63	3.16 85

Components of **WMNSTR4**

Sample:	**wa72a2**	**wa73**	**wa74**
Last ring date AD:	1181	1187	1191
wa71	4.67 / 108	5.24 / 154	7.09 / 182
	wa72a2	7.68 / 108	4.31 / 108
		wa73	6.40 / 154

Components of **WMNSTR5**

Sample:	**wa82**	**wa84**
Last ring date AD:	1330	1322
wa81	3.91 / 131	5.21 / 143
	wa82	5.53 / 139

Components of **WMNSTR6**

Sample:	**wa91**
Last ring date AD:	1111
wa967	3.45 / 70

Components of **WMNSTR7**

Sample:	**wa23**	**wa24**	**wa26**	**wa28**
Last ring date AD:	1342	1369	1328	1368
wa22	3.97 / 46	4.90 / 64	2.52 / 32	2.24 / 64
	wa23	3.55 / 55	1.73 / 41	1.59 / 55
		wa24	6.48 / 62	4.25 / 101
			wa26	2.10 / 61

Components of **WMNSTR8**

Sample:	**wa33**
Last ring date AD:	1588
wa3246	3.04 / 72

Table 3: Ring-width data for site master curves

WMNSTR1 AD 924-1030 The door called 'Pyx', Chapter House Vestibule, Westminster Abbey - English material 2-timber mean of **wa41a** + **wa41b** + **wa41c** + **wa42a** + **wa42c**
107 rings, starting date AD 924

ring widths (0.01mm)	number of samples in master
190 94 79 71 90 173 102 47 111 60	1 2 2 2 2 2 2 2 2 2
182 119 118 144 161 203 183 110 70 85	2 2 2 2 3 3 4 4 4 4
157 225 217 355 327 281 321 114 84 69	4 4 4 4 4 4 4 5 5 5
44 50 62 129 189 168 173 184 220 176	5 5 5 5 5 5 5 5 5 5
187 215 229 241 201 150 123 147 184 115	5 5 5 5 5 5 5 5 5 5
196 184 214 207 155 287 203 168 135 265	5 5 5 5 5 5 5 5 5 5
190 174 237 236 196 175 165 122 129 120	5 5 5 5 5 5 5 5 5 5
95 146 121 152 172 174 184 177 171 159	5 5 5 4 4 4 3 3 3 3
170 128 152 200 229 191 147 143 185 112	3 3 3 3 3 3 3 3 3 3
108 110 77 92 56 68 93 100 106 133	3 3 3 3 3 3 3 3 3 3
121 103 125 100 130 130 120	3 2 2 1 1 1 1

WMNSTR2 AD 1165-1267 Outer door, Pyx Chamber, Westminster Abbey - Baltic material 2-timber mean of **wa53** + **wa54**
103 rings, starting date AD 1165

ring widths (0.01mm)	number of samples in master
150 129 213 267 140 165 199 207 210 163	1 1 1 1 1 1 1 1 1 2
151 172 193 164 173 174 141 150 174 146	2 2 2 2 2 2 2 2 2 2
168 188 176 186 148 254 166 145 149 130	2 2 2 2 2 2 2 2 2 2
180 157 146 205 215 197 176 139 181 163	2 2 2 2 2 2 2 2 2 2
152 99 110 78 96 154 126 127 144 156	2 2 2 2 2 2 2 2 2 2
145 126 131 125 167 128 108 99 75 60	2 2 2 2 2 2 2 2 2 2
74 79 124 111 171 157 146 83 103 114	2 2 2 2 2 2 2 2 2 2
111 118 142 154 97 84 118 126 99 153	2 2 2 2 2 2 2 2 2 2
157 140 115 146 203 192 151 178 133 145	2 2 2 2 2 2 2 2 2 2
98 141 107 98 128 124 119 115 91 141	2 2 2 2 2 2 2 2 2 2
116 165 141	2 2 1

WMNSTR3 AD 1137-1275 Inner door, Pyx Chamber, Westminster Abbey - Baltic material 5-timber mean of **wa52** + **wa61** + **wa62** + **wa63** + **wa64**
139 rings, starting date AD 1137

ring widths (0.01mm)	number of samples in master
65 79 60 66 101 43 69 156 119 71	1 1 1 1 1 1 1 1 1 1
114 134 101 98 72 99 125 112 87 137	1 1 1 1 1 2 2 2 2 2
112 99 119 132 152 126 119 124 140 150	2 2 2 2 2 3 3 3 4 4
127 127 125 126 74 138 153 119 123 114	4 4 4 4 4 4 4 4 4 4
83 90 113 95 89 115 152 147 117 157	4 4 4 4 4 4 4 4 4 4
183 141 124 149 151 125 116 121 164 141	4 4 5 5 5 5 5 5 5 5
157 157 181 146 133 116 144 142 141 135	5 5 5 5 5 5 5 5 5 5
132 132 121 123 145 125 100 102 101 88	5 5 5 5 5 5 5 5 5 5
107 82 138 164 140 131 114 116 105 139	5 5 5 5 5 5 5 5 5 5
127 146 176 171 106 167 151 159 125 133	5 5 5 5 5 5 5 5 5 5
182 150 164 150 130 124 140 128 116 80	5 5 5 5 5 5 5 5 5 5
79 69 130 141 125 105 101 107 170 124	5 5 5 5 5 5 5 5 5 5
135 101 106 114 146 112 118 113 88 148	5 5 5 5 5 5 5 4 4 4
90 98 128 117 164 124 131 112 89	4 4 4 4 4 4 4 3 1

Table 3 (continued): Ring-width data for site master curves

WMNSTR4 AD 1004-1219 North-east Vice Door, North Transept, Westminster Abbey - German material 4-timber mean of **wa71** + **wa72a2** + **wa73** + **wa74**

216 rings, starting date AD 1004

ring widths (0.01mm)										number of samples in master									
81	77	108	79	84	88	136	138	138	136	1	1	1	1	1	1	2	2	2	2
101	95	102	112	125	99	120	101	174	149	2	2	2	2	2	2	2	2	2	2
177	126	139	110	148	162	154	137	92	119	2	2	2	2	2	2	2	2	2	2
100	124	93	129	135	133	144	161	128	92	3	3	3	3	3	3	3	3	3	3
90	103	109	118	108	148	135	129	138	132	3	3	3	3	3	3	3	3	3	3
90	116	141	127	108	105	116	109	91	111	3	3	3	3	3	3	3	3	3	3
84	129	108	122	156	129	92	102	119	138	3	3	3	3	3	3	3	3	3	3
110	121	121	117	107	127	122	122	146	130	4	4	4	4	4	4	4	4	4	4
123	127	138	109	94	126	122	112	134	127	4	4	4	4	4	4	4	4	4	4
120	134	138	124	110	88	124	104	106	132	4	4	4	4	4	4	4	4	4	4
138	120	122	92	96	95	98	102	99	116	4	4	4	4	4	4	4	4	4	4
118	117	87	109	134	109	109	95	130	137	4	4	4	4	4	4	4	4	4	4
117	81	91	106	112	84	92	102	107	92	4	4	4	4	4	4	4	4	4	4
107	105	103	100	110	90	112	125	91	120	4	4	4	4	4	4	4	4	4	4
105	123	112	128	90	118	98	97	85	118	4	4	4	4	4	4	4	4	4	4
105	120	132	123	100	109	116	125	117	118	4	4	4	4	4	4	4	4	4	4
111	103	100	83	125	107	102	131	141	147	4	4	4	4	4	4	4	4	4	4
93	95	99	74	88	79	86	84	93	113	4	4	4	4	4	4	4	4	3	3
121	113	113	115	111	82	124	97	128	104	3	3	3	3	2	2	2	2	1	1
114	122	107	75	121	115	135	115	149	171	1	1	1	1	1	1	1	1	1	1
98	106	97	81	89	112	149	134	86	92	1	1	1	1	1	1	1	1	1	1
83	130	89	112	83	107					1	1	1	1	1	1				

WMNSTR5 AD 1162-1330 South-east Vice Door, South Transept, Westminster Abbey - Baltic material 3-timber mean of **wa81** + **wa82** + **wa84**

169 rings, starting date AD 1162

ring widths (0.01mm)										number of samples in master									
110	151	208	190	135	86	157	96	96	91	1	1	1	1	1	1	1	1	1	1
114	119	143	138	133	77	70	96	125	129	2	2	2	2	2	2	2	2	2	2
161	137	138	122	179	172	164	108	129	158	2	2	3	3	3	3	3	3	3	3
136	110	96	131	127	165	165	147	190	167	3	3	3	3	3	3	3	3	3	3
125	137	145	133	131	106	133	115	97	119	3	3	3	3	3	3	3	3	3	3
112	86	85	92	91	83	78	102	121	92	3	3	3	3	3	3	3	3	3	3
114	103	79	90	85	84	106	109	121	94	3	3	3	3	3	3	3	3	3	3
107	93	109	83	101	113	140	136	118	112	3	3	3	3	3	3	3	3	3	3
91	89	84	84	82	100	87	121	110	132	3	3	3	3	3	3	3	3	3	3
83	85	89	151	106	114	76	98	98	95	3	3	3	3	3	3	3	3	3	3
131	124	148	122	174	107	107	99	75	129	3	3	3	3	3	3	3	3	3	3
114	98	120	121	112	91	77	86	119	124	3	3	3	3	3	3	3	3	3	3
111	102	99	88	87	65	76	81	74	107	3	3	3	3	3	3	3	3	3	3
82	88	85	75	89	92	103	98	97	97	3	3	3	3	3	3	3	3	3	3
121	109	93	78	72	82	89	93	81	99	3	3	3	3	3	3	3	3	3	3
85	98	109	108	146	121	119	99	113	99	3	3	3	2	2	2	2	2	2	2
89	84	88	86	107	85	104	85	93		2	1	1	1	1	1	1	1	1	

