AUDLEY END, LONDON ROAD, SAFFRON WALDEN, ESSEX
DENDROCHRONOLOGICAL ANALYSIS OF SIXTEEN PANEL PAINTINGS ON OAK BOARDS

SCIENTIFIC DATING REPORT

Ian Tyers

ENGLISH HERITAGE

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SUMMARY

A tree-ring assessment, measurement, and analysis programme was commissioned on 16 panel paintings normally located at Audley End, Saffron Walden, Essex. These panels were mostly portraits of sixteenth- and seventeenth-century sitters, which in total comprised 39 oak boards. Direct tree-ring measurement was undertaken on 37 of these boards whilst the panels were undergoing conservation treatment between 2010 and 2014. The results dated 29 of these boards and identified that all but one of the dated boards were derived from timbers imported from the eastern Baltic. The timbers provide likely usage dates for these panels mostly supporting previous attributions.

CONTRIBUTORS

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ACKNOWLEDGEMENTS

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DATE OF INVESTIGATION

2010–2014

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INTRODUCTION

This document is a technical archive report on the tree-ring analysis of oak boards from 16 panel paintings normally located at Audley End, Saffron Walden, Essex. It is beyond the dendrochronological brief to describe these objects in detail. Elements of this report may be combined with detailed descriptions, photographs, and other technical reports at some point in the future to form either a comprehensive publication or an archive deposition on these objects.

METHODOLOGY

These panels were constructed from one or more horizontally or vertically aligned oak boards. Typically these boards taper slightly from one end to the other. They are bevelled around the edges and have original surfaces on the reverse face. Most panel paintings utilise boards from a radial, or near radial oak board and use straight-grained slow growing oak (*Quercus* spp). Each panel was given an analysis number, and each board within each individual panel was labelled from A onwards from either top or left as viewed from the front.

Tree-ring dating employs the patterns of tree-growth to determine the calendar dates for the period during which the sampled trees were alive. The amount of wood laid down in any one year by most trees is determined by the climate and other environmental factors. Trees over relatively wide geographical areas can exhibit similar patterns of growth, and this enables dendrochronologists to assign dates to some samples by matching the growth pattern with other ring-sequences that have already been linked together to form reference chronologies.

Timbers intended for dendrochronological analysis need to be free of aberrant anatomical features such as those caused by physical damage to the tree, which may prevent or significantly reduce the chances of successful dating.

Standard dendrochronological analysis methods (see eg English Heritage 1998) were applied to each suitable board in each panel. Complete or partial sequences of the annual growth rings were measured to an accuracy of 0.01mm using a micro-computer based travelling stage. The sequences of ring widths were then plotted onto semi-log graph paper to enable visual comparisons to be made between sequences. In addition, cross-correlation algorithms (eg Baillie and Pilcher 1973) were employed to search for positions where the ring sequences were highly correlated. Highly correlated positions were checked using the graphs and, if any of these were satisfactory, new composite sequences were constructed from the synchronised sequences. Any *t*-values reported below were derived from the original CROS algorithm (Baillie and Pilcher 1973). A *t*-value of 3.5 or over is usually indicative of a good match, although this is with the proviso that high *t*-values at the same relative or absolute position needs to have been obtained from a

range of independent sequences, and that these positions were supported by satisfactory visual matching.

Not every tree can be correlated by the statistical tools or the visual examination of the graphs. There are thought to be a number of reasons for this: genetic variations; site-specific issues (for example a tree growing in a stream bed will be less responsive to rainfall); or some traumatic experience in the tree's lifetime, such as injury by pollarding, defoliation events by caterpillars, or similar. These could each produce a sequence dominated by a non-climatic signal. Experimental work with modern trees shows that 5–20% of all oak trees, even when enough rings are obtained, cannot be reliably cross-matched.

Converting the date obtained for a tree-ring sequence into a useful date requires a record of the nature of the outermost rings of the sample. If bark or bark-edge survives, a felling date precise to the year or season can be obtained. If no sapwood survives, the date obtained from the sample gives a *terminus post quem* for its use. If some sapwood survives, an estimate for the number of missing rings can be applied to the end-date of the heartwood. This estimate is quite broad and varies by region. This report uses a minimum of 8 rings as a sapwood estimate for the eastern Baltic boards based on comparative data from other groups of eastern Baltic data (eg Tyers 1998; Sohar *et al* 2012), and a minimum of 10 rings for the English board (eg English Heritage 1998).

The analysis may highlight potential same-tree identifications if two or more tree-ring sequences are obtained that are exceptionally highly correlated. Such pairs, or sometimes more, are then used as a same-tree group and each can be given the interpreted date of the most complete of the samples. They are most useful where several timbers date but only one has any sapwood or where same-tree identifications yield linkages within or between objects.

Eastern Baltic boards of *c* 250–325mm width are likely to have been minimally trimmed as this appears to have been the 'standard' size of the traded boards. The tree-ring results obtained from boards of these sizes thus appear to be broadly indicating the usage period for these panels. In this case an estimated usage date based on a range of 8–40 trimmed rings is used following Baillie (1984).

RESULTS

One panel was examined at the Courtauld Institute conservation studio, London, in September 2010, two were examined at the EH conservation studio, London, in February and March 2013, and 13 panels were examined at the Hamilton Kerr Institute, Cambridge, during December 2010 and April 2014. These 16 panels comprised 39 oak boards, of which 37 were suitable for measurement and 29 were dated. Twenty-eight were of eastern Baltic origin, with the remaining board being English. Dated boards were present in all 16 panels. Most of the eight analysed boards which were not dated, and the two boards which were not analysed, were not obviously different from the other boards in their respective panels, although the bottom corner board (board D) of the Sir Thomas Cornwallis panel is likely to be a later repair.

The following 16 sub-sections provide individual results for each panel, and include the associated figures and tables so that each set of information derived from each panel is in a single sub-section. These sub-sections are in EH accession number order, and use the painting descriptions and artist attributions provided at the onset of these analyses.

The measurement data for the measured boards are listed in Appendix 1.

81031020 Member of the Standen family, English School

This panel is c 693mm high and c 548mm wide comprising three relatively narrow vertical oak boards (Fig 1; Table 1), with a maximum of thickness c 11mm. The boards, labelled A to C from the left, were all suitable for measurement. Complete sequences were obtained from one end of each board. The three series did not match each other and were compared with reference data of historic date from throughout England and northern Europe. A number of statistically significant matches were obtained between the board B sequence and reference series, along with other contemporaneous objects. These indicate that the board B sequence dates from AD 1452–1554 inclusive (Fig 2; Table 2). The series from boards A and C did not give significant correlations to reference data and both remain undated.

The dated board B is of eastern Baltic origin. The boards which were not dated, boards A and C, are not obviously different from the dated board in the panel.

The dated board retained eight rings of sapwood and thus the interpretation given to the dated board is a felling date range based on the minimum and maximum estimated number of missing sapwood rings, using a range of 8–24 annual rings. The interpreted date thus represents the likeliest felling date range for the dated individual board. This indicates that board B was felled between AD 1554 and AD 1570.

Figure 1: The construction of the Member of the Standen Family panel painting from Audley End. The locations of the board joints are approximate. Photo kindly supplied by the Hamilton Kerr Institute

Audley End	Span of ring sequences	
Standen Family member	Board B ▨	⊢AD 1554-70
Calendar Years	AD 1500　　　AD 1550	
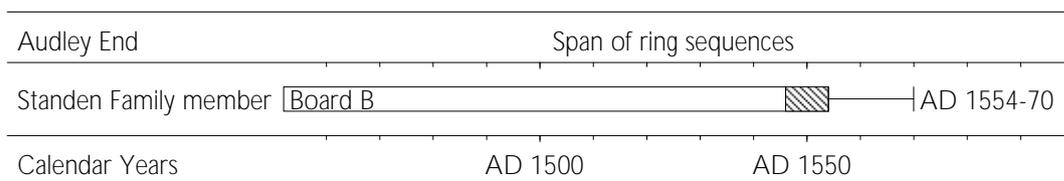
Figure 2: Bar diagram showing the absolute dating position of the dated tree-ring sequence for board B from the Member of the Standen Family panel painting from Audley End. The interpreted felling date is also shown for the dated board
KEY. White bar is eastern Baltic oak heartwood, hatched bar is sapwood

Table 1: Details of the three oak boards from the Member of the Standen Family panel painting from Audley End

OS0919 Board	Width (mm)	Rings	AGR (mm)	Date of measured sequence	Interpreted result
Board A	135–139	138	0.96	undated	-
Board B	198–209	103 (8 sap)	1.91	AD 1452–1554	AD 1554–70
Board C	195–215	174	1.22	undated	-

KEY: sequences obtained from the upper edge of the board A, and the lower edges of boards B and C; AGR = average growth rate per year

Table 2: Example t-values between the composite sequence from board B from the Member of the Standen Family panel painting from Audley End and eastern Baltic oak reference data

	Board B AD 1452–1554
London, Brooke House panelling (Tyers forthcoming)	8.08
Catherine Parr, attributed to Master John, NPG4451 (Tyers 2012b)	8.05
Sir Francis Walsingham, Knole (Tyers 2013)	7.69
François Hercule de France, studio of François Clouet, Louvre (Tyers 2011a)	7.67
Baltic2, Fletcher panel paintings (Hillam and Tyers 1995)	7.22
Elizabeth I Darnley Portrait, NPG2082 (Tyers 2012b)	6.54

81031021 Thomas Howard 4th Duke of Norfolk, Stephen van der Meulen

This panel is *c* 432mm high and *c* 328mm wide. It comprises a single vertical oak board (Fig 3, Table 3), which is *c* 9mm thick at its maximum and was suitable for measurement. The innermost part of the board is very thin and a partial sequence was measured from the lower edge that did not include the innermost section of tree-rings. This series was compared with reference data of historic date from throughout England and northern Europe. A number of statistically significant matches were obtained between the board sequence and reference series, along with other contemporaneous objects. These indicate that the board sequence dates from AD 1366–1545 inclusive (Fig 4; Table 4).

The dated board is of eastern Baltic origin.

The board retained two rings of sapwood at its right-hand edge and thus the interpretation given to the panel is a felling date range based on the minimum and maximum estimated number of missing sapwood rings, using a range of 8–24 annual rings. The interpreted date thus represents the likeliest felling date range for the dated board as being felled between AD 1551 and AD 1567.

Figure 3: The construction of the Thomas Howard, 4th Duke of Norfolk panel painting from Audley End. Photo kindly supplied by the Hamilton Kerr Institute
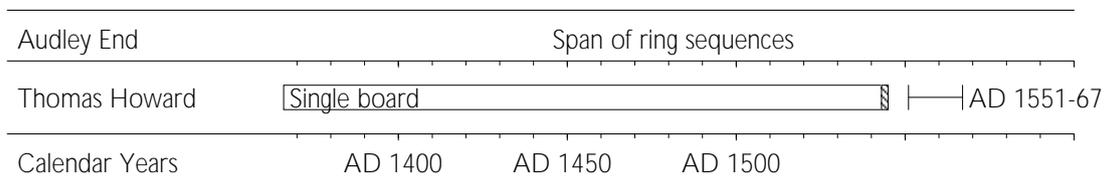
Figure 4: Bar diagram showing the absolute dating position of the dated tree-ring sequence for the board from the Thomas Howard, 4th Duke of Norfolk panel painting from Audley End. The interpreted felling date is also shown for the dated board
KEY. White bar is eastern Baltic oak heartwood, hatched bar is sapwood

Table 3: Details of the oak board from the Thomas Howard, 4th Duke of Norfolk panel painting from Audley End

OS0915 Board	Width (mm)	Rings	AGR (mm)	Date of measured sequence	Interpreted result
Single	326–328	180 (2 sap)	1.50	AD 1366–1545	AD 1551–67

KEY: sequence obtained from the lower edge of the board; AGR = average growth rate per year

Table 4: Example t-values between the sequence from the board from the Thomas Howard, 4th Duke of Norfolk panel painting from Audley End and eastern Baltic oak reference data

	Single Board AD 1366–1545
Baltic2, Fletcher panel paintings (Hillam and Tyers 1995)	10.66
James VI and I, Audley End, board A (this report, page 32)	9.97
London, Brooke House panelling (Tyers forthcoming)	9.59
Edward Hastings, Lord Loughborough (Tyers 2012a)	9.14
Sir Thomas Audley, Audley End, board C (this report, page 24)	8.86
Henry VIII ex Hornby Castle, NPG4980(14) (Tyers 2012b)	8.69

81031022 Sir Henry Neville, Cornelius Johnson

This panel is *c* 605mm high and *c* 482mm wide. It comprises three vertical oak boards (Fig 5; Table 5), which are *c* 9mm thick at their maximum. The boards were labelled A to C from the left. The paint and ground layer is chipped on all four edges of the panel, suggesting that it has been trimmed down from a larger panel painting. All three boards are exceptionally slow growing and it seems likely that all three are derived from the same tree. The right-hand board (C) was not considered suitable for measurement due to its small size. Sequences were obtained from the upper edges of boards A and B. These were found to strongly cross-match (*t*-value 11.63), and these boards are likely to be derived from a single tree (Fig 6). These were synchronised and combined into a single composite sequence. This composite was mathematically constructed from the matched series at their synchronised position producing a series of 412 years length. This composite series was compared with reference data of historic date from throughout England and northern Europe. A number of statistically significant matches were obtained between the composite sequence and reference series, along with other contemporaneous objects. These indicate that the composite sequence dates from AD 1181–1592 inclusive (Fig 7; Table 6).

Both the dated boards are of eastern Baltic origin. Board C is very slow growing and visually similar to the other boards in the panel.

Neither of the boards retained sapwood and thus the interpretations given to the dated boards are *terminus post quem* dates based on the minimum estimate of eight missing sapwood rings. The interpreted date represents the earliest possible felling date for the dated individual board. This indicates that board B was felled after AD 1600.

Assuming only minimal trimming has occurred provides a suggested usage date of AD 1600–32.

