RESEARCH REPORT SERIES no. 32-2013

LINNELS MILL, HEXHAMSHIRE LOW QUARTER, HEXHAM, NORTHUMBERLAND
TREE-RING ANALYSIS OF TIMBERS

SCIENTIFIC DATING REPORT

Alison Arnold and Robert Howard

INTERVENTION
AND ANALYSIS

ENGLISH HERITAGE

This report has been prepared for use on the internet and the images within it have been down-sampled to optimise downloading and printing speeds.

Please note that as a result of this down-sampling the images are not of the highest quality and some of the fine detail may be lost. Any person wishing to obtain a high resolution copy of this report should refer to the ordering information on the following page.

Research Report Series 32-2013

LINNELS MILL, HEXHAMSHIRE LOW QUARTER, HEXHAM, NORTHUMBERLAND

TREE-RING ANALYSIS OF TIMBERS

Alison Arnold and Robert Howard

NGR: NY 95144 61491

ISSN 2046-9799 (Print)
ISSN 2046-9802 (Online)

The Research Report Series incorporates reports by the expert teams within the Investigation & Analysis Division of the Heritage Protection Department of English Heritage, alongside contributions from other parts of the organisation. It replaces the former Centre for Archaeology Reports Series, the Archaeological Investigation Report Series, the Architectural Investigation Report Series, and the Research Department Report Series.

Many of the Research Reports are of an interim nature and serve to make available the results of specialist investigations in advance of full publication. They are not usually subject to external refereeing, and their conclusions may sometimes have to be modified in the light of information not available at the time of the investigation. Where no final project report is available, readers must consult the author before citing these reports in any publication. Opinions expressed in Research Reports are those of the author(s) and are not necessarily those of English Heritage.

Requests for further hard copies, after the initial print run, can be made by emailing:
Res.reports@english-heritage.org.uk
or by writing to:
English Heritage, Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth PO4 9LD
Please note that a charge will be made to cover printing and postage.

SUMMARY

Sixteen samples obtained from timbers of the structure and machinery at this mill were analysed resulting in the construction and dating of a single site sequence.
Site sequence LNLSSQ01 contains three samples and spans the period AD 1541–1712. Interpretation of sapwood demonstrates felling of a door lintel in AD 1630–55 and of two principal rafters in AD 1712/13. Three other site sequences, accounting for 11 samples, are undated, as are the remaining two ungrouped individual samples.

CONTRIBUTORS

Alison Arnold and Robert Howard

ACKNOWLEDGEMENTS

The Laboratory would like to thank Mr and Mrs Winter, owners of the mill, for allowing sampling to be undertaken, Hugh Massey of Hugh Massey Architects for facilitating access, and Duncan Hutt of the North East Mills Group for his *on site* advice. Thanks are also given to Cathy Tyers and Shahina Farid of the Scientific Dating Section at English Heritage for their advice and assistance throughout the production of this report. The drawings used to locate samples were produced by the Adult Education Class 1975/6, University of Newcastle upon Tyne.

ARCHIVE LOCATION

Northumberland Historic Environment Record
County Hall
Morpeth
Northumberland
NE61 2EF

DATE OF INVESTIGATION

2012/13

CONTACT DETAILS

Alison Arnold and Robert Howard
Nottingham Tree-ring Dating Laboratory
20 Hillcrest Grove
Sherwood
Nottingham NG5 1FT
roberthoward@tree-ringdating.co.uk
alisonarnold@tree-ringdating.co.uk

CONTENTS

INTRODUCTION

The Grade II* listed Linnels Mill is located adjacent to Linnels Bridge, just south-east of Hexham in Northumberland (Figs 1–3). Documentary sources suggest that it originated as a fulling mill, remodelled into its current form in the sixteenth/early seventeenth century with outshots added to the east and west in the late-eighteenth/early nineteenth century (Fig 4). Once milling ceased, the mill was converted to produce electricity for the neighbouring house. It is thought to be one of the oldest and best preserved corn mills in Northumberland.

The main mill building retains the millstone and water-wheel and is floored at its north end. The roof over this part of the building consists of two trusses of principal rafters, collar, purlins, and ridgebeam (Fig 5).

Located in the west outshot is what is thought to be one of the last *in situ* oat roasting kilns in the region; in the east outshot is a pearl barley grinding machine (Fig 6), the date of which is unknown.

SAMPLING

Sampling was requested by David Farrington (English Heritage, Heritage at Risk Architect/Surveyor) to provide independent dating evidence for the extant mill building and machinery and to identify any timbers which might represent an earlier structure. It was hoped that any results would enhance understanding of the historical development of the site and hence inform the significance and future management of this important corn mill.

A total of 21 timbers was sampled by coring. Each sample was given the code LNL-S and numbered 01–21. Eight are from the roof structure (LNL-S01–08), seven from the main mill machinery (LNL-S09–15), two from potentially primary mill building timbers (LNL-S16–17), and four from the pearl barley grinder (LNL-S18–21). The location of samples was noted at the time of sampling and has been marked on Figures 7–10. Further details relating to the samples can be found in Table 1. Interest had also been expressed in the mill wheel but this was found to be pine and the decision was made not to sample.

ANALYSIS AND RESULTS

Two of the roof samples, two of the mill machinery samples, and one of the pearl barley grinder samples had too few rings for secure dating and so were discarded prior to measurement. The remaining 16 samples were prepared by sanding and polishing and their growth-ring widths measured; the data of these measurements are given at the end of the report. Samples were then compared with each other by the Litton/Zainodin grouping programme (see Appendix), resulting in 14 samples matching to form four groups.