Table 3 (continued): Ring-width data for site master curves

WMNSTR6 AD 1000-1182 Door to Chapter House Undercroft, Westminster Abbey - English material 3-timber / 2 tree mean of **wa967** + **wa91**
183 rings, starting date AD 1000

ring widths (0.01mm)										number of samples in master									
124	127	120	124	130	107	107	123	124	126	1	1	1	1	1	1	1	1	1	1
126	134	156	163	134	130	155	127	125	119	1	1	1	1	1	1	1	1	1	1
102	105	105	124	111	82	106	97	114	103	1	1	1	1	1	1	1	1	1	1
104	75	79	87	81	94	79	88	86	93	1	1	1	1	1	1	1	1	1	1
93	80	176	163	175	163	142	174	139	145	1	1	2	2	2	2	2	2	2	2
106	141	169	156	107	158	165	133	163	164	2	2	2	2	2	2	2	2	2	2
152	139	154	147	167	140	143	206	149	119	2	2	2	2	2	2	2	2	2	2
146	157	182	154	160	162	159	139	148	142	2	2	2	2	2	2	2	2	2	2
167	133	165	189	132	157	189	133	168	141	2	2	2	2	2	2	2	2	2	2
114	148	157	163	157	194	165	161	171	149	2	2	2	2	2	2	2	2	2	2
146	117	132	145	123	139	127	135	180	138	2	2	2	2	2	2	2	2	2	2
121	135	204	178	147	200	150	139	163	160	2	2	1	1	1	1	1	1	1	1
157	159	178	182	218	146	139	157	149	157	1	1	1	1	1	1	1	1	1	1
131	129	159	138	144	185	152	123	166	124	1	1	1	1	1	1	1	1	1	1
148	150	159	147	160	130	163	130	151	150	1	1	1	1	1	1	1	1	1	1
154	114	156	187	136	143	188	208	147	186	1	1	1	1	1	1	1	1	1	1
166	149	153	126	130	142	167	172	158	220	1	1	1	1	1	1	1	1	1	1
239	170	249	237	228	200	226	140	201	260	1	1	1	1	1	1	1	1	1	1
243	209	269								1	1	1							

wa65 AD 1442-1593 Middle lock case, Inner Pyx Chamber Door, Westminster Abbey - English material
152 rings, starting date AD 1442

ring widths (0.01mm)									
403	459	380	255	140	249	328	393	273	310
261	226	196	234	276	185	163	144	182	137
75	222	122	129	178	139	79	136	75	95
78	89	55	60	64	69	91	89	90	116
94	87	81	49	79	108	105	93	94	65
69	63	99	122	135	127	85	84	75	94
82	111	114	79	63	88	56	78	54	87
90	75	70	58	85	74	70	75	69	53
60	55	93	82	70	79	73	65	86	80
50	46	65	91	75	95	91	84	78	64
49	72	68	95	70	85	103	103	90	80
70	80	92	86	63	66	44	73	79	62
85	85	75	77	87	89	86	89	85	64
63	58	57	60	67	62	57	68	65	61
64	54	62	60	73	52	48	61	62	52
64	85								

Table 3 (continued): Ring-width data for site master curves

wa83 AD 1168-1328 Board 3, South-east Vice Door, South Transept, Westminster Abbey - Baltic material
161 rings, starting date AD 1168
ring widths (0.01mm)

190 99 121 92 89 97 123 131 103 96
114 133 109 100 77 130 146 197 230 182
177 141 162 151 140 142 139 142 121 130
114 117 130 103 92 103 107 112 83 87
96 94 98 103 99 97 103 74 74 84
78 112 71 66 67 75 66 86 80 85
88 69 104 101 72 79 132 107 99 110
97 42 74 70 59 64 55 65 67 60
75 96 83 84 103 109 140 138 129 100
84 99 78 84 86 82 91 92 117 100
94 111 146 123 103 124 95 120 79 107
81 91 102 95 92 89 85 97 121 85
109 86 97 84 81 78 93 81 90 73
88 101 86 88 109 95 92 66 72 68
65 70 79 82 82 96 87 116 145 83
93 95 93 113 91 80 75 79 58 79
117

wa94 AD 1083-1198 Locking style, Door to Chapter House Undercroft, Westminster Abbey – English material
116 rings, starting date AD 1083

80 61 67 59 51 58 64 72 71 75
89 108 121 117 92 86 85 87 111 75
96 96 86 93 77 128 137 76 89 105
109 100 119 106 132 95 111 92 64 110
148 152 136 118 111 129 129 153 131 156
142 134 150 89 104 252 181 249 248 173
122 90 71 81 94 115 125 127 122 111
171 151 146 153 173 129 112 107 89 117
133 159 135 113 101 157 145 144 161 101
130 146 211 138 76 53 54 42 36 39
38 39 37 61 60 49 43 48 42 53
72 111 155 161 143 132

wa95 AD 1097-1181 Bottom rail, Door to Chapter House Undercroft, Westminster Abbey – English material
85 rings, starting date AD 1097

101 111 171 143 99 73 98 85 118 126
105 153 174 103 104 89 117 165 163 153
134 152 143 101 110 102 109 137 110 112
118 190 134 180 168 201 195 167 145 145
121 157 142 197 238 174 153 159 186 131
136 135 126 155 171 136 162 151 145 468
430 256 226 264 239 164 159 195 204 174
144 180 195 165 172 172 165 158 139 166
109 160 179 188 145

Table 4: Dating evidence for site master **WMNSTR1**, AD 924–1030 (file names for regional multi-site chronologies are in **BOLD**, an E in the first column indicates wood of English origin, and an I indicates wood imported into the country)

	County or region:	*Chronology name:*	*Short publication reference:*	*File name:*	*Spanning (AD):*	*Years overlap:*	*t-value:*
E	Essex	Greensted Church	(Tyers 1996a)	GREENSTD	878–1053	107	7.3
E	London	Old Bailey	(Tyers 1988)	BAILEY	908–1065	107	6.6
E	London	White Tower, Tower of London	(Miles and Worthington 1997)	WHTOWER1	907–1092	107	5.9
E	London	Fleet Valley	(Tyers and Hibberd 1993)	FLEET	745–1316	107	5.4
E	London	Fennings Wharf	(Tyers 2001)	FENNINGS	802–1435	107	5.3
E	London	Thames Exchange	(Nayling 1991)	THAMESX	645–1239	107	5.3
E	East Midlands	East Midlands Master	(Laxton and Litton 1988)	**EASTMID**	882–1981	107	4.7
E	Cambridgeshire	Peterborough Cathedral nave	(Tyers 1999a)	PETERC	887–1225	107	4.1

Table 5: Dating evidence for site master **WMNSTR2**, AD 1165–1267 (file names for regional multi-site chronologies are in **BOLD**, an E in the first column indicates wood of English origin, and an I indicates wood imported into the country)

	County or region:	*Chronology name:*	*Short publication reference:*	*File name:*	*Spanning (AD):*	*Years overlap:*	*t-value:*
I	Yorkshire	New Baxtergate, Grimsby	(Groves 1992)	GRIMSBY1	1100–1405	103	6.2
	Poland	Gdansk Master	(Wazny *pers comm*)	**GDANSK**	996–1985	103	6.1
I	Suffolk	Bridge Street, Ipswich	(Hillam 1985)	IPSWICH	1128–1293	103	6.0
I	Baltic	Baltic area 0	(Tyers *pers comm*)	**BALTIC0**	1052–1420	103	4.7
I	Yorkshire	Magistrates Court, Hull	(Tyers 1998)	HULLMC	1078–1369	90	4.1
I	Cambridgeshire	Peterborough Cathedral nave ceiling	(Groves *pers comm)*	PETERN	972–1230	66	3.6
I	London	Millennium Bridge	(Tyers 1999b)	MILLENM	1085–1415	83	3.5
I	Suffolk	Thornham Parva	(Tyers 2002)	THORNHM	1053–1309	103	5.1

Table 6: Dating evidence for site master **WMNSTR3**, AD 1137–1275 (file names for regional multi-site chronologies are in **BOLD**, an E in the first column indicates wood of English origin, and an I indicates wood imported into the country)

	County or region:	*Chronology name:*	*Short publication reference:*	*File name:*	*Spanning (AD):*	*Years overlap:*	*t-value:*
I	Hertfordshire	Presbytery Roof	(Howard *et al* 2002)	STALBANS	1050–1264	112	9.3
	Germany	Niedersachsen Nord	(Leuschner *pers comm*)	**NIEDER**	915–1873	112	5.2
	Poland	Southern Poland	(Krapiec *pers comm*)	**POLAND**	1100–1529	112	5.0
	Germany	Weserbergland	(Delorme 1972)	**WESER**	30BC-AD1960	112	4.9
I	Baltic	East St Helen's Street, Abingdon	(Miles and Haddon-Reece 1995)	STHELEN2	1216–1416	60	4.6
I	Baltic	Baltic area 0	(Tyers *pers comm)*	**BALTIC0**	1042–1420	112	4.7
I	Yorkshire	Magistrates Court, Hull	(Tyers 1998)	HULLMC	1078–1369	112	4.9
I	Yorkshire	Zouche Chapel	(Fletcher and Morgan 1981)	ZOUCHE	1118–1386	112	5.6

Table 7: Dating evidence for sample **wa65**, AD 1442–1593 (file names for regional multi-site chronologies are in **BOLD**, an E in the first column indicates wood of English origin, and an I indicates wood imported into the country)

	County or region:	*Chronology name:*	*Short publication reference:*	*File name:*	*Spanning (AD):*	*Years overlap:*	*t-value:*
E	Berkshire	Shalford	(Miles and Worthington 2001)	SHALFRD2	1403–1574	140	7.3
E	Berkshire	Shaw House, Newbury	(Miles *et al* 2004)	SHAW1	1391–1579	138	6.6
E	Surrey	Pirbright	(Miles and Worthington 2000)	PRBRIGHT	1403–1557	116	6.5
E	Oxfordshire	Bodleian Library	(Miles and Worthington 1999)	BDLEIAN3	1395–1610	152	6.2
E	Hampshire	The Vyne, Sherbourne St John	(Miles and Worthington 1997)	THEVYNE1	1459–1630	135	6.0
E	Wiltshire	Dog Kennel Farm, Clarendon	(Miles *et al* 2004)	CLRENDN7	1351–1603	152	5.9
E	Oxfordshire	Upper House Farm, Nuffield	(Haddon-Reece *et al* 1989)	NUFF	1404–1627	152	5.4
E	Shropshire	Oldfields Farm	(Miles and Haddon-Reece 1994)	OLDFIELD	1404–1572	131	5.4
E	Hampshire	Great Barn, Old Basing	(Bridge 1997)	BOBROOF	1347–1535	94	5.3

Table 8: Dating evidence for site master **WMNSTR4**, AD 1004–1219 (file names for regional multi-site chronologies are in **BOLD**, an E in the first column indicates wood of English origin, and an I indicates wood imported into the country)

	County or region:	*Chronology name:*	*Short publication reference:*	*File name:*	***Spanning (AD):***	***Years overlap:***	*t-value:*
I	Cambridgeshire	Peterborough Cathedral nave ceiling	(Groves *pers comm*)	PETERN	972–1230	116	11.6
	Germany	Niedersachsen Nord	(Leuschner *pers comm*)	**NIEDER**	915–1873	116	9.1
	Denmark	West Denmark	(Bonde *pers comm*)	**DENMARK**	109BC–AD1986	116	7.6
	Germany	Trier	(Hollstein 1980)	**TRIER**	546BC–AD1975	116	7.0
	Germany	Schleswig-Holstein	(Eckstein *et al* 1970)	**SCHWGH**	436–1968	116	6.6
	Germany	Weserbergland	(Delorme 1972)	**WESER**	30BC–AD1960	116	6.0
I	Hertfordshire	Presbytery roof	(Howard *et al* 2002)	STALBANS	1050–1264	59	5.1