The composite sequence matches exceptionally well to a series obtained from the central board of a previously analysed panel in the collection of the National Portrait Gallery, London. This panel depicts Thomas Cromwell, Earl of Essex, and is a seventeenth-century copy of the well-known Holbein image (NPG1727). These two panels undoubtedly use boards derived from a single tree (*t*-value 22.53; Fig 8), and it is reasonable to conclude that the two panels were made at the same period in the same panel makers workshop. The NPG panel is of three vertical oak boards and is *c* 784mm high and *c* 620mm wide. The Audley End panel contains five additional rings compared to the sequence obtained from the central board of the NPG panel.

Figure 5: The construction of the Sir Henry Neville panel painting from Audley End. The locations of the board joints are approximate. Photo kindly supplied by the Hamilton Kerr Institute
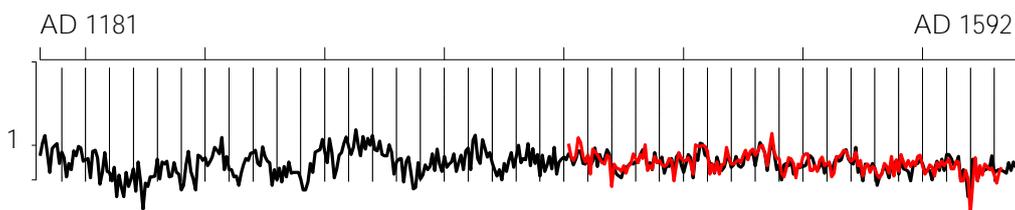
Figure 6: The series from board A (red) and board B (black) from the Sir Henry Neville panel painting from Audley End. These are derived from a single tree (t-value 11.63)

Audley End		Span of ring sequences		
Sir Henry Neville			Board A	├─→ after AD 1591
	Board B			├─→ after AD 1600
Calendar Years	AD 1250	AD 1400	AD 1550	
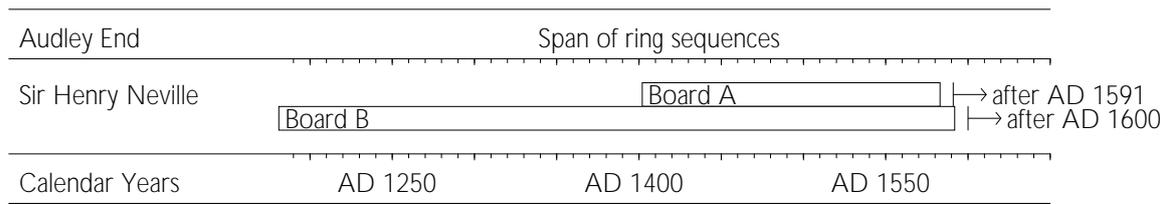
Figure 7: Bar diagram showing the absolute dating positions of the dated tree-ring sequences for boards A and B from the Sir Henry Neville panel painting from Audley End. The interpreted felling dates are also shown for each dated board
KEY. White bars are eastern Baltic oak heartwood

AD 1181   AD 1592

1
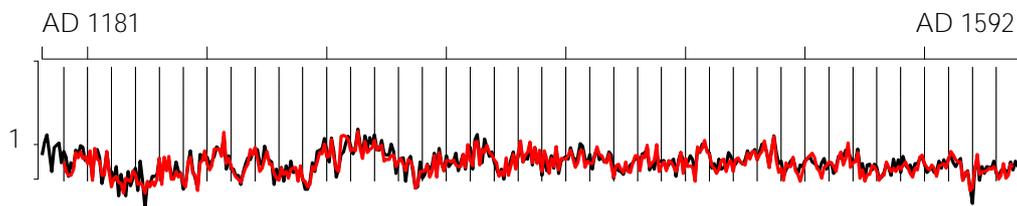
Figure 8: The composite series from boards A and B (black) from the Sir Henry Neville panel painting from Audley End, and board B from the NPG1727 Thomas Cromwell panel (red). These are derived from a single tree (t-value 22.53)

Table 5: Details of the three oak boards from the Sir Henry Neville panel painting from Audley End

OS0918 Board	Width (mm)	Rings	AGR (mm)	Date of measured sequence	Interpreted result
Board A	123–133	182	0.73	AD 1402–1583	after AD 1591
Board B	287–298	412	0.72	AD 1181–1592	after AD 1600
Board C	51–72	-	-	not analysed	-

KEY: sequences obtained from the upper edges of boards A and B; AGR = average growth rate per year

Table 6: Example t-values between the composite sequence from boards A and B from the Sir Henry Neville panel painting from Audley End and eastern Baltic oak reference data

	Boards A+B AD 1181–1592
Thomas Cromwell, Earl of Essex, after Holbein, NPG1727 (Tyers 2012b)	22.53
Poland, Gdansk, Copper Wreck wainscot (Wazny pers comm)	9.03
Netherlandish panel paintings (Eckstein *et al* 1975)	8.27
Baltic1, Fletcher panel paintings (Hillam and Tyers 1995)	7.35
Edmund Standen, Audley End (this report page 14)	7.03
Baltic2, Fletcher panel paintings (Hillam and Tyers 1995)	6.55

81031024 Edmund Standen, English School

This panel is *c* 683mm high and *c* 538mm wide. It comprises two vertical oak boards (Fig 9; Table 7), *c* 11mm thick at their maximum. The boards were labelled A and B from the left and both boards were suitable for measurement. Sequences were obtained from the upper and lower edges of board A, and from the lower edge of board B. The series from board A were synchronised and combined into a single composite sequence for this board. This composite was mathematically constructed from the matched series at their synchronised position, this series was 205 years in length. The two board series were found to strongly cross-match (*t*-value 21.16), and these boards are undoubtedly derived from a single tree (Fig 10). These were synchronised and combined into a single composite sequence. This composite was mathematically constructed from the matched series at their synchronised position, this produced a series of 205 years length. This composite series was compared with reference data of historic date from throughout England and northern Europe. A number of statistically significant matches were obtained between the composite board sequence and reference series, along with other contemporaneous objects. These indicate the composite sequence dates from AD 1339–1543 inclusive (Fig 11; Table 8).

The dated boards are of eastern Baltic origin.

Neither of the boards retained sapwood and thus the interpretations given to the dated boards are *terminus post quem* dates based on the minimum estimate of eight missing sapwood rings. The interpreted dates represents the earliest possible felling date for the dated individual board. This indicates that both boards were felled after AD 1551.

Assuming only minimal trimming has occurred provides a suggested usage date of AD 1551–83.

Figure 9: The construction of the Edmund Standen panel painting from Audley End. The location of the board joint is approximate. Photo kindly supplied by the Hamilton Kerr Institute
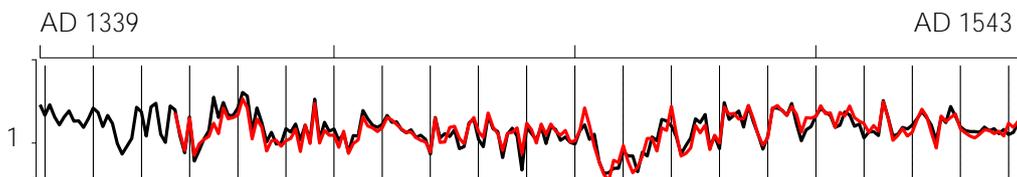
*Figure 10 The series from board A (black) and board B (red) from the Edmund Standen panel painting from Audley End. These are derived from a single tree (t-value 21.16)*

Audley End	Span of ring sequences	
Edmund Standen	Board A	⊢——→ after AD 1551
	Board B	⊢——→ after AD 1551
Calendar Years	AD 1350 AD 1450 AD 1550	
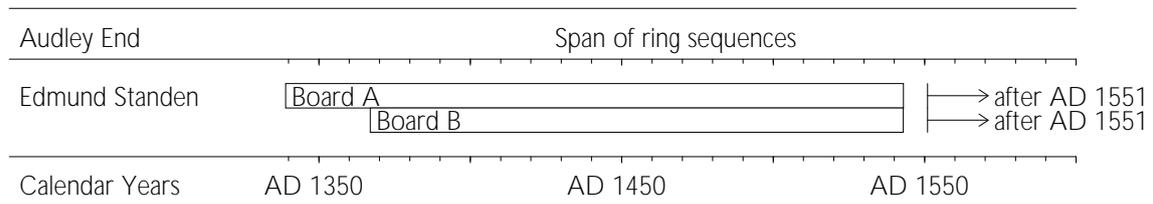
Figure 11: Bar diagram showing the absolute dating positions of the dated tree-ring sequences for both boards from the Edmund Standen panel painting from Audley End. The interpreted felling dates are also shown for each dated board
KEY. White bars are eastern Baltic oak heartwood

Table 7: Details of the two oak boards from the Edmund Standen panel painting from Audley End

OS0920 Board	Width (mm)	Rings	AGR (mm)	Date of measured sequence	Interpreted result
Board A	273–286	205	1.35	AD 1339–1543	after AD 1551
Board B	250–265	177	1.30	AD 1367–1543	after AD 1551

KEY: sequences obtained from the upper and lower edges of board A, and from the lower edge of board B; AGR = average growth rate per year

Table 8: Example t *-values between the composite sequence from boards A and B from the Edmund Standen panel painting from Audley End and eastern Baltic oak reference data*

	Boards A+B AD 1339–1543
Netherlandish panel paintings (Eckstein *et al* 1975)	7.78
Sir Henry Neville, Audley End (this report page 10)	7.03
Thomas Cromwell, Earl of Essex, after Holbein, NPG1727 (Tyers 2012b)	6.69
Baltic2, Fletcher panel paintings (Hillam and Tyers 1995)	6.43
Thames at Westminster, de Jongh, Yale (Tyers 2011b)	6.34
Stephen Gardiner, Trinity (Tyers 2009)	5.78

81031038 Lady Elizabeth Audley, Adriaen Thomasz Key

This panel is *c* 1002mm high and *c* 747mm wide. It comprises three vertical oak boards (Fig 12; Table 9), of *c* 10mm thick at their maximum. The boards were labelled A to C from the left and all three were suitable for measurement. A complete ring width sequence was derived from the lower end of board B and a partial series from the lower end of the other two boards. The three series did not match each other. The three individual series were compared with reference data of historic date from throughout England and northern Europe. A number of statistically significant matches were obtained between each of the board sequences and reference series, along with other contemporaneous objects (Tables 10–12).

The dated boards are each of eastern Baltic origin.

Two of the boards retained sapwood. Board A has three rings of sapwood and ends at AD 1553, whilst board C has two rings of sapwood and ends at AD 1556. The interpretations given to both these boards is a felling date range based on the minimum and maximum estimated number of missing sapwood rings, using a range of 8–24 annual rings (Fig 13). The interpreted date thus represents the likeliest felling date range for the dated individual board. This indicates that board A was felled between AD 1558 and AD 1574, and that board B was felled between AD 1562 and AD 1578. These boards are derived from different trees, and in combination suggest a felling date between AD 1562 and AD 1574.

This date range is close to that obtained from the Sir Thomas Audley panel (page 24), which is almost identical in size.

Figure 12: The construction of the Lady Elizabeth Audley panel painting from Audley End. The locations of the board joints are approximate. Photo kindly supplied by the Hamilton Kerr Institute
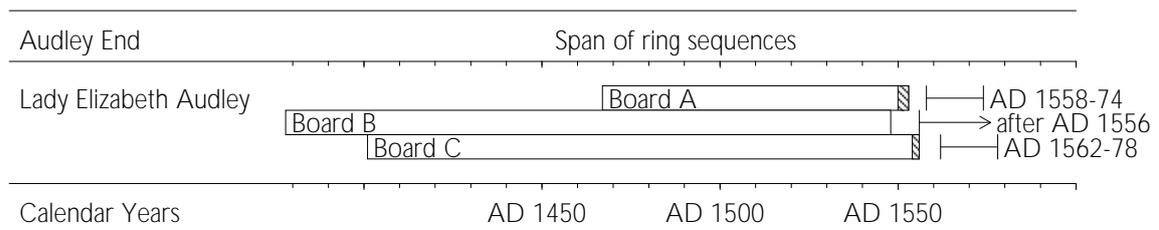
Figure 13: Bar diagram showing the absolute dating positions of the dated tree-ring sequences for three boards from the Lady Elizabeth Audley panel painting from Audley End. The interpreted felling dates are also shown for each dated board
KEY. White bars are eastern Baltic oak heartwood, hatched bars are sapwood

Table 9: Details of the three oak boards from the Lady Elizabeth Audley panel painting from Audley End

OS0566 Board	Width (mm)	Rings	AGR (mm)	Date of measured sequence	Interpreted result
Board A	182–197	87 (3 sap)	1.84	AD 1467–1553	AD 1558–74
Board B	278–294	171	1.62	AD 1378–1548	after AD 1556
Board C	265–272	156 (2 sap)	1.12	AD 1401–1556	AD 1562–78

KEY: sequences obtained from the lower edges of the boards; AGR = average growth rate per year

Table 10: Example t*-values between the sequence from board A from the Lady Elizabeth Audley panel painting from Audley End and eastern Baltic oak reference data*

	Board A AD 1467–1553
Unknown woman, van der Meulen? Yale (Tyers 2011b)	8.34
John Foxe, NPG24 (Tyers 2012b)	7.17
Robert Smith, Peterhouse (Tyers 2004a)	6.85
Sir Thomas Audley, Audley End, board A (this report, page 24)	6.20
William Cecil 1st Baron Burghley, NPG362 (Tyers 2012b)	5.98
Baltic2, Fletcher panel paintings (Hillam and Tyers 1995)	5.30

Table 11: Example t*-values between the sequence from board B from the Lady Elizabeth Audley panel painting from Audley End and eastern Baltic oak reference data.*

	Board B AD 1378–1548
Sir Philip Sydney, NPG5732 (Tyers 2012b)	8.13
Mary Queen of Scots, NPG1766 (Tyers 2012b)	7.77
London, Sutton House wall panelling (Tyers 1991)	7.29
Henry VIII full length, after Holbein, Chatsworth (Tyers 2001a)	7.27
Lady Scudamore, Gheeraerts, Yale (Tyers 2011b)	7.10
Elizabeth I Armada Portrait, attributed to Gower, NPG541 (Tyers 2012b)	6.88

Table 12: Example t*-values between the sequence from board C from the Lady Elizabeth Audley panel painting from Audley End and eastern Baltic oak reference data.*

	Board C AD 1401–1556
London, Sutton House wall panelling (Tyers 1991)	6.54
Henry VIII full length, after Holbein, Chatsworth (Tyers 2001a)	5.77
Margaret Audley, Audley End, boards B+C (this report, page 20)	5.72
Edward Hastings, Lord Loughborough (Tyers 2012a)	5.64
Netherlandish panel paintings (Eckstein *et al* 1975)	5.51
Sir William Butts, after Holbein, NPG210 (Tyers 2012b)	5.50

81031039 Margaret Audley, Duchess of Norfolk, Hans Eworth

This panel is *c* 1079mm high and *c* 849mm wide. It comprises four horizontal oak boards (Fig 14; Table 13), *c* 18mm thick at their maximum. The boards were labelled A to D from the top and all four boards were suitable for measurement. Ring-width sequences were derived from the right-hand edge of all four boards. Board D was a tangential section and only a partial sequence was obtained from this board. The boards B and C series were found to match strongly (*t*-value 21.87, Fig 15), and are undoubtedly derived from the same tree. These series were synchronised and combined into a single composite sequence. This composite was mathematically constructed from the matched series at their synchronised position producing a series of 158 years length. The other two series did not match each other or this composite. The two individual series and the composite were compared with reference data of historic date from throughout England and northern Europe. A number of statistically significant matches were obtained between the board A sequence, and the boards B and C composite and reference series, along with other contemporaneous objects. These indicate the board A sequence dates from AD 1307–1534 inclusive, and the boards B and C composite from AD 1389 to AD 1546 inclusive (Fig 16; Tables 14 and 15). The board D series did not give significant correlations to reference data and remains undated.