Table 9: Dating evidence for site master **WMNSTR5**, AD 1162–1330 (file names for regional multi-site chronologies are in **BOLD**, an E in the first column indicates wood of English origin, and an I indicates wood imported into the country)

	County or region:	*Chronology name:*	*Short publication reference:*	*File name:*	***Spanning (AD):***	***Years overlap:***	*t-value:*
I	Baltic	Baltic area 0	(Tyers *pers comm*)	**BALTIC0**	1052–1420	169	8.6
I	Oxfordshire	New College Oxford	(Worthington and Miles *in prep*)	NWCOLLG2	1086–1357	169	8.6
I	London	Southwark boat chronology	(Tyers 1996b)	STHWRK	1133–1333	169	8.2
I	Yorkshire	Hull Magistrates Court	(Tyers 1998)	HULLMC	1078–1369	153	8.1
	Poland	West Central Poland	(Krapiec *pers comm*)	**POLAND**	1197–1606	134	6.8
I	Baltic	Magdalen College, Oxford	(Miles and Worthington 2000)	MAGDALN2	1080–1416	169	6.4
I	Yorkshire	Zouche Chapel	(Fletcher and Morgan 1981)	ZOUCHE	1118–1386	169	5.1
	Poland	East Pomerania	(Wazny and Eckstein 1991)	**EPOMRNA**	996–1985	169	5.0

Table 10: Dating evidence for sample **wa83**, AD 1168–1328 (file names for regional multi-site chronologies are in **BOLD**, an E in the first column indicates wood of English origin, and an I indicates wood imported into the country)

	County or region:	*Chronology name:*	*Short publication reference:*	*File name:*	***Spanning (AD):***	***Years overlap:***	*t-value:*
I	Yorkshire	New Baxtergate, Grimsby	(Groves 1992)	GRIMSBY1	1100–1405	161	5.8
I	London	Southwark boat	(Tyers 1996b)	SYM-T9	1133–1333	161	5.0
I	Baltic	Magdalen College, Oxford	(Miles and Worthington 2000)	MAGDALN2	1080–1416	161	4.3
I	Baltic	East St Helen's Street, Abingdon	(Miles and Haddon-Reece 1995)	STHELEN3	1188–1397	141	4.2
I	Baltic	Baltic area 0	(Tyers pers comm)	**BALTIC0**	1052-1420	161	5.3
I	Suffolk	Thornham Parva	(Tyers 2002)	THORNHM	1053-1309	142	5.1
I	Yorkshire	Hull Magistrates Court	(Tyers 1998)	HULLMC	1078-1369	151	4.7

Table 11: Dating evidence for site master **WMNSTR6**, AD 1000–1182 (file names for regional multi-site chronologies are in **BOLD**, an E in the first column indicates wood of English origin, and an I indicates wood imported into the country)

	County or region:	*Chronology name:*	*Short publication reference:*	*File name:*	***Spanning (AD):***	***Years overlap:***	*t-value:*
E	London	London Master Chronology	(Tyers *pers comm*)	**LONDON**	413–1728	183	7.8
E	Southern England	South Master Chronology	(Hillam and Groves 1994a)	**SOUTH**	406–1594	183	7.3
	Wales	Welsh Master Chronology	(Miles 1997b)	**WALES97**	404–1981	183	7.2
E	Hampshire	Hampshire Master Chronology	(Miles 2003)	**HANTS02**	443–1972	183	7.1
	Wales	Chepstow Castle Gates	(Miles and Worthington 1998)	CHEPSTW1	1045–1151	107	6.8
E	Cambridgeshire	Peterborough Cathedral	(Tyers 1999a)	PETERC	887–1225	183	6.7
E	Yorkshire	Beverley	(Hillam 1981)	BEVERLEY	858–1310	183	6.6
E	Bristol Area	Bristol Master Chronology	(Hillam 1994)	**BRISTOL**	770–1320	183	6.5

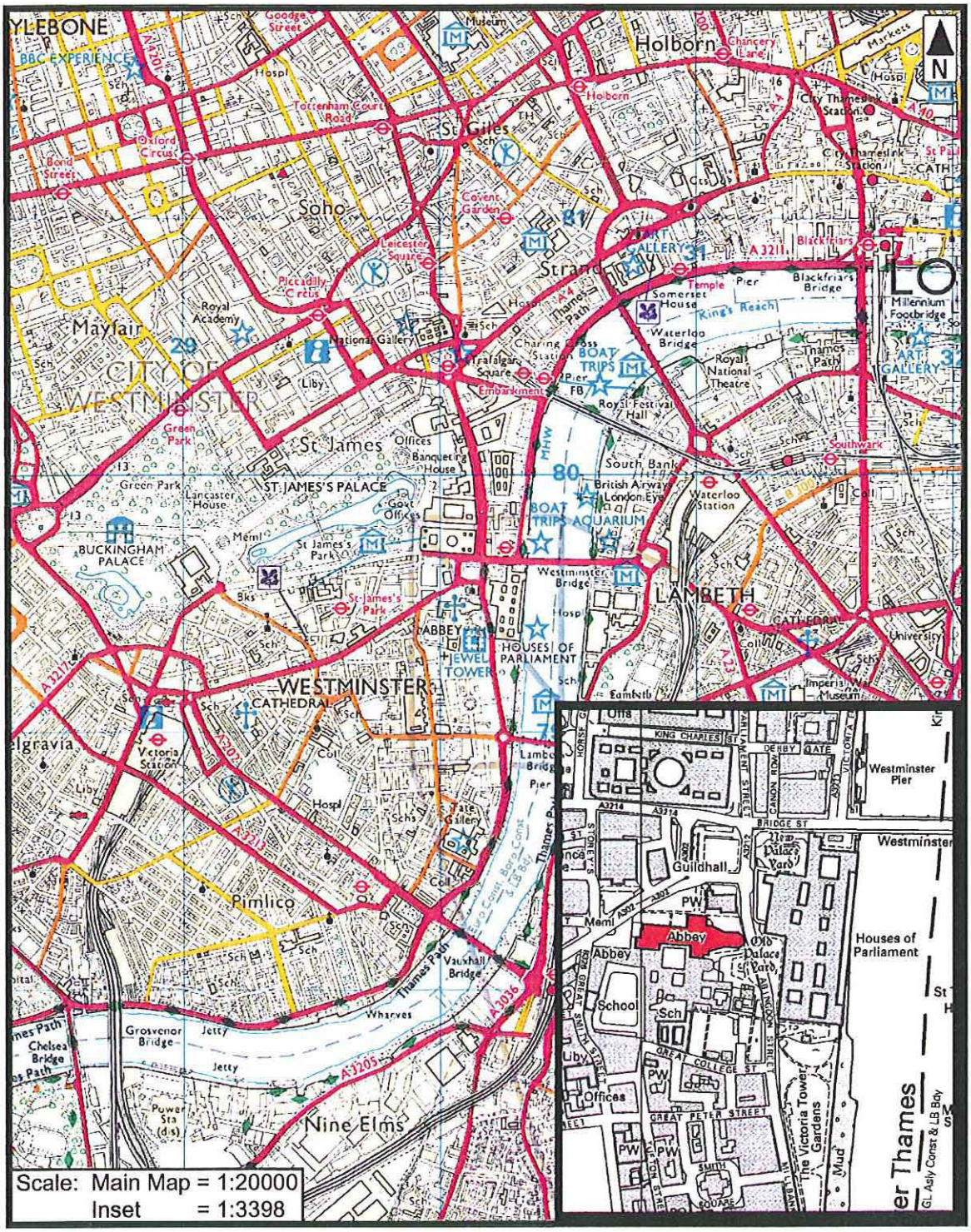
Table 12: Dating evidence for sample **wa94**, AD 1083–1198 (file names for regional multi-site chronologies are in **BOLD**, an E in the first column indicates wood of English origin, and an I indicates wood imported into the country)

	County or region:	*Chronology name:*	*Short publication reference:*	*File name:*	***Spanning (AD):***	***Years overlap:***	*t-value:*
E	London	London Master Chronology	(Tyers *pers comm*)	**LONDON**	413–1728	116	5.5
E	Cambridgeshire	Peterborough Cathedral	(Tyers 1999)	PETERC	887–1225	116	5.5
E	Hampshire	Hampshire Master Chronology	(Miles 2003)	**HANTS02**	443–1972	116	5.4
E	Southern England	South Master Chronology	(Hillam and Groves 1994a)	**SOUTH**	406–1594	116	5.0
E	Hampshire	Rockborne Manor Barn	(Miles and Haddon-Reece 1995)	ROCKBORN	1094–1263	105	4.9
E	Greater Manchester	Baguley Hall	(Nayling 2004)	BAGT7	1015–1371	116	4.8
	Great Britain	British Isles Master Chronology	(Haddon-Reece and Miles 1993)	**MASTERAL**	404–1987	116	4.8

Table 13: Dating evidence for sample **wa95**, AD 1097–1181(file names for regional multi-site chronologies are in **BOLD**, an E in the first column indicates wood of English origin, and an I indicates wood imported into the country)

	County or region:	*Chronology name:*	*Short publication reference:*	*File name:*	***Spanning (AD):***	***Years overlap:***	*t-value:*
E	London	London Master Chronology	(Tyers *pers comm*)	**LONDON**	413–1728	85	6.6
	Great Britain	British Isles Master Chronology	(Haddon-Reece and Miles 1993)	**MASTERAL**	404–1987	85	5.8
E	City of London	Swan Lane	(Groves and Hillam 1987)	SWANMED	938–1192	85	5.8
E	Bristol	Canynges House, Bristol	(Hillam 1988)	CANYNGES	866–1181	85	5.3
E	Southern England	South Master Chronology	(Hillam and Groves 1994a)	**SOUTH**	406–1594	85	5.1
E	Oxfordshire	Coxwell Barn	(Siebenlist-Kerner *et al* 1978)	COXWELL	1043–1267	85	5.0
E	Hertfordshire	Westwick	(Howard *et al* 1999)	WESTWICK	940–1179	83	5.0
E	Wiltshire	Salisbury Cathedral	(Miles *et al* 2004)	SARUM14	1053–1241	85	4.8

Figure 1:



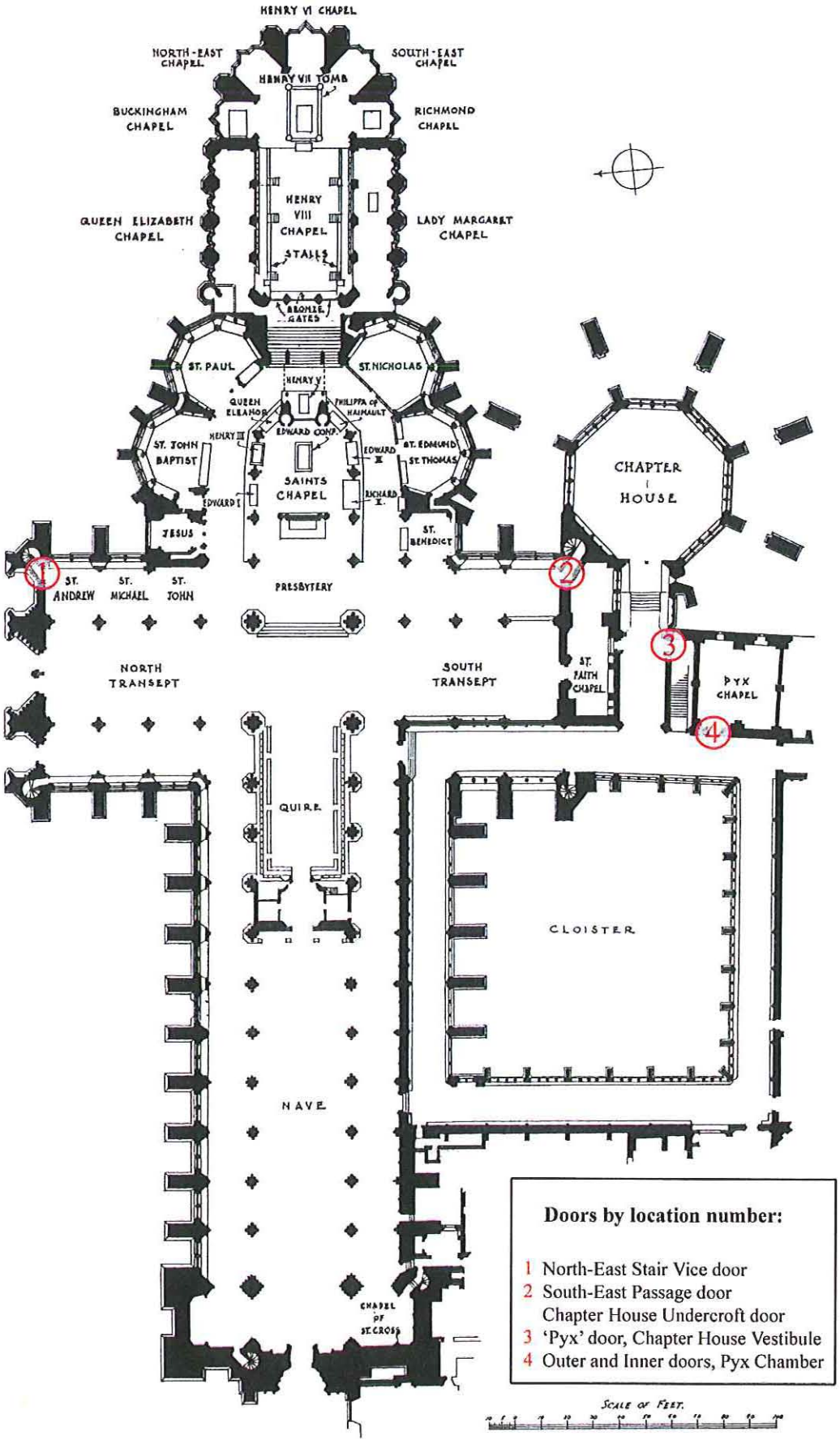


Figure 2: Plan of the Abbey showing locations of doors sampled in red (English Heritage)

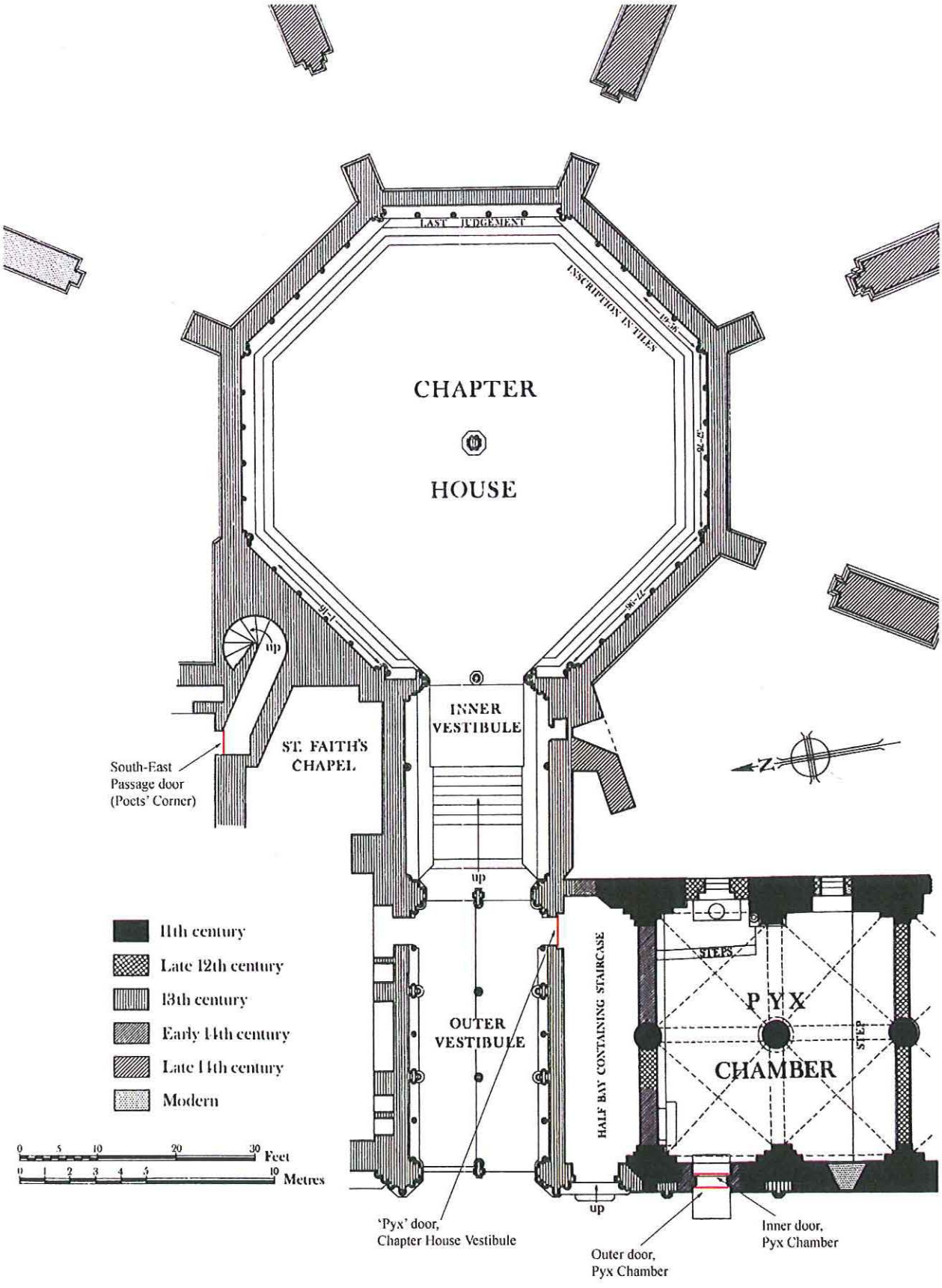


Figure 3: Plan of Chapter House and Pyx showing locations of doors sampled (HMSO 1976)

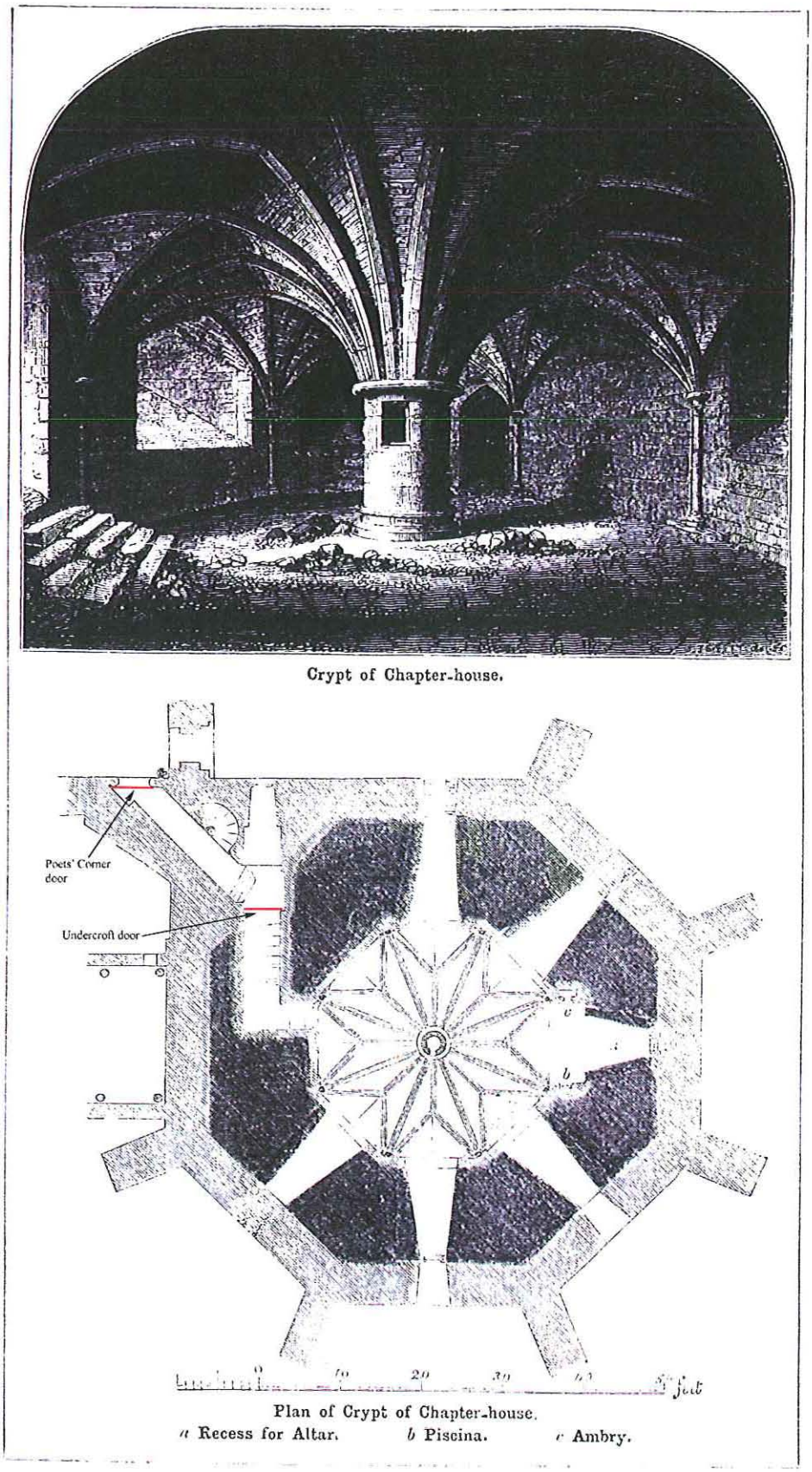


Figure 4: Plan of Chapter House undercroft showing locations of doors sampled (Scott 1863)

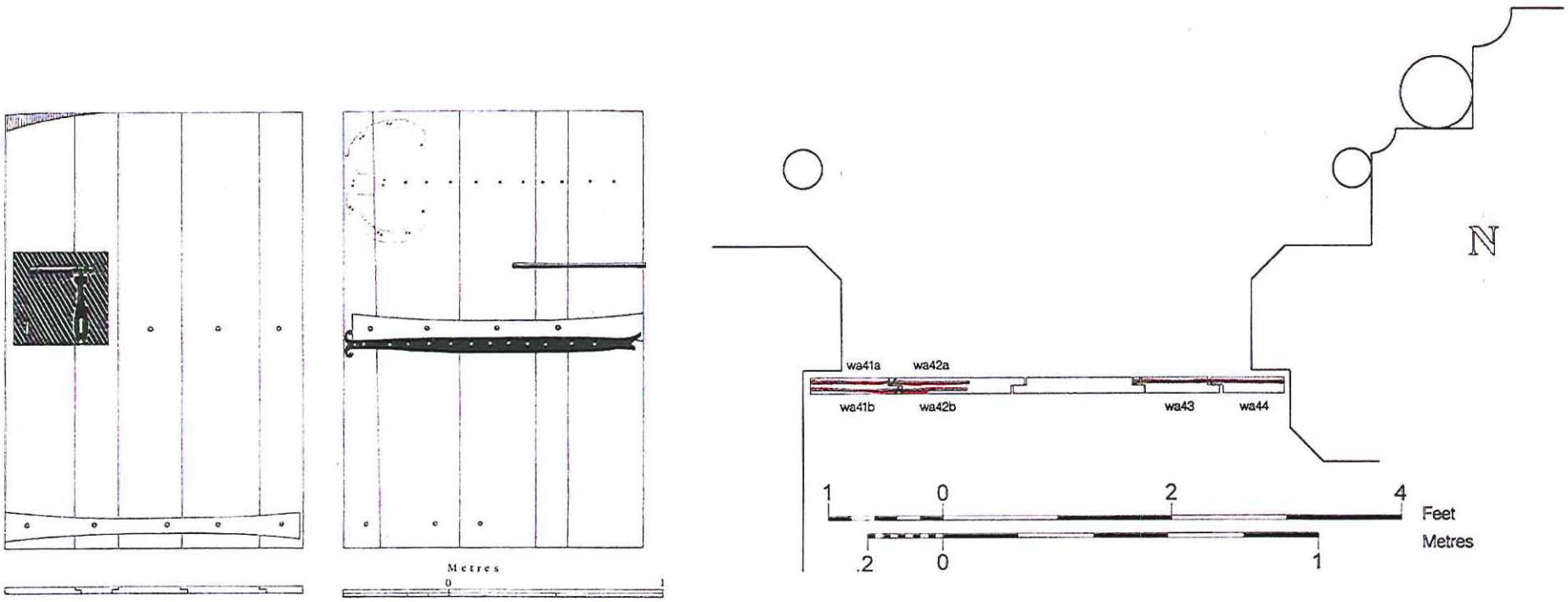


Figure 5: Measured drawing of Chapter House vestibule (Pyx) door (NMR 96/8214), and detailed section of boards (D Miles)

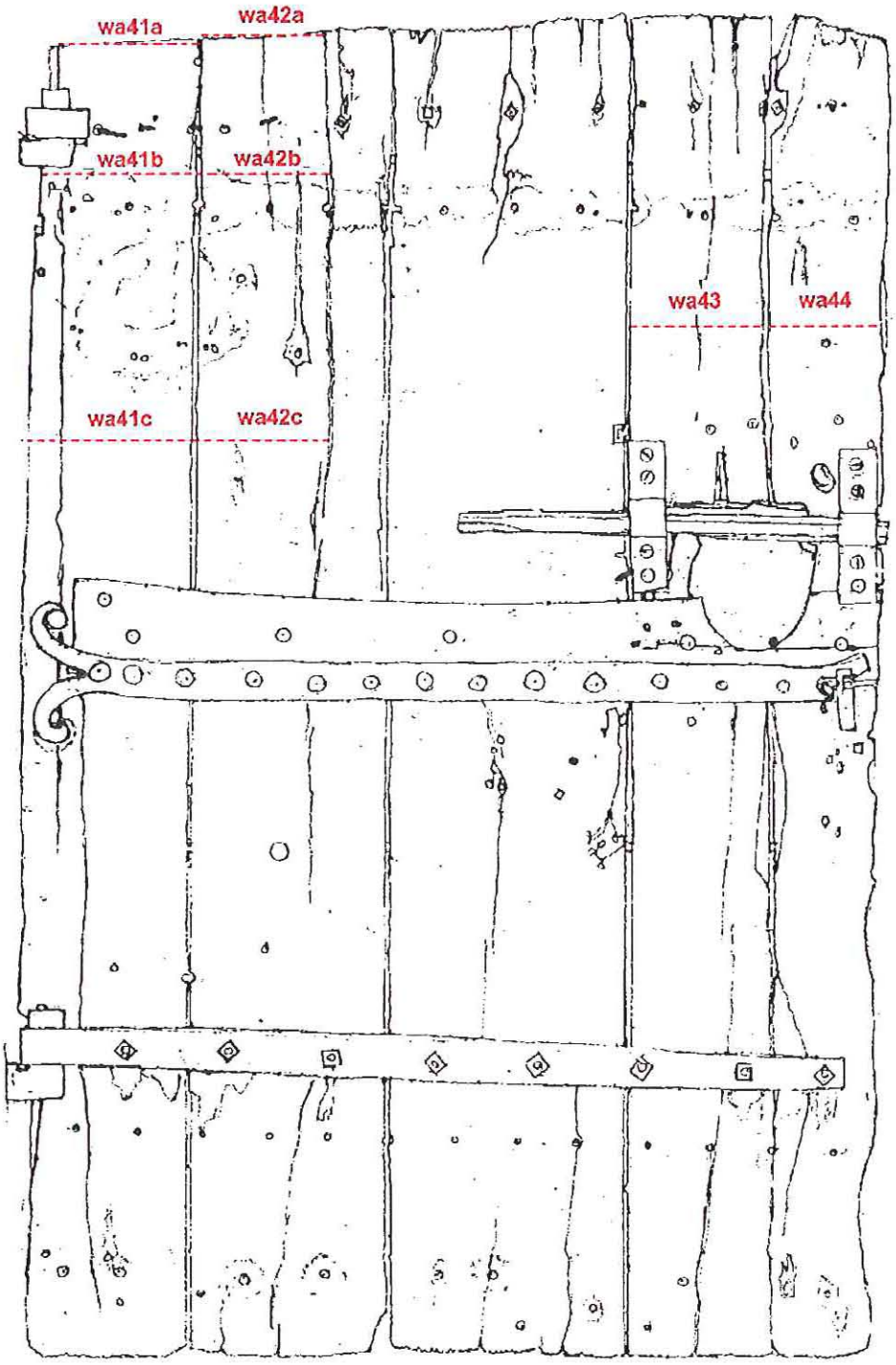


Figure 6: Rear face of the Chapter House vestibule 'Pyx' door (after Angela Thomas) showing sample locations.

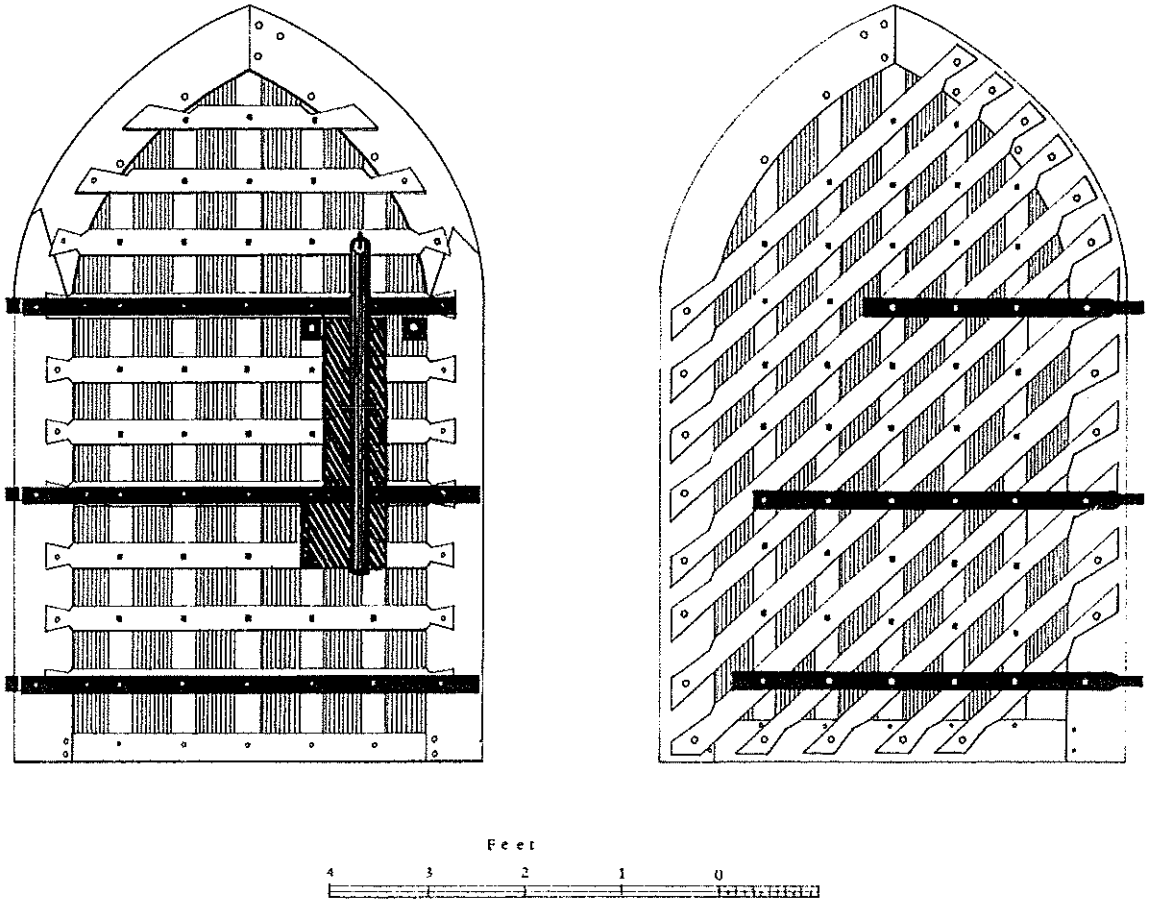


Figure 7: Measured drawing of outer Pyx Chamber door (NMR 96/8214)