The three dated boards are of eastern Baltic origin. Board D, which was not dated, is not obviously different from the other boards in the panel.

None of these boards retained sapwood and thus the interpretations given to the dated boards are *terminus post quem* dates based on the minimum estimate of eight missing sapwood rings. The interpreted date represents the earliest possible felling date for the dated individual boards. Board B contains the latest heartwood rings, and this indicates this board was felled after AD 1554.

Assuming only minimal trimming has occurred provides a suggested usage date of AD 1554–86 for this panel.

Figure 14: The construction of the Margaret Audley panel painting from Audley End. The locations of the board joints are approximate. Photo kindly supplied by English Heritage

AD 1389

AD 1546

1

Figure 15: The series from board B (black) and board C (red) from the Margaret Audley panel painting from Audley End. These are derived from a single tree (t-value 21.87)

| Audley End	Span of ring sequences
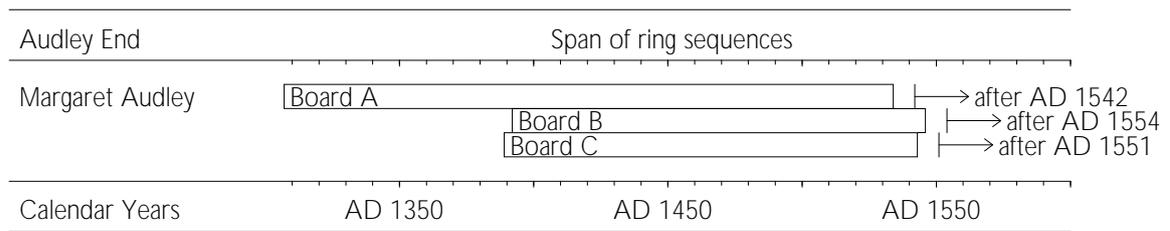
Figure 16: Bar diagram showing the absolute dating positions of the dated tree-ring sequences for three of the boards from the Margaret Audley panel painting from Audley End. The interpreted felling dates are also shown for the dated boards
KEY: White bars are eastern Baltic oak heartwood

Table 13: Details of the four oak boards from the Margaret Audley panel painting from Audley End

OS0833 Board	Width (mm)	Rings	AGR (mm)	Date of measured sequence	Interpreted result
Board A	250–259	228	1.08	AD 1307–1534	after AD 1542
Board B	269–281	155	1.82	AD 1392–1546	after AD 1554
Board C	273–279	155	1.80	AD 1389–1543	after AD 1551
Board D	268–282	142	1.20	undated	-

KEY: sequences obtained from the right-hand edges of the boards; AGR = average growth rate per year

Table 14: Example t-values between the sequence from board A from the Margaret Audley panel painting from Audley End and eastern Baltic oak reference data

	Board A AD 1307–1534
Baltic1, Fletcher panel paintings (Hillam and Tyers 1995)	6.87
Henry VIII full length, Holbein, NT Petworth House (Tyers 2001b)	6.75
Netherlandish panel paintings (Eckstein *et al* 1975)	6.46
James Douglas SNPG1857 (Tyers 2010a)	6.45
Henry VIII full length, after Holbein, Walker Gallery (Tyers 2000a)	5.88
London, Sutton House wall panelling (Tyers 1991)	5.61

Table 15: Example t-values between the composite sequence from boards B and C from the Margaret Audley panel painting from Audley End and eastern Baltic oak reference data

	Boards B+C AD 1389–1546
Baltic1, Fletcher panel paintings (Hillam and Tyers 1995)	11.80
Anthony Browne, 1st Viscount Montague, Eworth, NPG842 (Tyers 2012b)	10.27
Henry VIII full length, after Holbein, Walker Gallery (Tyers 2000a)	10.26
Henry VIII full length, Holbein, NT Petworth House (Tyers 2001b)	8.67
Thomas Cranmer, Flicke, NPG535 (Tyers 2012b)	7.98
London, Brooke House panelling (Tyers forthcoming)	7.54

81031040 Sir Thomas Audley, Adriaen Thomasz Key

This panel is *c* 1002mm high and *c* 749mm wide. It comprises three vertical oak boards (Fig 17; Table 16), *c* 10mm thick at their maximum. The boards were labelled A to C from the left and all three boards were suitable for measurement. Partial ring-width sequences were derived from the lower ends of each of the boards. Both boards B and C have some slight grain curvature and retain sapwood further up into the panel. Boards B and C matched each other significantly (*t*-value 7.13) but are sufficiently different that it seems likely these are from different trees. The three individual series were compared with reference data of historic date from throughout England and northern Europe. A number of statistically significant matches were obtained between the three board sequences and reference series, along with other contemporaneous objects (Fig 18; Tables 17–19).

The dated boards are of eastern Baltic origin.

It was possible to trace the grain along the back surface of board C to identify that two unmeasured heartwood rings were present between the last heartwood ring measured along the bottom edge and the small area of sapwood in the panel. The interpretation given to board C is therefore a felling date range based on the minimum and maximum estimated number of missing sapwood rings, using a range of 8–24 annual rings. The interpreted date thus represents the likeliest felling date range for the dated individual board. This indicates that board C was felled between AD 1554 and AD 1570.

This date range is close to that obtained from the Lady Elizabeth Audley panel (page 17), which is almost identical in size.

Figure 17: The construction of the Sir Thomas Audley panel painting from Audley End. The locations of the board joints are approximate. Photo kindly supplied by the Hamilton Kerr Institute
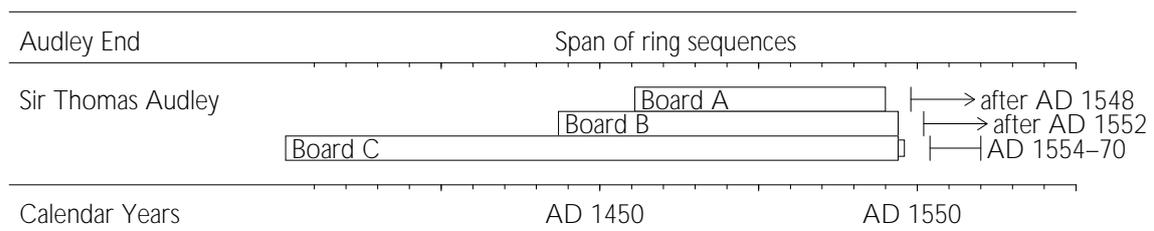
Figure 18: Bar diagram showing the absolute dating positions of the dated tree-ring sequences for the three boards from the Sir Thomas Audley panel painting from Audley End. The interpreted felling dates are also shown for the dated boards

KEY. White bars are eastern Baltic oak heartwood, the narrow bar is unmeasured outer heartwood rings, that terminate at the possible onset of sapwood

Table 16: Details of the three oak boards from the Sir Thomas Audley panel painting from Audley End

OS0567 Board	Width (mm)	Rings	AGR (mm)	Date of measured sequence	Interpreted result
Board A	199–206	80	1.51	AD 1461–1540	after AD 1548
Board B	259–265	108	1.67	AD 1437–1544	after AD 1552
Board C	275–291	194+*2*+H/S	1.34	AD 1351–1544	AD 1554–70

KEY: sequences obtained from the lower edges of the boards, in all cases these are outermost partial series; board C has two additional unmeasured outermost rings, and these are followed by the heartwood/sapwood boundary, AGR = average growth rate per year

Table 17: Example t-values between the sequence from board A from the Sir Thomas Audley panel painting from Audley End and eastern Baltic oak reference data

	Board A AD 1461–1540
Unknown woman, van der Meulen? Yale (Tyers 2011b)	7.18
Sir Thomas Gresham, NPG352 (Tyers 2012b)	7.10
Robert Smith, Peterhouse (Tyers 2004a)	6.64
Lady Elizabeth Pope, attr Peake, Tate (Tyers 2004b)	6.34
Lady Elizabeth Audley, Audley End, board A (this report, page 17)	6.20
Nicholas Ridley, NPG296 (Tyers 2012b)	6.17

Table 18: Example t-values between the sequence from board B from the Sir Thomas Audley panel painting from Audley End and eastern Baltic oak reference data

	Board B AD 1437–1544
London, Brooke House panelling (Tyers forthcoming)	7.54
Baltic2, Fletcher panel paintings (Hillam and Tyers 1995)	7.52
Thomas Howard, Audley End, (this report, page 7)	7.13
Sir Thomas Audley, Audley End, board C (this panel)	7.13
Edward Hastings, Lord Loughborough (Tyers 2012a)	6.85
London, Sutton House wall panelling (Tyers 1991)	6.73

Table 19: Example t-values between the sequence from board C from the Sir Thomas Audley panel painting from Audley End and eastern Baltic oak reference data

	Board C AD 1351–1544
Baltic2, Fletcher panel paintings (Hillam and Tyers 1995)	9.55
London, Brooke House panelling (Tyers forthcoming)	8.31
Suffolk, Otley Hall wall panelling (Tyers 2000b)	7.40
Elizabeth of York, NPG311 (Tyers 2012b)	7.14
James VI and I, Audley End, board A (this report, page 32)	7.14
Sir Thomas Audley, Audley End, board B (this panel)	7.13

81031041 Henry, Prince of Wales, Paul van Somer

This panel is *c* 468mm high and *c* 389mm wide. It comprises a single vertical oak board (Fig 19; Table 20), which is *c* 10mm thick at its maximum. This board was suitable for measurement although it was faster grown than any other board in this study. A single sequence was obtained from the lower edge of the board, no other later rings were present elsewhere in the board. This series was compared with reference data of historic date from throughout England and northern Europe. A number of statistically significant matches were obtained between the sequence and reference series, along with other contemporaneous objects. These indicate that the sequence dates from AD 1455–1531 inclusive (Fig 20; Table 21).

The dated board is of English origin. The board retained no sapwood and thus the interpretation given to this board is a *terminus post quem* date based on the minimum estimate of ten missing sapwood rings, the appropriate minimum for English sourced material. The interpreted date represents the earliest possible felling date for the board as being felled after AD 1541.

The date obtained from the panel is much too early for the subject portrayed. This panel is the only one in this group that uses a fast grown, distorted grained, and English sourced board. As with some similar examples of English oak boards seen in sixteenth- and seventeenth-century panel paintings this particular English board is wider, at 389mm, than any of the Baltic boards in the other panels discussed here. This leads to the conclusion that locally sourced boards could be useful in panel making but that eastern Baltic material was more commonly used. Since the latter is much straighter grained it was presumably somewhat more predictable as a raw material, though there may in addition have been issues of cost or supply with local boards. The board is notable for its extremely rapid growth rate (~ 5mm/year average, in contrast with the Baltic boards which have average growth rates ranging between 0.7mm/year and 2.1mm/year). If we assume this tree continued to grow at the rate of the outermost extant section each trimmed decade of its growth is potentially equivalent to *c* 25mm of board width, as the outer rings are narrower. An interpretation invoking even a minor trimming of outer heartwood rings would imply significant wastage. This tree may of course have had an excessive amount of sapwood, or it may have slowed down in growth abruptly, or it may have had a flaw that required removal of a section. If none of those situations occurred and this is a contemporaneous panel it would require this board to be a small part of a tree at least 1m in diameter. It is more likely that it was a reused piece of timber, and subsequent X-ray images show an upside down female portrait underneath the present one (A von-Hedenstroem pers comm). The use of a locally sourced board, in this case probably from south-eastern England, London, or East Anglia, does not necessarily mean that this panel is a rural commission since several high-grade panels from apparently cosmopolitan workshops use English boards.