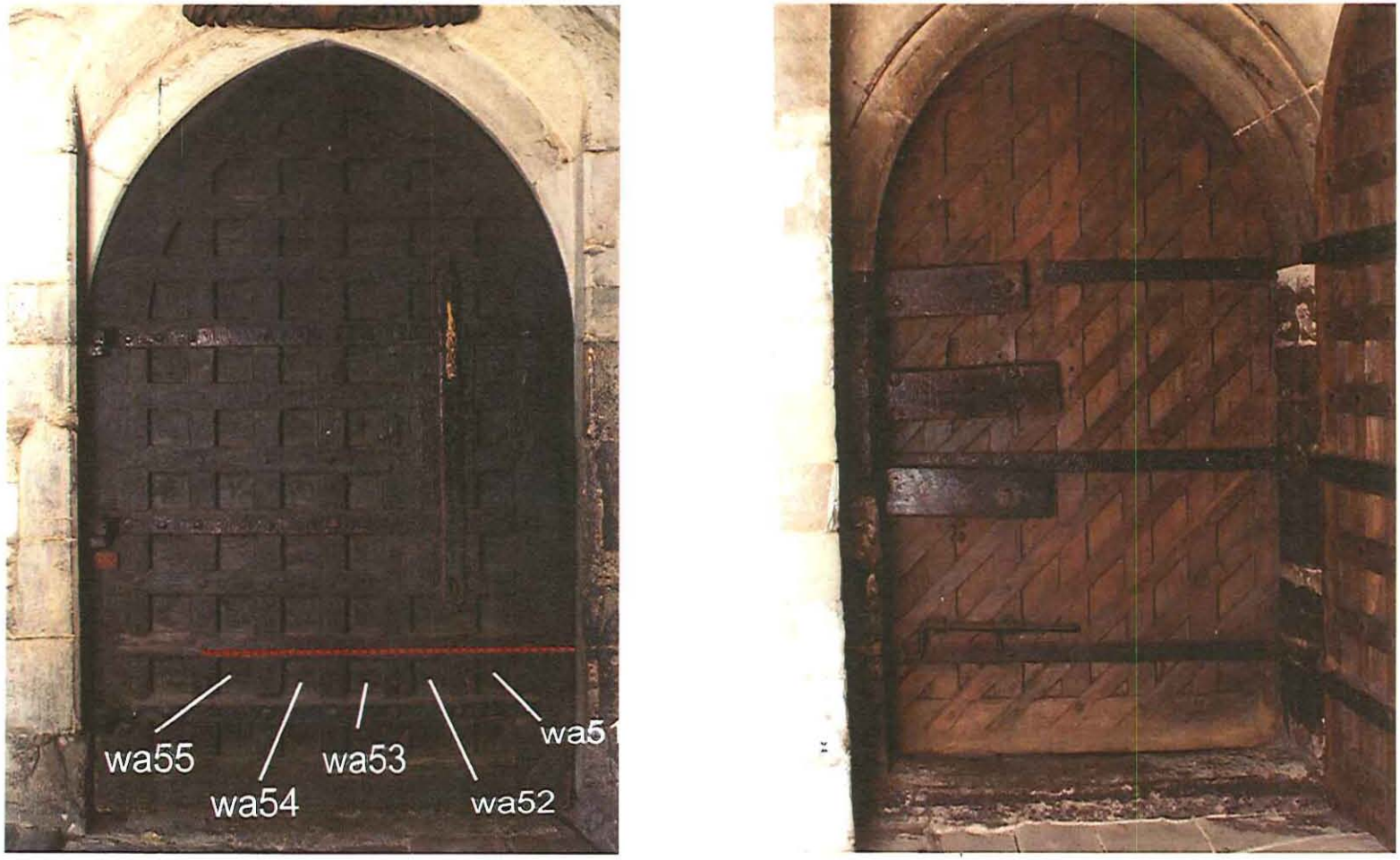


Figure 8: Rectified photographs of outside and inside faces of outer Pyx Chamber door showing sample locations (English Heritage Metric Survey Team)

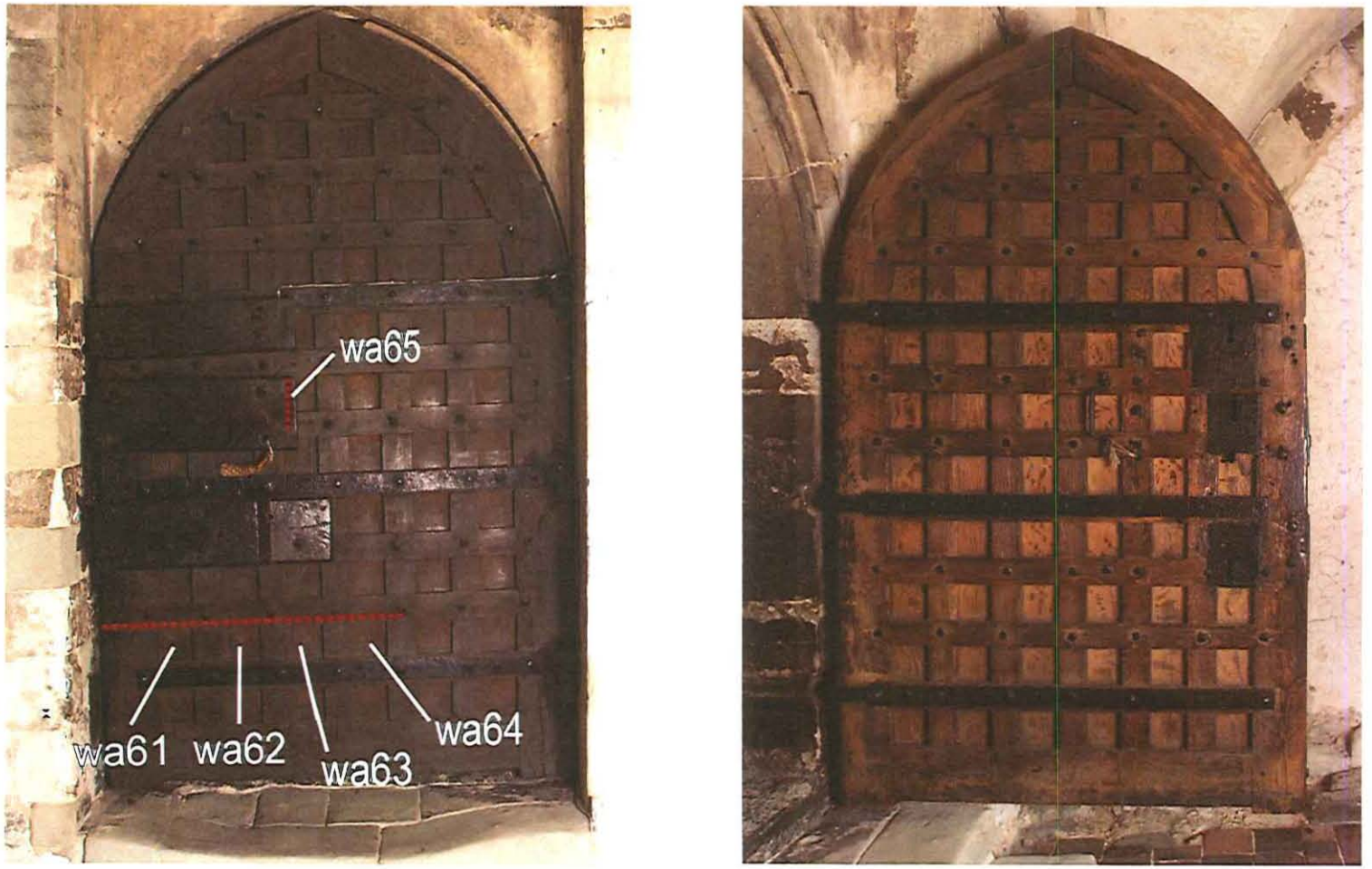


Figure 9: Rectified photographs of outside and inside faces of inner Pyx Chamber door showing sample locations (English Heritage Metric Survey Team)

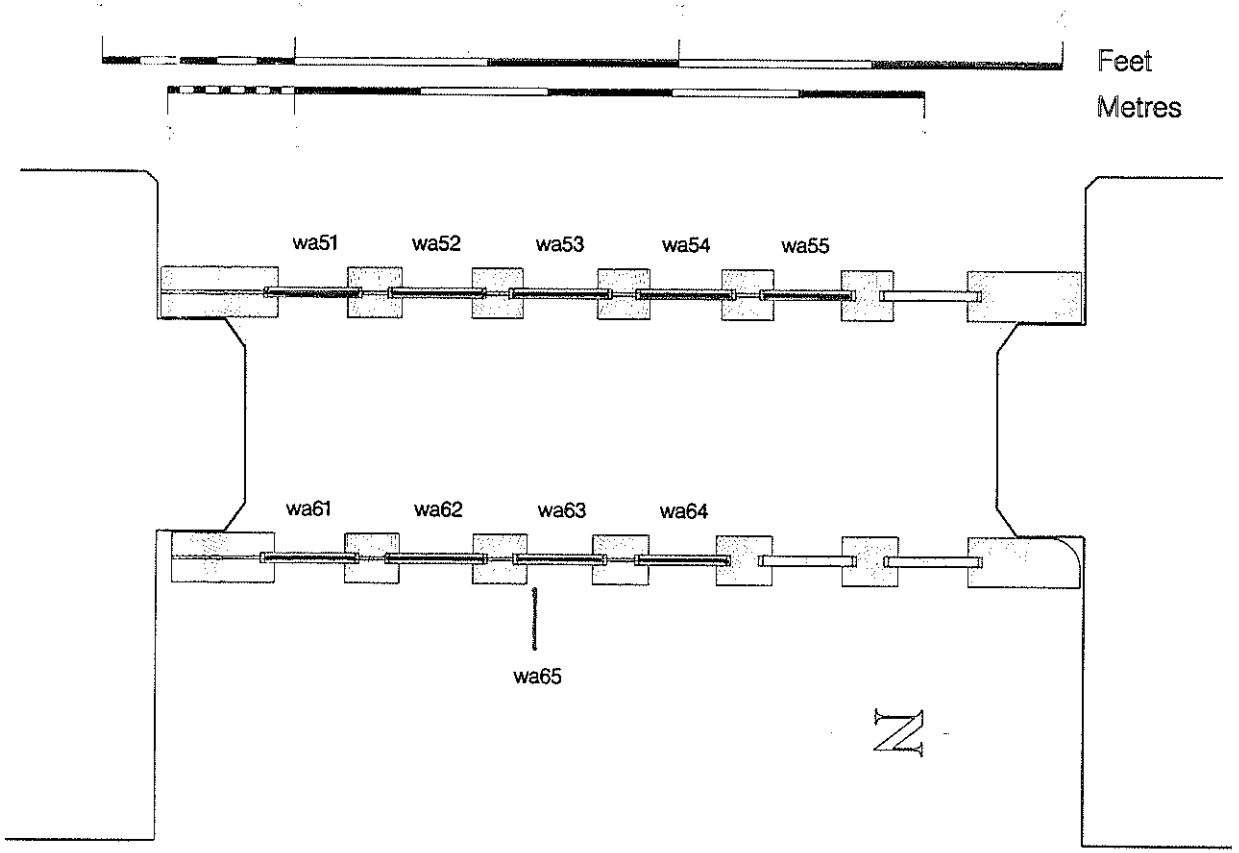


Figure 10: Section drawing of Pyx Chamber doors and jambs showing line of sampling (D Miles)

Figure 11: Photograph of outside face (after W Rodwell) and inside face (D Miles) of north transept stair vice door showing sample locations

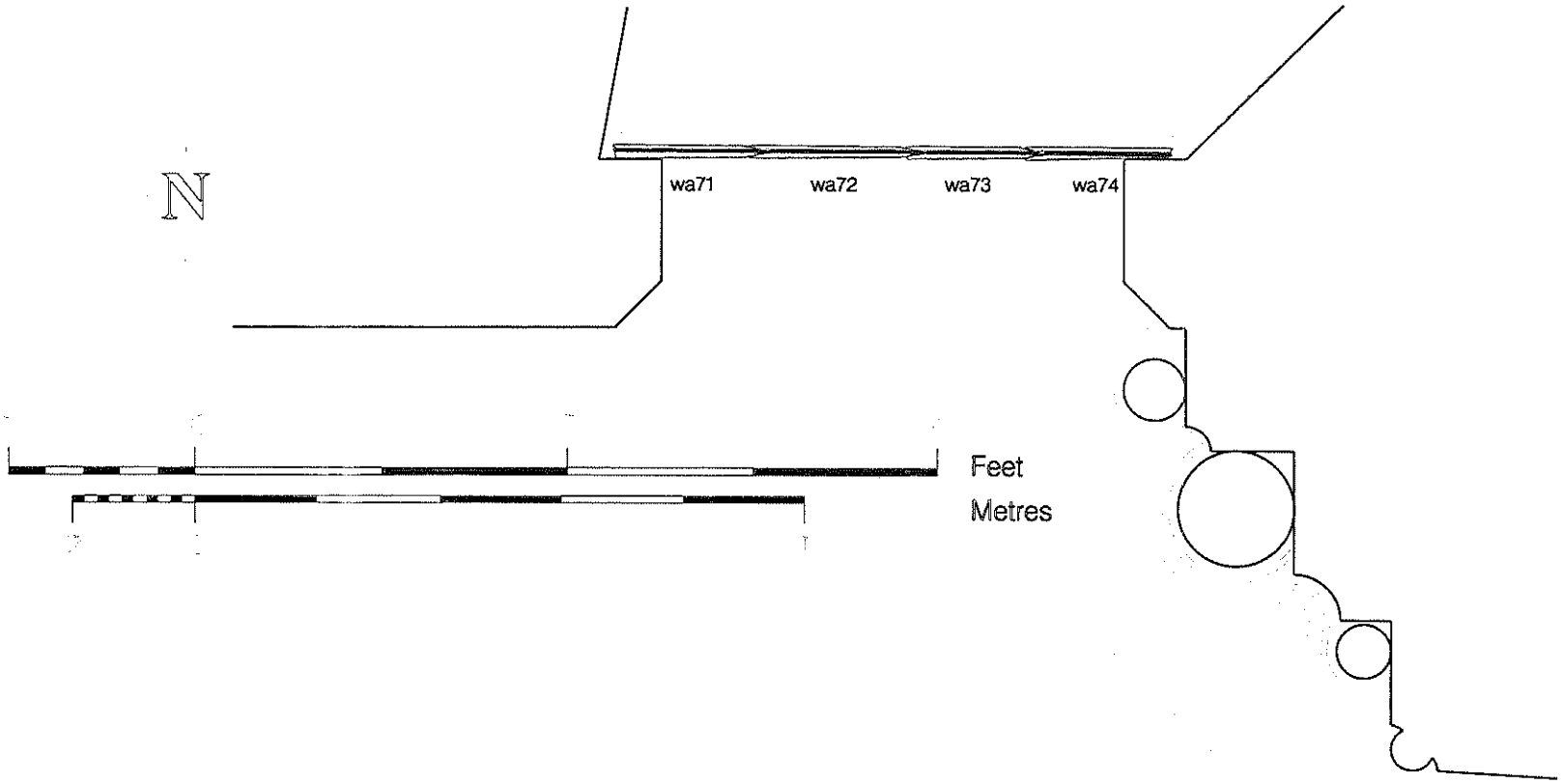


Figure 12: Section drawing of north transept door and jambs showing line of sampling (D Miles)

Figure 13: Photograph of outside face (after W Rodwell) and inside face (D Miles) of south transept (Poets' Corner) passage door showing sample locations

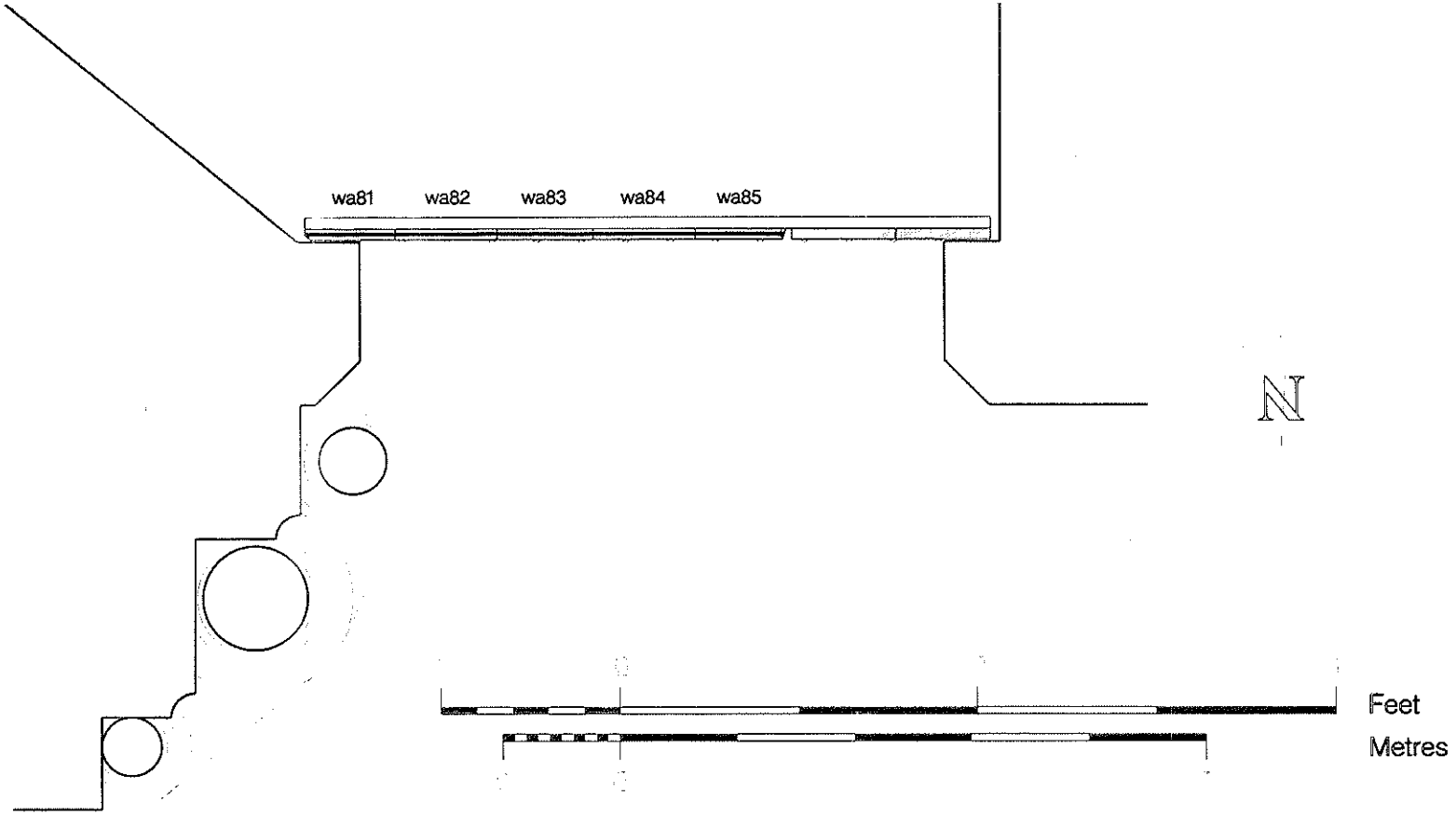


Figure 14: Section drawing of south transept (Poets' Corner) passage door and jambs showing line of sampling (D Miles)

Figure 15: Outer (after W Rodwell) and inner faces of door to Chapter House undercroft showing sample locations

Figure 16: Detail of peg inserted into reused brace (**wa91**) used in the construction of the Chapter House undercroft door (D Miles)