Figure 19: The construction of the Henry, Prince of Wales panel painting from Audley End. Photo kindly supplied by the Hamilton Kerr Institute

| Audley End	Span of ring sequences	
Henry, Prince of Wales	Single board	after AD 1541
Calendar Years	AD 1500	
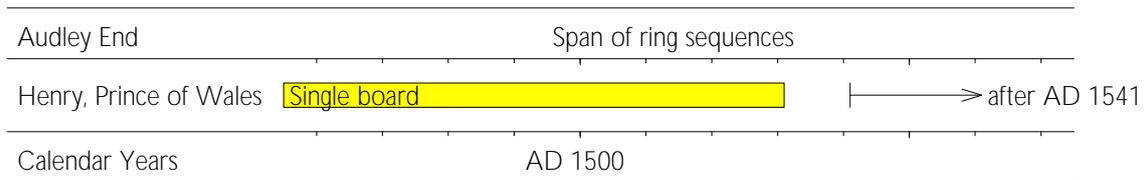
Figure 20: Bar diagram showing the absolute dating position of the dated tree-ring sequence for the board from the Henry, Prince of Wales panel painting from Audley End. The interpreted felling date is also shown for the dated board
KEY. Yellow bar is English oak heartwood

Table 20: Details of the oak board from the Henry, Prince of Wales panel painting from Audley End

OS0917 Board	Width (mm)	Rings	AGR (mm)	Date of measured sequence	Interpreted result
Single	388–389	77	5.01	AD 1455–1531	after AD 1541

KEY: sequence obtained from the lower edge of the board; AGR = average growth rate per year

Table 21: Example t-*values between the sequence from the board from the Henry, Prince of Wales panel painting from Audley End and English oak reference data*

	Single board AD 1455–1531
London, Hays Wharf excavations (Blatherwick and Bluer 2009)	7.53
Kent, Walmer Castle Deal (Howard *et al* 1997)	7.48
Essex, Magdalen Laver Church (Tyers and Boswijk 1998)	6.67
Reginald Pole, NPG220 (Tyers 2012b)	6.56
Essex, Moyns Park Birdbrook (Tyers 1999)	6.50
London, Victoria Wharf excavations (Tyers and Hall 1997)	6.38

81031042 Sir Thomas Audley, Lord Audley, Flemish School

This panel is *c* 398mm high and *c* 296mm wide. It comprises a single vertical oak board (Fig 21; Table 22), which is *c* 7mm thick at its maximum and suitable for measurement. A ring width sequence was derived from the lower end of the board. This series was compared with reference data of historic date from throughout England and northern Europe. A number of statistically significant matches were obtained between the board sequence and reference series, along with other contemporaneous objects. These indicate that the board sequence dates from AD 1377–1548 inclusive (Fig 22; Table 23).

The board is of eastern Baltic origin. It retained no sapwood and thus the interpretation given to this board is a *terminus post quem* date based on the minimum estimate of eight missing sapwood rings. The interpreted date represents the earliest possible felling date for the board. This indicates that the board was felled after AD 1556.

Assuming only minimal trimming has occurred provides a suggested usage date of AD 1556–1588.

Figure 21: The construction of the Sir Thomas Audley, Lord Audley panel painting from Audley End. Photo kindly supplied by the Hamilton Kerr Institute

Audley End	Span of ring sequences		
Sit Thomas Audley	Single board	⊢——→ after AD 1556	
Calendar Years	AD 1450	AD 1500	AD 1550
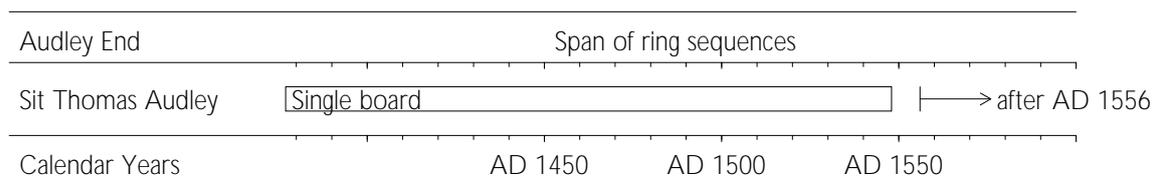
Figure 22: Bar diagram showing the absolute dating position of the dated tree-ring sequence for the board from the Sir Thomas Audley, Lord Audley panel painting from Audley End. The interpreted felling date is also shown for the dated board
KEY. White bar is eastern Baltic oak heartwood

Table 22: Details of the oak board from the Sir Thomas Audley, Lord Audley panel painting from Audley End

OS0913 Board	Width (mm)	Rings	AGR (mm)	Date of measured sequence	Interpreted result
Single	296	172	1.71	AD 1377–1548	after 1556

KEY: sequence obtained from the lower edge of the board; AGR = average growth rate per year

Table 23: Example t*-values between the sequence from the board from the Sir Thomas Audley, Lord Audley panel painting from Audley End and eastern Baltic oak reference data*

	Single Board AD 1377–1548
Robert Smith, Peterhouse (Tyers 2004a)	9.38
Lady Elizabeth Pope, attr Peake, Tate (Tyers 2004b)	8.24
Elizabeth I Coronation Portrait, NPG5175 (Tyers 2012b)	7.53
James VI and I as a boy SNPG992 (Tyers 2010a)	7.36
Sir Thomas Gresham, NPG352 (Tyers 2012b)	7.30
Elizabeth I, NPG2471 (Tyers 2012b)	7.30

81031044 James VI and I

This panel is *c* 460mm high and *c* 375mm wide. It comprises two vertical oak boards (Fig 23; Table 24), of *c* 6mm thickness at their maximum. Both boards were suitable for measurement and labelled A and B from the left. Ring-width sequences were derived from the lower ends of both boards. The two series did not match each other. The two individual series were compared with reference data of historic date from throughout England and northern Europe. A number of statistically significant matches were obtained between both the board sequences and reference series, along with other contemporaneous objects (Fig 24; Tables 25 and 26).

The dated boards are both of eastern Baltic origin.

Neither of these boards retained sapwood and thus the interpretations given to the dated boards are *terminus post quem* dates based on the minimum estimate of eight missing sapwood rings. The interpreted dates represent the earliest possible felling dates for the two dated individual boards. This indicates that the wider board A was felled after AD 1539.

It is inappropriate to assume only minimal trimming has occurred as the two boards in this panel are both less than 250mm wide.

Figure 23: The construction of the James VI and I panel painting from Audley End. The location of the board joint is approximate. Photo kindly supplied by the Hamilton Kerr Institute
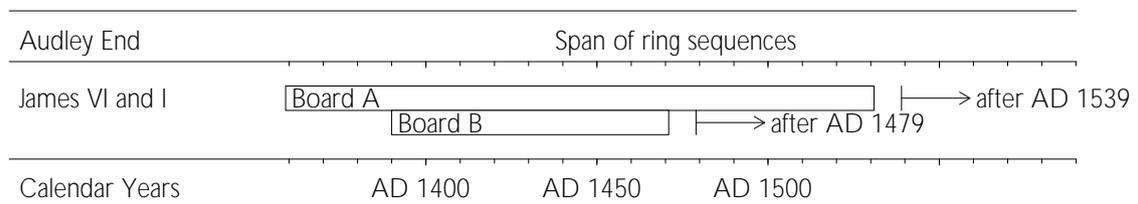
Figure 24: Bar diagram showing the absolute dating positions of the dated tree-ring sequences for both boards from the James VI and I panel painting from Audley End. The interpreted felling dates are also shown for the dated boards
KEY. White bars are eastern Baltic oak heartwood

Table 24: Details of the two oak boards from the James VI and I panel painting from Audley End

OS0569 Board	Width (mm)	Rings	AGR (mm)	Date of measured sequence	Interpreted result
Board A	225–230	173	1.30	AD 1359–1531	after AD 1539
Board B	143–150	82	1.75	AD 1390–1471	after AD 1479

KEY: sequences obtained from the lower edges of both boards; AGR = average growth rate per year

Table 25: Example t*-values between the sequence from board A from the James VI and I panel painting from Audley End and eastern Baltic oak reference data*

	Board A AD 1359–1531
Edward Hastings, Lord Loughborough (Tyers 2012a)	11.15
Thomas Howard, Audley End, (this report, page 7)	9.97
Baltic2, Fletcher panel paintings (Hillam and Tyers 1995)	8.92
London, Brooke House panelling (Tyers forthcoming)	7.86
Sir Thomas Audley, Audley End, board C (this report, page 24)	7.14
Elizabeth 1, NPG542 (Tyers 2012b)	6.66

Table 26: Example t*-values between the sequence from board B from the James VI and I panel painting from Audley End and eastern Baltic oak reference data.*

	Board B AD 1390–1471
Mary I without carnation, Trinity (Tyers 2009)	6.29
Thomas Howard, NPG6676 (Tyers 2012b)	6.18
Henry VII, NPG416 (Tyers 2012b)	6.11
London, Brooke House panelling (Tyers forthcoming)	5.85
Baltic1, Fletcher panel paintings (Hillam and Tyers 1995)	5.82
London, Sutton House wall panelling (Tyers 1991)	5.42

81031053 Edward VI, Guilem Scrots

This panel is *c* 496mm high and *c* 378mm wide. It comprises two horizontal oak boards (Fig 25; Table 27) of *c* 11mm thickness at their maximum. The boards were labelled A and B from the top, and both boards were suitable for measurement. Ring-width sequences were derived from the left-hand ends of both boards. The two series did not match each other. The two individual series were compared with reference data of historic date from throughout England and northern Europe. A number of statistically significant matches were obtained between the board B sequence and reference series, along with other contemporaneous objects. These indicate that the board B sequence dates from AD 1387–1563 inclusive (Fig 26; Table 28). The board A series did not give significant correlations to reference data and remains undated.

The dated board is of eastern Baltic origin. The analysed board which was not dated is not obviously different from the other board in the panel.

Neither of the boards retained sapwood and thus the interpretations given to the dated board is a *terminus post quem* date based on the minimum estimate of eight missing sapwood rings. The interpreted date represents the earliest possible felling date for the dated individual board. This indicates that board B was felled after AD 1571.

Assuming only minimal trimming has occurred provides a suggested usage date of AD 1571–AD 1603. Edward died in 1553. The unusual format suggests that this may be a recycled fragment of a larger piece of panelling, and subsequent X-ray images suggest that there is an earlier image underneath the present one (A von-Hedenstroem pers comm).

Figure 25: The construction of the Edward VI panel painting from Audley End. The location of the board joint is approximate. Photo kindly supplied by the Hamilton Kerr Institute

Audley End	Span of ring sequences		
Edward VI	Board B		⊢⟶ after AD 1571
Calendar Years	AD 1450	AD 1500	AD 1550
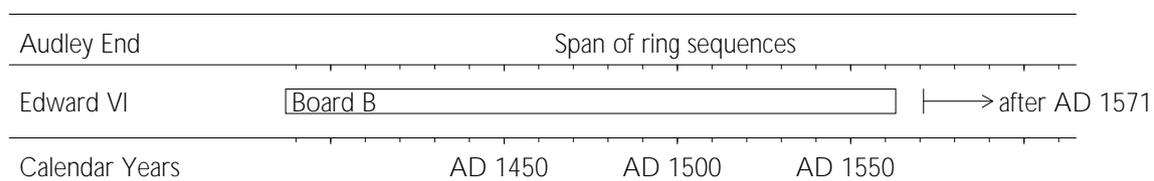
Figure 26: Bar diagram showing the absolute dating position of the dated tree-ring sequence for board B from the Edward VI panel painting from Audley End. The interpreted felling date is also shown for the dated board
KEY. White bar is eastern Baltic oak heartwood

Table 27: Details of the two oak boards from the Edward VI panel painting from Audley End

OS0916 Board	Width (mm)	Rings	AGR (mm)	Date of measured sequence	Interpreted result
Board A	241	289	0.83	undated	-
Board B	255	177	1.41	AD 1387–1563	after AD 1571

KEY: sequences obtained from the left-hand edges of both boards; AGR = average growth rate per year

Table 28: Example t*-values between the sequence from board B from the Edward VI panel painting from Audley End and eastern Baltic oak reference data*

	Board B AD 1387–1563
Baltic2, Fletcher panel paintings (Hillam and Tyers 1995)	7.71
Robert Dudley Earl of Leicester, Yale (Tyers 2011b)	7.12
William Cecil 1st Baron Burghley, NPG362 (Tyers 2012b)	6.57
Sir Anthony Browne, NPG5186 (Tyers 2012b)	6.34
Lady Elizabeth Knightley, Gheeraerts, Yale (Tyers 2011b)	6.19
Walter Ralegh, NPG7 (Tyers 2012b)	5.90

81031054 Thomas Gresham, Stephen van der Meulen

This panel is *c* 371mm high and *c* 268mm wide. It comprises a single vertical oak board (Fig 27; Table 29), *c* 6mm thick at its maximum width and suitable for measurement. A ring-width sequence was derived from the lower end of the board. This series was compared with reference data of historic date from throughout England and northern Europe. A number of statistically significant matches were obtained between the board sequence and reference series, along with other contemporaneous objects. These indicate that the board sequence dates from AD 1427–1547 inclusive (Fig 28; Table 30).

The dated board is of eastern Baltic origin. The measured sequence ends at the onset of sapwood and thus the interpretation given to the dated board is a *felling date range* based on the minimum and maximum estimated number of missing sapwood rings, using a range of 8–24 annual rings. The interpreted date thus represents the likeliest felling date range for the dated board. This indicates that this board was felled between AD 1555 and AD 1571.