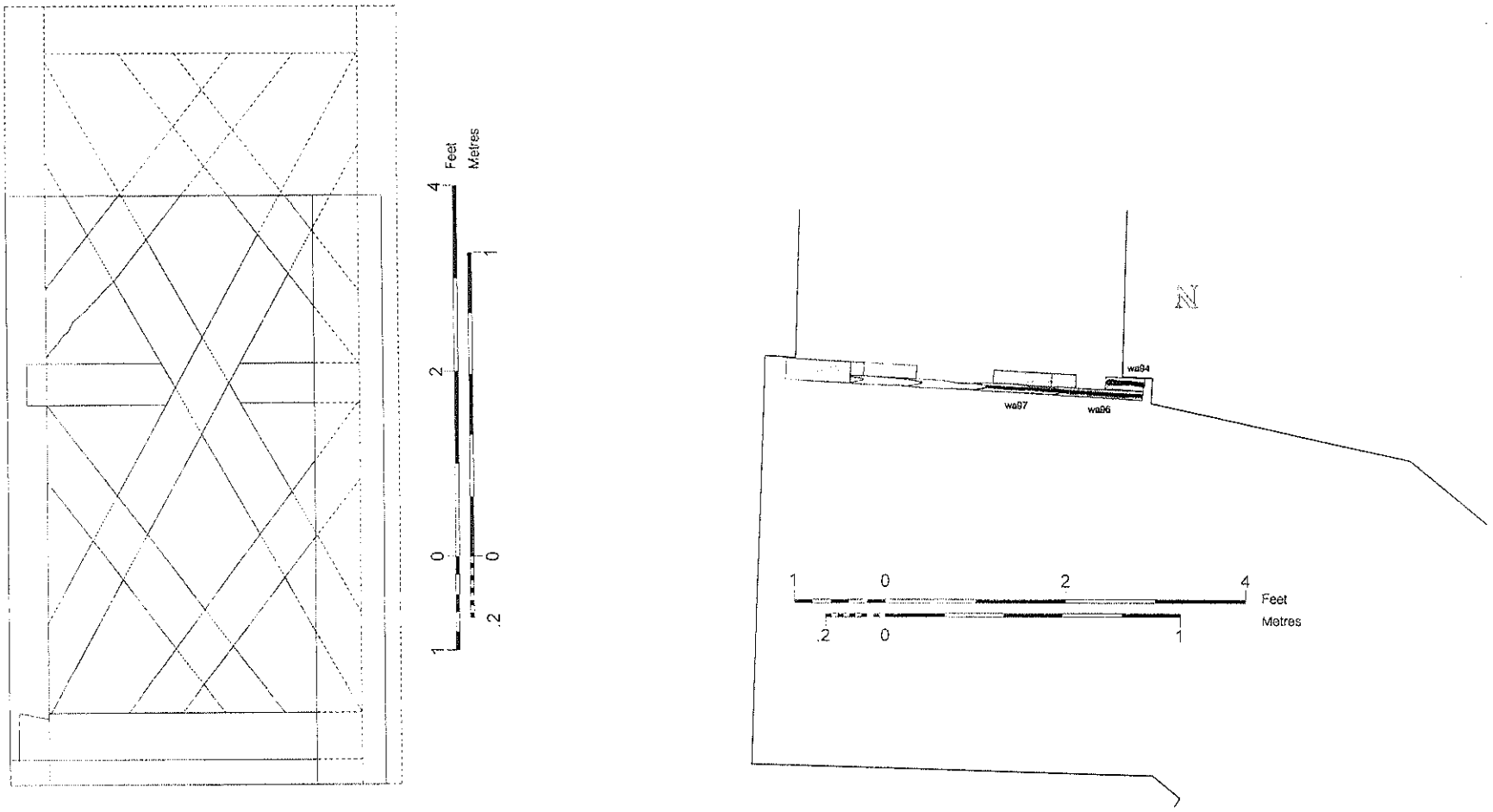


Figure 17: Measured drawing of inside face of door to Chapter House undercroft and detailed section showing line of sampling (D Miles)

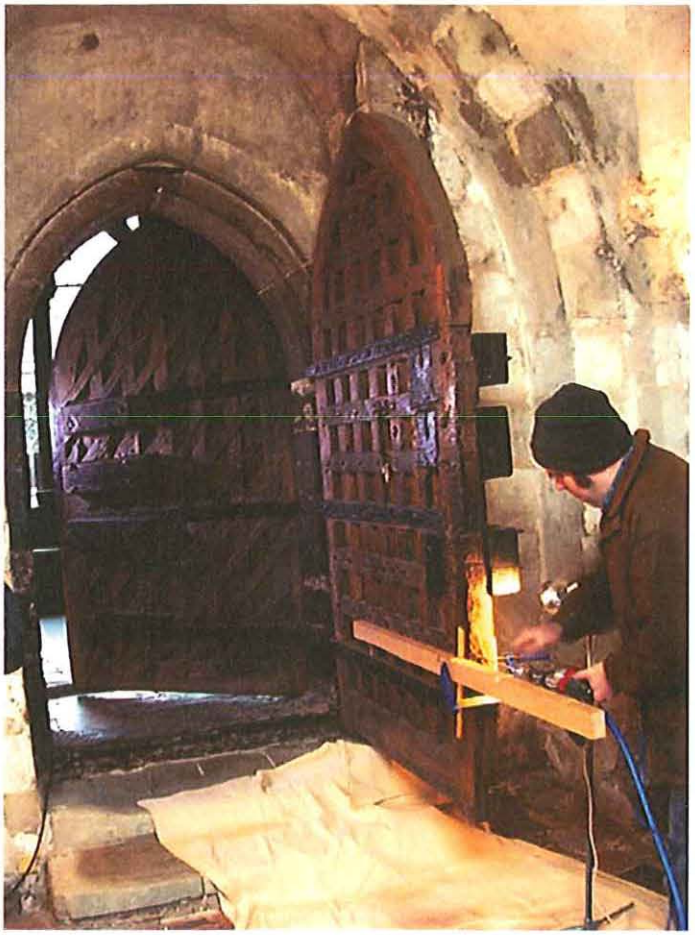


Figure 18: Micro-boring jig and drill set up to drill the inner Pyx Chamber door (M Bridge)

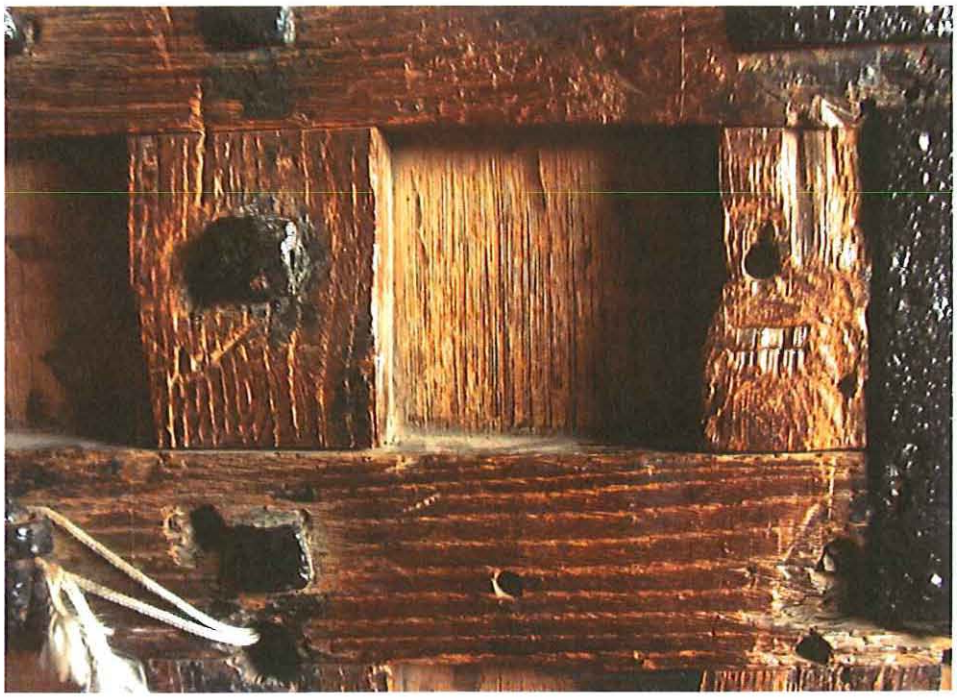


Figure 19: Detail of the ledges and muntins of the inner Pyx Chamber door showing their wide rings (M Bridge)

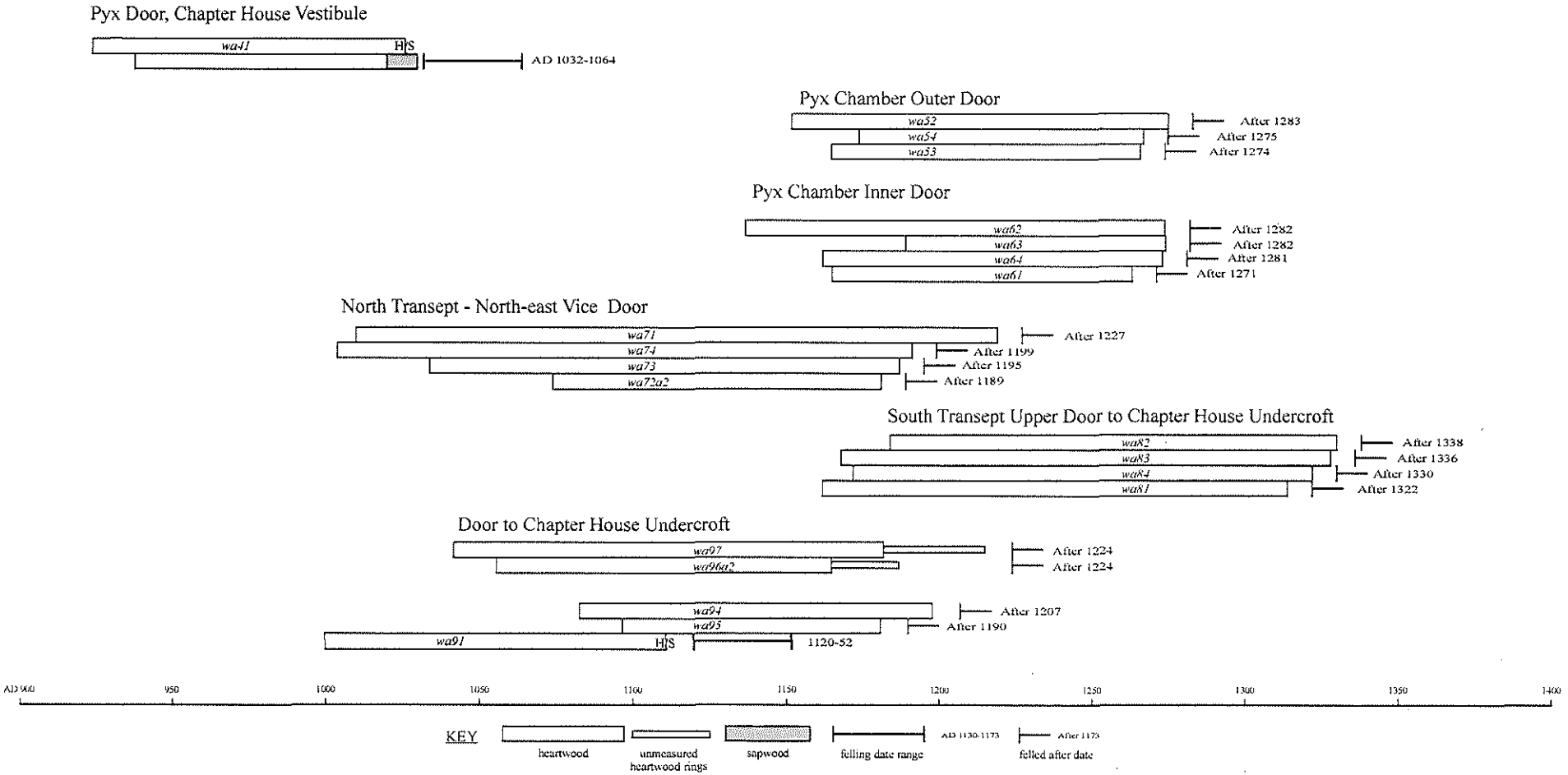


Figure 20: Bar diagram showing dated samples in chronological position