Figure 27: The construction of the Thomas Gresham panel painting from Audley End. Photo kindly supplied by the Hamilton Kerr Institute

| Audley End	Span of ring sequences		
Thomas Gresham	Single board		⊢———⊣ AD 1555–71
Calendar Years	AD 1450	AD 1500	AD 1550
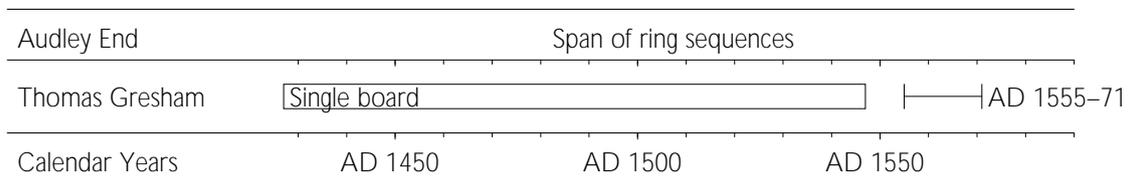
Figure 28: Bar diagram showing the absolute dating position of the dated tree-ring sequence for the board from the Thomas Gresham panel painting from Audley End. The interpreted felling date is also shown for the dated board
KEY. White bar is eastern Baltic oak heartwood

Table 29: Details of the oak board from the Thomas Gresham panel painting from Audley End

OS0914 Board	Width (mm)	Rings	AGR (mm)	Date of measured sequence	Interpreted result
Single	267–268	121(H/S)	2.01	AD 1427–1547	AD 1555–71

KEY: sequence obtained from the lower edge of the board; H/S heartwood/sapwood boundary; AGR = average growth rate per year

Table 30: Example t*-values between the sequence from the board from the Thomas Gresham panel painting from Audley End and eastern Baltic oak reference data*

	Single Board AD 1427–1547
Nicholas Heath, Archbishop of York, Eworth, NPG1388 (Tyers 2012b)	9.91
London, Brooke House panelling (Tyers forthcoming)	9.21
St Jerome, Marinus van Reymerswaele (Tyers 2006)	8.97
Sir Hamon Le Strange, Peake (unpubl data)	8.94
Hugh Latimer, NPG295 (Tyers 2012b)	8.77
Baltic1, Fletcher panel paintings (Hillam and Tyers 1995)	7.93

81031055 Frances Howard, Countess of Somerset, Robert Peake

This panel is *c* 527mm high and *c* 419mm wide. It comprises three vertical oak boards (Fig 29; Table 31), which are *c* 8mm thick at their maximum. The boards were labelled A to C from the left, and all three boards were suitable for measurement. Board A contains too few rings for independent dating, but it was analysed primarily to identify if it was from the same tree as one of the other boards in this panel. Ring-width sequences were derived from the upper and lower ends of both boards B and C, and the lower end of board A. The board B and C pairs were synchronised and combined into single composite sequences for each board. These composites were mathematically constructed from the matched series at their synchronised positions, to produce series of 217 and 163 years length respectively. These two series did not match each other, and the short series from board A matched neither. The individual series were compared with reference data of historic date from throughout England and northern Europe. A number of statistically significant matches were obtained between the board B sequence and reference series, along with other contemporaneous objects. These indicate that the board B composite sequence dates from AD 1376–1592 inclusive (Fig 30; Table 32). The board A and board C series did not give significant correlations to reference data and remain undated.

The dated board is of eastern Baltic origin. The two analysed boards which were not dated are not obviously different from the dated board in this panel.

The sequence from board B ends at the probable onset of sapwood and thus the interpretation given to the dated board is a felling date range based on the minimum and maximum estimated number of missing sapwood rings, using a range of 8–24 annual rings. The interpreted date thus represents the likeliest felling date range for the dated board. This indicates that this board was felled between AD 1600 and AD 1616.

Figure 29: The construction of the Frances Howard, Countess of Somerset, panel painting from Audley End. The locations of the board joints are approximate. Photo kindly supplied by the Hamilton Kerr Institute
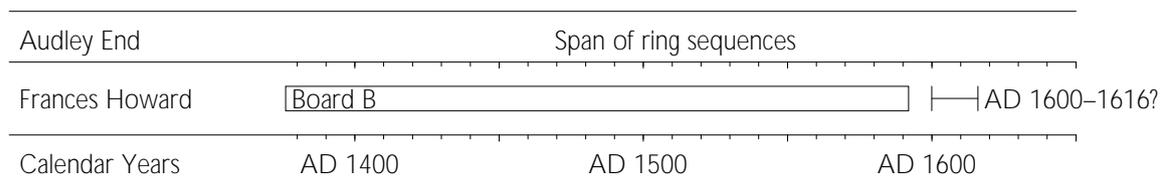
Figure 30: Bar diagram showing the absolute dating position of the dated tree-ring sequence for board B from the Frances Howard, Countess of Somerset, panel painting from Audley End. The interpreted felling date is also shown for the dated board
KEY. White bar is eastern Baltic oak heartwood

Table 31: Details of the three oak boards from the Frances Howard, Countess of Somerset, panel painting from Audley End

OS0568 Board	Width (mm)	Rings	AGR (mm)	Date of measured sequence	Interpreted result
Board A	35–39	32	1.19	undated	-
Board B	279–285	217(H/S?)	1.31	AD 1376–1592	AD 1600–1616?
Board C	99–101	163	0.71	undated	-

KEY: sequences obtained from the upper and lower edges of boards B and C, and the lower edge of board A; H/S? possible heartwood/sapwood boundary; AGR = average growth rate per year

Table 32: Example t-values between the composite sequence from board B from the Frances Howard, Countess of Somerset, panel painting from Audley End and eastern Baltic oak reference data

	Board B AD 1376–1592
London, Sutton House wall panelling (Tyers 1991)	9.78
Elizabeth I Coronation Portrait, NPG5175 (Tyers 2012b)	7.54
Sir Philip Sydney, NPG5732 (Tyers 2012b)	7.10
Balsham, Deynman and Warkeworthe, Peterhouse (Tyers 2004a)	7.08
François Hercule de France, studio of François Clouet, Louvre (Tyers 2011a)	6.87
London, Brooke House panelling (Tyers forthcoming)	6.53

81031078 A Coastal Scene, Isaac Willaerts

This panel is *c* 525mm high and *c* 1032mm wide. It comprises two horizontal oak boards (Fig 31; Table 33), which, having been thinned, had an added cradle to the back. The boards were labelled A and B from the top. Both boards were suitable for measurement. Ring-width sequences were derived from both ends of board A and the right-hand end of board B. The board A series was synchronised and combined into a single composite sequence. This composite was mathematically constructed from the matched series at their synchronised positions, producing a series 136 years long. The composite board A series and the board B series did not match each other. These two series were compared with reference data of historic date from throughout England and northern Europe. A number of statistically significant matches were obtained between both board sequences and reference series, along with other contemporaneous objects (Fig 32; Tables 34 and 35).

Both the dated boards are of eastern Baltic origin. Neither of these boards retained sapwood and thus the interpretations given to these boards are *terminus post quem* dates based on the minimum estimate of eight missing sapwood rings. The interpreted dates represent the earliest possible felling dates for the dated individual boards which indicates that board A was felled after AD 1607.

Assuming only minimal trimming occurred provides a suggested usage date of AD 1607–1639.

Figure 31: The construction of the Coastal Scene panel painting from Audley End. Photo kindly supplied by English Heritage
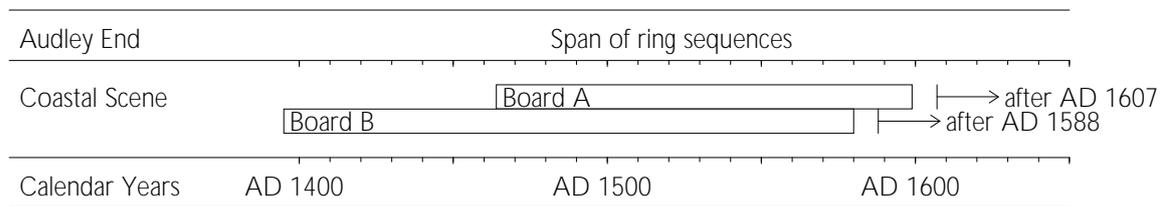
Figure 32: Bar diagram showing the absolute dating positions of the dated tree-ring sequences for both boards from the Coastal Scene panel painting from Audley End. The interpreted felling dates are also shown for the dated boards
KEY. White bars are eastern Baltic oak heartwood

Table 33: Details of the two oak boards from the Coastal Scene panel painting from Audley End

OS0841 Board	Width (mm)	Rings	AGR (mm)	Date of measured sequence	Interpreted result
Board A	248–260	136	1.86	AD 1464–1599	after AD 1607
Board B	265–277	186	1.39	AD 1395–1580	after AD 1588

KEY: sequences obtained from the right and left-hand edges of board A, and the right-hand edge of board B; AGR = average growth rate per year

Table 34: Example t-values between the composite sequence from board A from the Coastal Scene panel painting from Audley End and eastern Baltic oak reference data

	Board A AD 1464–1599
Phineus Pett, NPG2035 (Tyers 2012b)	8.69
Sir Francis Walsingham, de Critz, Yale (Tyers 2011b)	8.54
Catherine Parr, attributed to Master John, NPG4451 (Tyers 2012b)	7.46
Lady Jane Grey, NPG6804 (Tyers 2012b)	7.20
Edward VI, Trinity (Tyers 2009)	7.07
Lady Elizabeth Pope, Peake, Tate (Tyers 2004b)	6.96

Table 35: Example t-values between the sequence from board B from the Coastal Scene panel painting from Audley End and eastern Baltic oak reference data

	Board B AD 1395–1580
Netherlandish panel paintings (Eckstein *et al* 1975)	6.39
Henry Howard, Earl of Surrey, Knole (Tyers 2013)	6.31
Portrait of a Woman, Gerrit Dou, Leiden (Tyers 2010b)	6.29
Unknown Man attr Janssens, Trinity (Tyers 2009)	6.13
Sir Walter Mildmay, Knole (Tyers 2013)	5.98
Henri Duke of Guise, Knole (Tyers 2013)	5.80

81031172 Sir Thomas Cornwallis, George Gower

This panel is *c* 938mm high and *c* 699mm wide. It comprises three vertical oak boards, the rightmost of which is in two unequal parts (Fig 33; Table 36). All are *c* 6mm thick at their maximum. The boards were labelled A to C from the left, with the small board at lower end of the right edge labelled board D. Boards A and B were badly damaged by a former woodworm infestation and visually seemed likely to be from the same tree. Both these boards were fragile and only a partial section of board A was suitable for measurement. Ring-width sequences were derived from the lower ends of boards A and D, and the upper end of board C. These series did not match each other. The individual series were compared with reference data of historic date from throughout England and northern Europe. A number of statistically significant matches were obtained between the board C sequence and reference series, along with other contemporaneous objects. These indicate the board C sequence dates from AD 1450–1549 inclusive (Fig 34, Table 37). The board A and board D series did not give significant correlations to reference data and remain undated.

The dated board is of eastern Baltic origin. Board A and B are not obviously different from board C in this panel, although board D is rather faster grown and this may be a repair.

None of these boards retained sapwood and thus the interpretation given to the dated board is a *terminus post quem* date based on the minimum estimate of eight missing sapwood rings. The interpreted date represents the earliest possible felling date for the dated individual board. This indicates that board C was felled after AD 1557.

The dated board is only 142mm wide so it is inappropriate to assume only minimal trimming has occurred.

Figure 33: The construction of the Sir Thomas Cornwallis panel painting from Audley End. The locations of the board joints are approximate. Photo kindly supplied by the Hamilton Kerr Institute
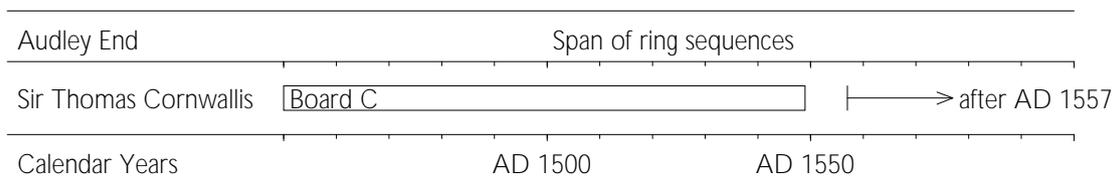
Figure 34: Bar diagram showing the absolute dating position of the dated tree-ring sequence for board C from the Sir Thomas Cornwallis panel painting from Audley End. The interpreted felling date is also shown for the dated board
KEY. White bar is eastern Baltic oak heartwood

Table 36: Details of the four oak boards from the Sir Thomas Cornwallis panel painting from Audley End

OS0570 Board	Width (mm)	Rings	AGR (mm)	Date of measured sequence	Interpreted result
Board A	273–287	47	0.85	undated	-
Board B	269–279	-	-	not analysed	-
Board C	142	100	1.37	AD 1450–1549	after AD 1557
Board D	143	61	2.10	undated	-

KEY: sequences obtained from the lower edges of boards A and D, and from the upper edge of board C; AGR = average growth rate per year

Table 37: Example t-*values between the sequence from board C from the Sir Thomas Cornwallis panel painting from Audley End and eastern Baltic oak reference data*

	Board C AD 1450–1549
Sir William Butts, after Holbein, NPG210 (Tyers 2012b)	7.23
London, Sutton House wall panelling (Tyers 1991)	6.75
Mary Queen of Scots, NPG1766 (Tyers 2012b)	6.72
John Whitgift and Joseph Cosins, Peterhouse (Tyers 2004a)	6.33
Henry VIII full length, after Holbein, Chatsworth (Tyers 2001a)	5.88
London, Brooke House panelling (Tyers forthcoming)	5.86

81031226 The Money Lenders, Marinus van Reymerswaele

This panel is *c* 1221mm high and *c* 920mm wide. It comprises four vertical oak boards (Fig 35; Table 38), of *c* 9mm thickness at their maximum. The boards, labelled A to D from the left, were all suitable for measurement. Ring-width sequences were derived from both ends of boards A and B, and from the upper ends of boards C and D. The board A and board B pairs were synchronised and combined into single composite sequences for each of these boards. These composites were mathematically constructed from the matched series at their synchronised positions. These series were 242 and 155 years in length respectively. The four series did not match each other in a way that indicates any were a same-tree pair, although board B did match board D reasonably strongly. The four individual series were compared with reference data of historic date from throughout England and northern Europe. A number of statistically significant matches were obtained between all four of the board sequences from this panel and reference series, along with other contemporaneous objects (Fig 36; Tables 39–42).

All four of the dated boards are of eastern Baltic origin. None retained sapwood and thus the interpretations given to these boards are *terminus post quem* dates based on the minimum estimate of eight missing sapwood rings. The interpreted dates represent the earliest possible felling dates for the dated individual boards. This indicates that board A was felled after AD 1612.

Assuming only minimal trimming occurred provides a suggested usage date of AD 1612–1644.

Figure 35: The construction of the Money Lenders panel painting from Audley End. The locations of the board joints are approximate. Photo kindly supplied by English Heritage
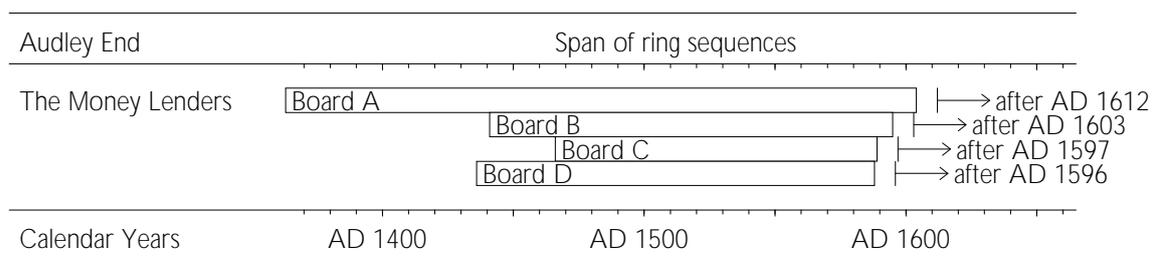
Figure 36: Bar diagram showing the absolute dating positions of the dated tree-ring sequences for the boards from the Money Lenders panel painting from Audley End. The interpreted felling dates are also shown for the dated boards
KEY. White bars are eastern Baltic oak heartwood

Table 38: Details of the four oak boards from the Money Lenders panel painting from Audley End

OS0549 Board	Width (mm)	Rings	AGR (mm)	Date of measured sequence	Interpreted result
Board A	256–285	242	1.20	AD 1363–1604	after AD 1612
Board B	193–200	155	1.19	AD 1441–1595	after AD 1603
Board C	239–243	124	1.95	AD 1466–1589	after AD 1597
Board D	199–224	153	1.27	AD 1436–1588	after AD 1596

KEY: sequences obtained from the upper and lower edges of boards A and B, and from the upper edges of boards C and D; AGR = average growth rate per year

Table 39: Example t-values between the composite sequence from board A from the Money Lenders panel painting from Audley End and eastern Baltic oak reference data

	Board A AD 1363–1604
Netherlandish panel paintings (Eckstein *et al* 1975)	10.23
Don John of Austria, Knole (Tyers 2013)	10.23
Robert Cecil, 1st Earl of Salisbury, de Critz, NPG107 (Tyers 2012b)	9.74
Sir Francis Walsingham, Knole (Tyers 2013)	9.46
The Constable of Bourbon, Knole (Tyers 2013)	9.17
Anne, Lady Carleton, after Mierevelt, NPG111 (Tyers 2012b)	9.00

Table 40: Example t-values between the composite sequence from board B from the Money Lenders panel painting from Audley End and eastern Baltic oak reference data

	Board B AD 1441–1595
Sir Christopher Hatton, NPG1518 (Tyers 2012b)	6.38
William Warham, after Holbein, NPG2094 (Tyers 2012b)	6.01
Sir Nathaniel Bacon, self-portrait, NPG2142 (Tyers 2012b)	5.74
The Money Lenders, Reymerswaele Audley End, board D (this panel)	5.70
called Admiral Blake, Knole (Tyers 2013)	5.26
Elizabeth I, NPG542 (Tyers 2012b)	5.25

Table 41: Example t*-values between the sequence from board C from the Money Lenders panel painting from Audley End and eastern Baltic oak reference data*

	Board C AD 1466–1589
Unknown Man attr Janssens, Trinity (Tyers 2009)	7.20
Sir Hamon Le Strange, Peake (unpubl data)	7.14
Sir Francis Drake, Knole (Tyers 2013)	6.77
Sir Walter Mildmay, Knole (Tyers 2013)	6.73
Netherlandish panel paintings (Eckstein *et al* 1975)	6.40
A Self-portrait of an Artist Seated at an Easel, Leiden (Tyers 2010b)	6.12

Table 42: Example t*-values between the sequence from board D from the Money Lenders panel painting from Audley End and eastern Baltic oak reference data*

	Board D AD 1436–1588
Portrait of a Man with a Hat, Gerrit Dou (Tyers 2010b)	6.31
called Admiral Blake, Knole (Tyers 2013)	6.17
Lady Chandos, Bettes, Yale (Tyers 2011b)	6.10
Suffolk, Otley Hall wall panelling (Tyers 2000b)	6.03
Two Scholars Disputing, Gerrit Dou, Leiden (Tyers 2010b)	5.92
The Money Lenders, Reymerswaele Audley End, board B (this panel)	5.70

DISCUSSION

All 16 panels discussed here utilise between one and four oak boards. All the boards are a single radius, ranging from true radials to moderately tangential sections, with no centres or centrelines within the boards. Usually in a portrait format panel (that is taller than it is wide) the boards are arranged with the grain vertical, and in landscape format panels it is horizontal. Typically each of these boards tapers both slightly from one end of the panel to the other and also in thickness, with the thicker sections towards the middle of the panel. These panels were mostly constructed using boards a maximum of 6–11mm thick, sometimes tapering down to only 2–3mm thickness. The joinery uses one or more irregular sectioned and tapering boards to construct flat and right angled panels. Several of these panels exhibit riven and sawn surfaces on their reverse faces. The joints are simple butt joints, though at least two of these examples have pegs on the butted edges. These are typically small, square oak dowels in round holes. These pegs are difficult to observe in intact panels and their presence is generally likely to be under recorded.

Tree-ring results of varying degrees of usefulness were obtained from all 16 analysed panels. Whilst there is no internal evidence to link pairs or groups of panels by the use of trees in common it is likely that most of these panels are from the third quarter of the sixteenth century, with four from the first half of the seventeenth century. The portraits contain a group of 11 panels that could all have been executed between c AD 1557 and c AD 1574, although individually they have dates spread slightly wider. This group is probably therefore mostly from the early Elizabethan period. The remaining portraits include two panels from after AD 1600 (Sir Henry Neville, and Frances Audley), and one probably intermediate between these groups (the Edward VI copy). The two panels that produced the earliest potential dates are of two of the latest sitters (Henry, Prince of Wales, and his father James VI and I) and both these and the Edward VI panel probably represent recycling of earlier panels in the later Elizabethan and/or early Stuart period. Subsequent X-ray images on both of these (Henry, Prince of Wales, and Edward VI) show earlier images beneath the present ones (A von-Hedenstroem pers comm).

Most groups of panels from English collections that have been examined hitherto are dominated by eastern Baltic oak boards and very few retain any sapwood. The Audley End material thus conforms to expectations by including 15 panels using an eastern Baltic source for their boards; 13 of these are probably English productions and the remaining two are seventeenth-century Netherlandish paintings. In addition there is a common construction methodology where the panel makers appear to be deliberately removing sapwood. This latter feature has been identified in many other panel paintings from both England and the rest of western Europe, and is known to be a formal statute of the panel makers guild in seventeenth-century Antwerp (Wadum 1998). Four of the Audley End panels retain some measurable sapwood, and another two have the onset of sapwood on the outer edges of dated boards.

Thirteen of the 15 panels that definitely contain eastern Baltic boards include some boards around the previously observed typical maximum widths of *c* 250–325mm. In total there are 20 boards amongst these 13 panels that are between 255 and 328mm wide at their widest ends. These widths appear so frequently that it can be assumed that they relate to the usable sizes derived from the traded Baltic boards after the trimming of feathered edges and removal of sapwood. The two panels that are the exceptions to this rule use only narrower Baltic boards. Member of the Standen Family uses a 215mm widest board, and James VI and I uses a 230mm widest board. There must have been issues of choice and convention that affect panel making, including the removal of sapwood, not using the narrow feathered inner edges of riven boards, or needing to use the more substantial sections of boards in order to make satisfactory joints, for pegging or gluing. The format seen in the Frances Howard, Countess of Somerset, panel, a wide central board with two narrow outer boards, is typical of many seventeenth-century portraits and may have been a convention intended to avoid joints across the faces of the sitter. Since they have narrower boards both the Member of the Standen Family panel and the James VI and I panel are candidates for extra trimming potentially removing numbers of outermost heartwood rings. Thus, both these may require a more relaxed interpretation of the *terminus post quem* dates obtained from them due to the potential for the outermost rings having been removed. Sir Thomas Cornwallis does contain boards using the typical widths outlined above, however the tree-ring date is derived from one of its narrow boards. Since this board may also have been trimmed of outer rings, its tree-ring date should likewise be treated with some caution.

A remarkable overall uniformity of board size and panel construction is clearly seen here. This leads inevitably to a situation where, whenever the format of a panel is outside of that uniformity, it is appropriate that we apply some caution in the interpretation of the tree-ring evidence. This caution should particularly consider the usefulness of the tree-ring evidence with respect to the actual date of painting in non-conventional panels. Amongst these Audley End panels, for example, as we have seen above, that two panels utilise slightly narrow boards (Member of the Standen Family, James VI and I). Sir Henry Neville had edges that indicate it had definitely been cut down from a larger panel, although in this case the tree-ring evidence is not significantly affected by this since its central board is still its original width. Of potentially greater significance is where a portrait-format panel is found to use horizontally arranged boards, rather than vertical boards (here both Margaret Audley and Edward VI have this feature). This format is quite rare and it is possible that, in both these cases, this indicates reused boards, recycled panels, shortages of materials, or other unusual circumstances of commission or ownership. Both examples have one or more reasonably wide boards so, as with Sir Henry Neville, this may not affect the usefulness of the tree-ring evidence in either case. All three of these panels may be the intact parts of originally larger panels. The Margaret Audley panel is also the panel using the thickest boards discussed, of up to 18mm in thickness.

Eastern Baltic tree-ring data is not internally uniform. There are three major subgroups that probably indicate different zones of export across the region. These zones shift

through time and since there are intermediate tree-ring series these areas probably overlap to some extent. The identification and delimiting of those zones is still the subject of on-going research and debate amongst dendrochronologists. Currently the two major sixteenth-century zones are called Baltic1 and Baltic2 following Hillam and Tyers (1995), pending the identification of their geographical source region. There is a third group that was originally identified in seventeenth-century Netherlandish panels (Eckstein *et al* 1975) but is now also known to be present in many English seventeenth-century panels. The Audley End material contains examples of all three subtypes. It has a noteworthy, though only slight, predominant usage of Baltic2, unlike most assemblages of Tudor period English panels which are found to utilise predominantly Baltic1. This may reflect the potentially narrow date window for many of these panels as there is some evidence to suggest that Baltic2 was used more extensively in England during a short period in the later sixteenth century. The use of the three composite series (Baltic1, Baltic2, from Hillam and Tyers and the Netherlandish panels sequence of Eckstein *et al* 1975) in the supporting *t*-value tables in this report provides little risk of non-independent cross matching since none of the Audley End material had previously been prepared for tree-ring analysis, and there are no same-tree matches to any of the components of Baltic1 or Baltic2.

Any additional technical evidence for either seasoning or reuse of these boards (such as X-ray images showing earlier painting underneath) would make these panels later, possibly much later, than the dates given here. However it is of note that the analysis of panels with good attributions has demonstrated that the earliest possible dates identified from the dendrochronology usually indicate that the panels were most likely made from unseasoned oak.

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APPENDIX 1

os0549ali

223	182	144	114	199	209	157	216	176	259
219	169	229	174	180	190	123	136	117	183
167	211	161	138	157	149	150	134	196	192
139	163	140	148	165	165	129	131	134	114
102	122	135	102	112	143	142	117	116	140
134	141	84	122	153	150	156	157	129	156
117	129	121	110	77	87	79	97	113	145
130	111	106	122	107	77	76	72	81	61
80	84	67	75	75	105	93	84	117	100
122	103	119	132	134	91	120	79	80	102
122									

os0549alo

121	123	120	87	71	76	76	89	116	118
115	95	67	98	80	72	80	59	72	88
83	97	101	71	110	102	106	129	105	79
87	83	77	96	118	80	110	124	120	107
100	99	100	95	79	103	84	117	128	132
130	114	110	141	124	106	105	99	104	109
121	102	96	131	103	108	137	99	100	93
85	92	101	109	120	83				

os0549aui

218	159	117	261	116	108	160	104	161	98
121	85	111	175	153	166	146	201	173	154
173	186	109	120	173	180	129	104	171	186
141	183	165	234	154	144	242	191	173	194
159	145	127	145	163	181	149	123	126	133
130	113	142	171	129	133	113	133	151	162
107	109	142							

os0549auo

107	116	93	102	121	127	107	77	112	129
135	128	152	114	131	132	162	132	107	70
79	63	102	109	127	124	109	97	134	111
87	83	76	83	71	98	90	77	80	84
118	95	89	130	122	120	122	134	146	140
105	110	90	81	118	113	133	113	100	76
101	112	79	77	121	98	119	97	99	120
101	109	83	80	134	140	125	141	132	126
113	99	126	143	111	141	165	137	113	114
117	103	126	114	124	134	138	125	128	122
95	87	82	64	103	129	136	131	103	90
106	112	112	87	72	68	115	111	127	113
104	139	119	126	128	109	95	86	83	95
106	108	75	106	111	112	110	92	91	106
78	67	92	86	87	103	108	114	100	81
112	99	94	83	86	96	95	100	98	90
113	93	96	126	95	92	74	95	103	83
94	95								

os0549bl

331	276	359	182	219	181	162	194	159	174
111	117	115	110	123	90	114	95	103	140
62	72	71	96	108	102	104	136	86	116
119	79	76	79	93	92	80	91	67	133
156	139	128	123	137	123	139	137	133	185
111	102	111	169	122	115	149	184	167	151
149	129	111	105	134	104	185	173	115	141
118	120	136	114	98	163	147	144	154	128
157	166	128	123	104	140	142	137	97	90
87	70	85	113	100	112	115	110	130	100
110	98	77	88	145	113	100	97	94	95
94	115	124	99	103	119	93	94	80	88
93	64	76	77	88	91	94	68	85	79
70	90	85	86	93	83	96	137	125	115
120	119	85	80	100	103	111	126	140	119

os0549buo

65	65	71	71	90	86	77	69	81	96
93	97	90	93	99	94	103	156	150	100
118	113	92	75	100	117	120	128	119	100
116	109	107	99	96					

os0549cu

156	279	315	254	239	126	236	198	175	209
220	206	173	219	189	223	129	215	193	200
312	273	240	275	177	150	206	283	254	254
301	288	284	361	302	280	318	213	173	188
284	298	272	297	248	262	269	158	204	234
222	238	255	220	205	219	250	200	176	151
199	210	184	189	210	189	188	179	122	151
172	218	148	172	162	180	167	139	177	193
143	92	151	179	134	147	152	175	141	131
157	122	133	125	124	147	214	180	173	146
139	159	145	172	175	173	173	126	158	200
187	160	189	143	189	170	163	157	152	177
127	106	115	116						

os0549du

118	162	175	319	196	219	152	231	213	325
229	134	217	200	242	243	242	220	190	229
160	212	158	170	249	176	95	80	138	152
185	154	186	139	132	166	160	94	105	196
148	128	112	68	147	189	212	190	168	118
133	145	160	172	159	122	98	93	101	92
101	95	116	102	105	78	146	106	80	88
75	120	120	111	117	96	102	110	103	100
121	125	144	164	119	172	143	106	134	148
162	154	123	132	109	78	67	119	102	113
122	140	106	128	109	101	124	97	110	106
92	102	122	105	75	87	83	96	116	121
122	82	108	82	98	111	108	111	71	88
64	88	57	85	85	50	91	62	66	41
59	65	69	78	68	58	69	50	67	63
86	96	59							

os0566al

402	287	308	270	221	292	255	245	250	205
191	340	261	250	300	251	299	257	188	164
281	187	249	153	299	288	363	247	273	320
198	283	285	218	237	261	169	211	225	162
152	201	203	166	170	153	123	149	177	148
183	167	93	103	94	78	81	109	79	115
83	61	76	63	75	55	110	134	111	94
147	105	132	110	84	133	96	79	124	139
131	159	145	165	194	157	158			

os0566bl

186	242	253	380	275	232	181	155	157	227
231	136	127	226	303	195	165	189	207	180
211	171	283	182	163	96	123	134	224	196
246	233	212	172	198	136	191	184	220	153
181	191	172	181	143	114	105	109	105	105
129	156	146	111	151	202	146	130	158	192
220	158	140	202	202	203	217	230	177	168
110	116	99	128	103	83	144	92	98	96
81	108	115	99	79	96	94	88	159	125
121	126	120	102	103	103	90	103	95	91
75	92	112	148	158	143	151	129	150	149
157	186	140	146	137	188	186	237	215	148
138	109	171	207	182	163	188	152	175	206
200	173	162	210	183	136	133	225	198	213
170	174	172	135	133	152	196	159	188	186
170	123	140	188	162	155	155	146	172	155
146	130	152	185	256	246	199	172	126	92
126									

os0566cl

242	205	126	139	169	160	137	170	96	156
182	184	123	169	136	184	136	126	141	137
149	129	100	88	103	93	111	99	161	128
116	139	131	149	122	132	111	121	133	136
163	125	140	116	146	129	85	126	99	116
103	95	60	73	53	66	77	76	72	91
62	51	53	48	68	68	73	90	74	92
70	86	74	89	83	85	65	65	68	98
134	90	82	88	62	88	79	81	85	76
68	85	105	96	105	106	95	90	75	102
109	123	132	131	118	123	126	139	143	151
126	116	137	123	191	161	139	103	92	79
117	82	87	122	95	131	151	127	117	97
93	85	99	115	105	114	124	123	110	123
117	123	125	165	114	142	113	82	136	92
94	93	99	104	117	119				

os0567al

128	118	90	102	142	142	128	110	143	146
129	114	139	123	140	160	141	153	187	139
203	149	157	174	151	249	216	159	173	132
164	172	164	133	142	184	152	201	193	172
147	135	101	176	196	135	144	187	190	143
154	155	149	186	205	204	236	153	140	123
142	128	117	171	136	183	144	127	121	109
115	106	167	184	117	123	123	124	131	108

os0567bl

128	229	102	173	121	124	117	102	203	191
136	199	172	244	227	126	119	170	165	179
168	148	116	136	105	97	114	144	119	141
122	188	212	230	130	122	127	146	151	179
163	189	166	138	185	225	117	152	110	157
181	132	175	129	98	94	177	109	296	205
74	115	126	136	215	121	151	180	129	189
195	208	163	148	232	249	123	165	296	248
172	194	128	110	306	219	381	303	220	197
191	254	176	196	122	106	146	192	106	121
180	97	167	106	219	201	234	211		

os0567cl

170	160	214	229	223	154	152	144	158	122
104	143	194	186	138	141	146	172	147	189
139	113	95	95	123	115	119	154	112	114
128	105	121	120	130	154	153	180	167	163
122	112	88	78	50	71	52	105	113	150
149	162	85	94	102	137	122	106	92	101
96	100	87	92	99	95	86	75	70	75
84	72	59	66	67	73	51	76	89	91
106	93	81	116	102	100	83	106	100	110
116	87	88	93	134	183	177	111	139	175
190	189	124	152	136	136	136	139	101	144
145	125	133	117	103	113	129	120	138	96
105	128	113	117	116	125	99	158	148	122
128	164	186	144	148	186	190	166	212	200
150	150	126	133	154	182	71	104	184	129
191	160	177	154	121	189	159	166	177	169
207	205	140	147	192	202	189	157	114	129
199	194	183	194	155	143	159	171	158	169
132	83	138	144	116	113	164	134	171	168
178	168	155	165						

os0568al

131	151	139	93	160	162	139	124	110	103
102	117	101	104	82	89	123	139	159	145
126	136	137	139	128	156	105	82	82	80
92	79								

os0568bl

131	240	232	199	216	255	244	175	170	148
157	207	121	126	165	221	259	174	189	116
196	205	138	203	186	165	185	145	215	211
270	206	205	219	138	142	194	167	133	79
159	106	138	137	178	100	86	57	54	55
77	110	105	117	105	110	108	119	152	120
129	213	237	131	197	204	173	184	167	161
134	117	111	110	139	114	77	68	108	74
88	81	111	114	115	114	62	95	102	90
121	103	150	131	96	74	86	97	62	83
110	115	117	149	97	105	113	96	114	102
139	135	186	154	105	76	96	118	73	134
94	71	90	83	89	127	114	122	109	117
136	145	168	160	146	198	161	156	131	160
112	98	127	101	126	89	79	109	134	79
142	109	126	93	111	98	78	92	103	123
130	155	124	111	130	129	176	146	174	155
122	128	167	226	131	136	127	98	111	126
113	90	91	97	113	130	123	140	113	149
129	140	132	137	124	68	76	76	99	90
71	97	110	123	91	91	98	108	107	97
133	139	127	120						

os0568buo

125	108	125	89	105	83	75	83	108	123
114	145	113	112	125	114	179	147	162	153
125	120	147	215	138	146	116	101	99	127
108	89	92	100	109	128	135	156	122	141
142	144	121	145	112	78	80	85	84	86
72	93	108	127	92	99	106	106	106	104
133	143	135	117	115	130	142			

os0568cl

81	72	65	72	111	75	74	58	58	76
75	77	83	76	70	86	70	44	65	75
63	81	59	86	77	88	112	88	80	44
62	42	50	47	76	67	68	81	60	83
97	63	75	63	57	54	54	66	48	44
67	81	48	78	70	70	64	65	66	74
64	87	59	55	63	81	84	87	83	62
95	65	78	59	64	52	75	44	54	39
48	49	45	45	41	31	47	46	47	45
38	37	35	36	44	39	45	56	74	58
55	55	68	63	78	48	66	63	74	72
72	71	70	87	70	68	92	69	62	76
60	78	46	79	53	74	100	95	120	69
95	79	84	78	78	87	75	63	57	67
109	90	81	102	92	92	118			

os0568cu

110	98	109	85	87	73	86	87	84	84
71	75	112	87	107	72	92	78	70	64
104	80	70	79	59	77	73	61	87	73
85	84	56	46	67	71	56	86	60	95
70	83	102	73	66	43	60	35	50	47
79	59	74	79	70	93	97	77	81	57
64	59	60	60	50	50	73	88	51	77
60	76	57	75	65	86	83	73	58	49
54	87	93	93	83	64	95	70	72	68
73	50	56	51	51	40	51	43	36	52
48	48	43	55	53	51	52	46	43	55
38	49	49	63	61	73	69	59	88	71
68	68	69	72	96	106	81	90	65	97
81	74	83	76	76	66	73	78	56	78
61	69								

os0569al

130	184	132	185	298	329	200	349	392	389
388	254	228	119	129	109	210	179	170	214
137	244	296	230	222	191	195	165	223	239
188	243	240	197	145	156	98	138	111	176
220	190	165	197	90	144	137	178	160	200
191	138	125	125	121	178	189	116	119	96
86	61	80	65	63	77	101	73	65	100
97	100	99	110	110	147	89	110	76	134
103	151	111	85	113	126	164	133	131	103
123	160	155	100	67	88	82	95	88	95
95	115	79	83	75	92	91	110	107	139
125	131	122	128	97	84	93	90	77	84
81	87	123	165	101	93	65	103	101	122
122	102	87	67	73	81	115	101	77	82
88	124	129	102	104	106	58	82	78	97
96	80	92	85	87	83	88	77	101	78
65	68	78	89	113	86	58	77	61	101
82	72	74							

os0569bl

119	127	135	114	143	103	147	80	103	156
140	142	164	119	99	129	169	161	175	186
140	208	201	259	209	246	223	220	218	221
209	155	178	153	190	197	154	132	152	161
189	241	225	183	183	207	247	206	139	179
186	168	156	219	189	184	188	212	192	179
204	172	193	196	189	207	233	171	184	227
246	176	154	141	193	130	141	140	165	169
138	172								

os0570alo

92	107	99	88	110	89	62	71	69	92
71	57	59	50	48	71	78	71	49	84
72	107	80	80	67	99	82	71	72	109
84	115	83	90	92	96	110	78	68	76
99	106	122	116	89	110	87			

os0570cu

182	213	118	95	205	139	152	189	149	125
222	125	140	100	115	127	128	143	145	137
116	135	97	105	82	123	114	115	140	95
123	138	128	142	132	141	247	228	163	152
102	99	127	177	131	147	104	117	127	152
125	140	128	191	162	107	129	158	163	139
141	148	162	157	104	258	189	173	138	133
132	130	102	94	169	111	118	137	114	110
105	114	91	102	136	115	130	127	118	127
102	132	142	151	156	126	108	89	120	194

os0570dl

380	354	282	329	231	273	296	318	359	136
163	162	169	181	152	122	81	127	128	107
97	83	112	195	155	211	280	168	226	270
229	297	293	334	295	275	234	299	228	206
129	135	114	126	106	123	118	94	156	164
151	155	168	151	208	273	351	277	303	386
311									

os0833ar

81	109	122	92	118	114	114	112	91	134
74	115	84	97	70	78	80	68	87	101
87	96	90	52	87	77	75	74	80	117
86	104	113	99	127	97	138	104	104	108
101	97	129	130	125	135	128	125	110	110
80	79	117	127	102	101	103	113	118	124
130	129	108	120	110	106	121	117	110	105
137	139	133	158	177	132	166	149	141	124
137	140	143	130	120	115	123	126	121	150
131	124	131	131	108	122	113	148	136	136
132	118	102	106	104	102	97	90	99	81
103	83	70	70	76	72	73	76	97	110
104	92	94	97	103	107	80	67	86	98
112	98	74	106	99	115	142	134	140	105
128	132	129	117	149	110	130	109	130	128
130	118	117	128	117	118	91	118	114	86
85	96	117	91	123	110	100	88	120	115
112	92	81	115	96	118	106	132	123	126
139	150	119	168	135	121	106	89	112	100
96	66	78	93	106	115	100	80	96	87
81	84	88	84	99	96	96	79	90	85
85	91	87	73	92	113	106	107	85	85
115	117	120	94	110	102	102	89		

os0833br

143	213	162	125	129	87	161	226	248	205
268	196	220	184	264	189	232	208	217	254
226	162	184	210	227	214	254	166	175	140
135	100	152	139	132	119	109	127	110	79
118	148	140	116	178	186	205	217	189	172
184	182	176	238	180	154	188	154	130	206
156	154	216	175	152	172	133	173	172	127
114	118	161	153	117	193	202	169	132	117
167	137	135	130	150	134	132	83	192	205
197	123	184	133	186	206	188	225	217	221
131	142	150	172	173	189	178	130	197	260
196	208	175	234	193	223	191	239	165	207
217	240	201	264	226	193	204	190	132	199
247	203	227	218	214	224	204	182	171	203
178	212	238	209	255	265	218	203	206	203
229	210	208	197	206					

os0833cr

165	244	151	169	190	180	153	121	81	168
206	222	191	258	176	223	181	237	167	221
163	181	252	206	172	171	179	197	220	228
117	177	142	147	107	143	163	119	102	91
123	100	81	120	141	123	123	159	217	209
212	212	177	167	187	175	290	162	139	188
145	144	202	183	140	206	171	144	196	114
148	180	130	126	114	155	168	125	177	211
187	144	121	185	138	159	124	152	171	124
83	206	220	214	111	218	144	181	225	214
225	235	248	151	163	160	178	197	203	182
140	214	255	192	188	191	264	224	239	195
195	174	188	200	249	194	295	236	229	206
172	117	180	196	153	181	201	222	217	226
167	165	216	178	196	225	190	211	258	217
170	251	201	219	195					

os0833dr

117	129	167	158	151	156	139	141	120	117
144	115	114	101	107	117	118	129	112	95
125	85	60	64	67	75	77	57	79	58
64	48	64	59	72	91	69	64	83	101
96	71	92	117	97	118	146	115	115	81
112	156	135	134	117	106	132	141	121	144
165	161	210	219	117	101	100	110	115	123
123	137	129	90	108	126	115	98	108	82
92	103	107	135	142	162	162	162	135	182
101	139	123	168	97	112	97	91	122	110
119	118	130	123	126	145	137	114	111	111
163	121	133	142	130	139	132	124	121	163
153	135	145	128	189	168	169	119	121	150
158	136	121	121	120	118	103	141	171	130
151	121								

os0841al

179	170	211	207	238	238	194	161	267	255
238	256	363	313	343	381	405	565	403	330
395	367	455	356	349	293	339	205	148	201
185	285	210	175	209	204	206	245	228	202
224	209	263	233	230	213	211	217	262	170
206	217	213	233	235	205	124	179	242	188
167	165	213	198	163	179	130	126	125	134
149	134	159	171	143	184	100	125	156	166
195	180	123	117	147	119	136	141	186	167
120	131	142	124	137	114	147	170	153	96
97	133	139	89	82	139	124	112	123	128
113	95	93	109	82	125	101	123	127	125
84	122	114	116	116	108	101	96	77	109
92	153								

os0841aro

205	138	176	137	185	106	145	169	142	190
218	174	135	118	145	118	119	146	153	111
141	144	113	128	112	152	161	122	98	107
144	125	101	92	131	114	111	128	122	119
107	106	119	99	131	112	129	128	109	97
129	140	125	121	132	123	101	79	82	90
115	115	117	127	143					

os0841br

137	218	149	225	144	165	135	90	56	82
127	165	193	169	156	95	185	129	111	129
168	140	125	139	94	111	119	157	146	112
127	99	107	162	127	82	71	76	100	135
120	166	109	167	126	140	207	160	179	158
186	169	145	143	119	154	123	86	95	131
132	169	180	247	209	209	158	167	85	109
153	127	179	205	241	145	123	198	108	81
90	107	69	85	108	107	105	98	142	94
86	133	142	175	126	109	74	84	130	103
133	175	106	119	124	119	113	121	100	110
95	96	117	129	181	118	105	100	126	114
143	158	173	178	134	135	151	191	159	123
139	101	110	181	189	179	186	196	131	112
110	150	209	194	130	191	152	153	128	124
100	104	85	111	137	109	174	136	148	129
161	191	173	186	176	153	164	153	167	145
216	148	161	126	194	136	130	136	139	201
204	186	126	123	131	96				

os0913l

222	188	305	157	244	295	279	275	331	340
219	262	260	206	174	173	155	140	175	227
142	123	140	100	89	44	66	95	90	105
98	118	100	82	111	186	164	256	196	288
156	203	151	205	244	171	190	112	158	121
172	259	116	95	173	275	127	139	154	116
154	163	188	276	231	206	247	205	331	178
158	159	205	172	191	202	168	237	123	196
175	144	182	127	101	100	116	123	198	185
132	167	134	123	135	131	130	104	128	141
133	203	164	163	210	155	167	199	146	311
207	189	224	211	241	206	319	155	226	146
138	129	155	194	154	147	130	240	187	178
166	229	197	126	224	152	140	267	251	159
137	178	129	118	138	104	144	204	130	251
148	160	113	139	153	110	165	209	104	122
95	101	134	127	115	180	125	111	152	157
189	177								

os0914I

171	161	195	261	217	214	247	261	245	238
365	307	385	323	348	269	292	187	293	217
195	261	307	212	300	283	170	249	210	208
194	125	228	243	241	203	148	223	157	136
231	267	293	241	196	273	249	153	137	170
203	182	120	181	210	262	165	169	140	240
208	199	200	171	163	115	148	120	203	150
158	167	143	154	170	163	164	116	156	215
183	180	180	248	207	190	200	155	204	208
174	105	181	184	247	215	178	210	240	256
267	193	182	173	158	148	180	170	174	177
142	125	122	128	130	145	177	188	161	170
168									

os0915I

330	325	349	283	313	182	159	124	126	168
125	131	130	145	189	257	216	245	202	222
165	191	225	179	197	184	224	156	167	111
147	127	218	222	193	182	186	96	139	154
191	151	144	157	126	127	167	144	161	141
155	142	126	114	136	146	132	97	95	123
124	97	171	144	126	156	166	146	158	94
110	104	147	122	153	110	94	88	132	234
211	187	137	126	151	155	131	99	173	123
214	196	152	106	150	99	102	96	124	98
129	152	160	194	118	121	121	106	94	106
137	108	184	133	108	162	228	144	182	140
164	184	205	228	169	134	98	134	109	159
133	101	95	107	84	125	104	129	118	129
126	122	164	153	134	170	157	113	130	181
166	164	105	112	112	136	152	201	153	101
177	119	129	147	137	116	95	124	133	107
103	139	131	150	108	136	158	129	136	114

os0916al

84	90	140	130	108	91	95	67	69	65
59	62	67	88	87	68	72	96	64	71
69	61	84	76	102	95	110	91	79	77
97	77	101	69	87	95	95	113	84	96
125	139	111	93	118	90	89	88	69	81
88	100	71	82	70	95	83	83	79	90
77	69	78	80	82	65	79	86	88	85
71	95	78	103	102	56	54	73	71	84
80	77	70	56	58	61	61	71	65	67
86	69	77	76	88	85	93	94	65	67
58	71	79	70	85	78	80	75	83	106
75	89	94	79	95	74	85	75	71	69
91	59	70	88	67	83	67	93	81	57
70	53	60	80	70	90	70	74	77	77
82	90	80	72	75	89	57	75	63	73
57	75	51	77	72	72	52	66	71	99
81	116	96	74	88	73	106	102	97	89
95	86	97	71	86	75	98	107	107	71
73	69	95	83	79	100	107	120	95	89
68	51	64	79	75	93	72	87	91	84
80	93	92	96	84	81	69	97	93	69
90	93	89	80	70	84	109	101	68	111
77	84	76	98	126	112	79	67	82	68
110	84	80	90	74	78	87	81	105	116
86	83	64	94	91	87	89	86	79	76
68	104	67	71	67	78	77	96	79	71
69	74	73	70	75	65	78	86	117	105
111	110	104	101	118	106	108	112	90	89
87	96	103	87	92	79	79	84	77	

os0916bl

167	186	218	145	160	164	126	151	168	201
155	254	221	244	164	169	142	165	165	183
160	180	171	154	195	197	171	179	162	145
157	164	188	183	191	138	152	145	201	125
146	163	197	167	165	159	112	141	125	144
149	143	113	133	131	131	144	122	137	163
163	160	151	157	207	182	172	210	155	168
167	126	182	155	153	185	131	130	141	144
138	121	135	94	129	156	129	121	135	135
121	181	137	142	138	109	160	129	135	164
148	167	165	142	132	131	144	123	155	133
141	139	135	110	143	127	124	140	141	138
120	154	120	143	105	121	128	131	129	115
112	116	87	105	87	121	112	113	84	113
100	114	121	120	110	99	124	129	108	113
104	100	114	94	102	112	120	115	137	127
120	137	147	138	100	116	113	98	110	103
103	116	109	99	113	91	85			

os0917l

681	790	955	776	652	412	591	683	855	594
890	904	859	767	739	780	549	645	518	694
949	506	408	506	526	634	691	768	693	840
494	428	608	452	697	605	543	390	620	697
363	668	550	317	809	556	293	318	289	273
387	397	407	281	312	318	386	334	307	279
361	227	186	166	261	178	261	419	271	240
199	284	254	278	243	207	319			

os0918au

103	81	75	82	115	105	81	73	83	58
93	89	84	77	72	70	83	80	46	70
65	64	61	68	59	68	70	85	78	72
84	78	101	62	68	64	81	72	75	69
67	69	78	75	51	69	87	79	74	75
79	71	58	101	98	98	100	98	90	58
70	60	73	58	69	70	96	80	70	70
73	76	72	82	91	76	89	93	83	88
98	100	85	68	96	125	87	78	78	59
55	64	79	77	71	54	70	67	81	85
85	62	62	68	61	75	80	68	71	73
55	59	81	80	84	91	89	79	74	77
88	68	75	56	67	70	60	67	65	57
54	59	71	67	59	81	56	76	61	84
73	66	75	67	74	68	81	83	68	58
62	69	66	56	72	66	74	68	73	77
64	64	74	73	51	51	62	53	28	50
79	51	68	57	70	67	63	65	57	49
60	66								

os0918bu

82	104	120	86	60	94	99	103	71	88
79	55	71	63	90	82	98	95	74	76
78	54	89	91	79	48	60	87	61	60
51	66	38	57	45	38	60	46	53	64
42	73	50	30	49	46	55	55	56	77
53	73	70	74	55	56	72	60	58	43
47	69	89	61	53	43	83	81	75	79
68	73	80	96	91	85	116	63	81	63
63	55	56	47	59	69	78	75	86	87
91	71	68	97	81	74	72	47	63	52
65	50	67	55	73	59	60	60	60	53
43	43	50	71	60	88	90	92	112	88
72	113	87	54	64	83	87	104	117	98
84	96	134	100	82	118	93	114	100	120
92	90	108	84	82	82	101	88	58	73
77	78	50	73	80	60	44	45	72	53
57	69	63	67	85	62	93	70	61	81
66	70	73	85	61	72	83	63	90	95
63	110	121	78	71	111	95	80	87	72
63	56	63	52	71	61	75	87	66	80
100	72	78	76	103	68	94	71	84	56
83	61	69	81	64	96	58	73	77	80
76	85	80	69	77	90	89	71	70	83
68	74	95	67	84	72	78	92	85	61
65	58	56	54	63	66	68	72	70	74
72	84	92	88	63	72	63	87	72	72
80	59	69	67	78	59	80	86	69	60
70	84	79	54	85	75	104	102	83	81
71	70	59	80	69	62	66	77	80	66
69	81	68	66	69	88	82	84	89	68
86	105	96	87	62	87	112	85	63	69
52	69	71	68	77	58	61	66	66	67
68	76	82	78	67	62	67	74	59	70
70	61	71	80	74	76	89	92	77	72
70	96	60	65	51	70	69	64	71	65
47	55	59	69	62	54	71	69	75	58
76	64	63	61	51	67	70	71	76	71
61	62	62	52	64	74	62	77	62	84
84	78	69	70	81	51	63	61	38	38
77	75	51	64	60	63	64	65	82	59
62	63	62	61	59	72	62	73	66	70
45	44								

os0919au

136	140	106	91	107	127	137	114	94	109
111	125	130	105	97	121	110	98	100	55
57	56	59	72	57	63	56	54	50	52
52	58	56	47	53	54	53	70	76	72
84	60	79	103	115	108	93	100	115	119
113	104	101	150	133	118	98	90	95	93
80	93	62	64	82	69	76	97	100	89
71	66	70	64	74	79	66	51	67	51
106	90	76	95	88	98	110	101	99	122
113	82	97	96	101	130	102	119	124	123
133	109	109	67	86	103	85	81	102	135
126	117	146	121	130	120	131	152	126	138
128	173	117	122	83	119	116	126	108	98
82	86	98	109	106	109	112	108		

os0919bl

79	77	125	80	104	70	89	75	106	71
92	83	132	157	238	272	281	215	145	93
127	146	130	154	223	208	391	383	303	299
378	200	215	195	397	387	292	348	366	241
226	260	228	338	288	129	180	105	168	316
270	271	299	186	350	316	260	232	303	259
203	195	249	309	268	268	186	142	169	176
180	142	163	161	169	130	116	106	143	113
105	140	146	156	89	104	135	128	131	168
217	151	152	171	175	138	147	153	104	110
90	126	113							

os0919cl

216	158	161	135	154	104	103	143	119	103
98	129	119	117	131	130	131	120	123	123
131	98	144	123	140	124	133	123	145	111
127	142	162	173	167	133	109	118	146	132
128	118	125	116	124	148	128	154	137	124
104	106	101	106	101	96	112	100	117	120
119	111	149	111	119	98	127	128	130	146
107	148	101	118	97	164	144	140	116	97
134	99	87	88	107	120	127	83	94	64
112	117	122	121	140	87	121	109	103	108
79	120	104	136	161	103	87	155	134	120
136	111	152	123	135	111	106	102	105	112
120	145	100	111	128	114	165	138	113	140
135	114	92	113	117	135	127	115	105	122
116	142	109	112	79	100	104	85	126	131
179	116	127	154	120	121	136	119	124	121
156	110	97	130	107	114	137	116	134	126
154	103	126	103						

os0920ali

206	169	206	164	141	164	183	151	152	134
158	193	178	136	168	144	99	81	94	109
196	180	114	198	212	118	101	201	187	115
83	163	71	87	108	126	237	162	215	170
167	194	260	243	124	194	147	102	122	98
99	131	123	143	106	140	105	229	106	136
118	128	105	122	89	120	106	177	158	143
139	135	170	148	136	128	109	133	112	118
107	77	162	111	102	108	123	74	94	153
176	120	89	165	131	125	80	112	136	120
60	138	122	96	146	98	142	135	99	109
97	103	129	125	102	122	65			

os0920alo

87	94	60	86	75	92	84	136	137	136
98	60	78	85	150	130	145	85	99	77
238	147	177	182	137	200	147	113	81	113
195	192	176	166	221	151	98	120	136	166
192	178	168	134	140	180	170	137	143	110
123	124	115	223	161	114	118	134	130	140
158	181	161	140	104	163	147	199	165	136
127	124	124	122	135	126	131	119	129	117
122	146	121							

os0920aup

161	132	133	106	116	80	110	122	194	158
138	129	150	166	148	162	130	133	123	110
115	108	86	163	110	137	119	134	106	93
139	139	94	97	171	132	124	73	124	129
108	60	133	116	116	127	100	131	123	111
116	106	93	123	158	112	115	75	56	57
62	62	86	69	63	57	83	81	132	124
177	168	141	128	103	112	135	166	164	198
100	130	103	190	166	162	184	134	205	153
123	98	114	192	195	197	170	202	135	110
137									

os0920bl

177	121	87	160	79	98	107	113	145	119
193	158	161	169	230	194	108	157	135	86
104	105	94	104	109	130	85	140	99	211
100	127	116	116	92	125	82	99	106	164
138	133	124	133	162	154	142	130	122	123
111	105	102	84	160	101	102	134	137	109
99	143	162	124	111	176	135	119	87	120
122	133	82	145	128	100	143	117	143	125
116	127	102	104	127	194	139	94	70	55
49	72	69	95	71	57	63	78	109	109
86	133	127	200	120	78	82	91	139	121
140	88	116	100	197	172	175	157	159	203
159	117	96	110	192	203	184	169	199	171
123	161	160	165	202	174	177	134	178	167
201	161	151	144	122	139	125	217	160	105
115	131	114	122	155	189	165	122	91	166
150	162	173	131	121	114	110	118	128	127
119	125	114	145	134	151	112			

ENGLISH HERITAGE RESEARCH AND THE HISTORIC ENVIRONMENT

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

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

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

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

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

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

For further information visit www.english-heritage.org.uk