Firstly, three samples matched each other and were combined at the relevant offset positions to form LNLSSQ01, a site sequence of 172 rings (Fig 11). This site sequence was compared against a series of relevant reference chronologies for oak where it was found to span the period AD 1541–1712. The evidence for this dating is given by the *t*-values in Table 2.

Four other samples grouped to form LNLSSQ02, a site sequence of 86 rings (Fig 12). LNLSSQ03 contains four main mill machinery samples (Fig 13), and site sequence LNLSSQ04 contains three pearl barley grinder samples (Fig 14). These three site sequences and the two ungrouped samples were compared against the reference chronologies but all are undated.

INTERPRETATION

Tree-ring dating has resulted in the successful dating of three samples, two roof timbers and a door lintel. Sample LNL-S17, taken from a door lintel, has the heartwood/sapwood boundary ring date of AD 1615 which allows an estimated felling date range to be calculated for the timber represented of AD 1630–55. One of the roof samples, the east principal rafter from truss 2 (LNL-S03), has complete sapwood and the last-measured ring date of AD 1712, the felling date of the timber represented. The other dated roof sample, the west principal rafter from truss 2 (LNL-S04), was taken from a timber with complete sapwood, however, approximately 2mm of the outer, softer sapwood rings were lost during the sampling procedure. It is therefore possible to estimate that *c* 2–3 rings have been lost. Therefore, the addition of these lost rings to the last-measured ring date of AD 1710 gives this timber a felling date of *c* AD 1712–13. Given the high level of similarity between the ring sequences from LNL-S03 and LNL-S04 it is possible that they were derived from the same-tree and were thus both felled in AD 1712.

Felling date ranges have been calculated using the estimate that mature oak trees in this region have 15–40 sapwood rings.

DISCUSSION

It had been hoped that tree-ring dating would identify timbers associated with the primary construction of the present mill building but also potentially an earlier mill and perhaps the survival of early machinery parts. However, this has not been the case with only three timbers having been successfully dated, the earliest of which was felled in AD 1630–55.

There are no obvious signs that the door between the main building and the east outshot is a later modification and it is likely to have been an external door in use when the east outshot was added. Therefore, it could be that the lintel above it, dated to AD 1630–55, is primary to the building as seen today, putting construction in about the second quarter of the seventeenth century. However, some caution must be applied when assigning a date to a building on the basis of a single timber, especially in the case of a lintel which can relatively easily have had any signs of previous use removed.

It is now known that the roof over the main building contains at least two principal rafters which were felled in AD 1712/13. It may be that the roof as a whole dates to the early eighteenth century or that these dates simply represent work being undertaken on the roof structure at this time.

It is unfortunate that site sequence LNLSSQ02, containing four other roof timbers could not be dated as this may have clarified the situation. However, by looking at the relative heartwood/sapwood ring position of the samples in this site sequence (Fig 12) it is possible to say that the two principal rafters and two purlins represented were probably felled at the same time as each other, although it is not possible to say when that was.

In the same way it can be said that at least two of the timbers used in the construction of the pearl barley grinder were felled at the same time as each other (Fig 14), although again it is not possible to say when this would be.

It is disappointing that only one of the site sequences from Linnels Mill has been dated. Although none of the undated site sequences are particularly well replicated, they are of good length, and indeed site sequence LNLSSQ03 has 206 rings and might usually be thought to have a high chance of successful dating. It is possible that this poor success rate is due to the potentially late nature of the timber represented and the deficit of reference material of the later eighteenth and nineteenth centuries from the north-east region with which to compare them. If the lack of dating is due to a paucity of relevant reference material it would be hoped that at some point in the future, if this period becomes better represented within our reference databases, then these site sequences might be successfully dated.

BIBLIOGRAPHY

Arnold, A J, Howard, R E, and Litton, C D, 2003 *Tree-ring analysis of timbers from the roof of the Keep or Little Castle, Bolsover Castle, Derbyshire*, Centre for Archaeol Rep, **15/2003**

Arnold, A J, Howard, R E, and Litton, C D, 2004 *Tree-ring analysis of timbers from Fell Close, Healeyfield, near Consett, County Durham*, Centre for Archaeol Rep, **35/2004**

Arnold, A J, Howard, R E, and Litton, C D, 2005 *Tree-ring analysis of timbers from 17 and 19 St Mary's Chare, Hexham, Northumberland*, Centre for Archaeol Rep, **51/2004**

Arnold, A J, and Howard, R E, 2006 *Nottingham Tree-ring Dating Laboratory, Tree-ring analysis of timbers from the Main Guard, Pontefract Castle*, Centre for Archaeol Rep, **48/2005**

Arnold, A J, Howard, R E, and Hurford, M, 2008 unpubl Tree-ring analysis of timbers from 101 Meeting Street, Quorn, Leicestershire, unpubl computer file *QRNASQ01*, NTRDL

Arnold, A J, and Howard, R E, 2009 *Bentley Hall, Derby Lane, Hungry Bentley, Near Ashbourne, Derbyshire, Tree-ring analysis of timbers,* English Heritage Res Dep Rep Ser, **33/2009**

Howard, R E, Laxton, R R, and Litton, C D, 2003 *Tree-ring analysis of timbers from Staircase House, 30A &31 Market Place, Stockport, Greater Manchester*, Centre for Archaeol Rep, **12/2003**

Hurford, M, Tyers, C, Arnold, A, and Howard, R, 2009 *Ulnaby Hall, High Coniscliffe, Darlington, County Durham: Tree-Ring Analysis of Timbers*, English Heritage Res Dep Rep Ser, **61/2009**

TABLES

Table 1: Details of samples from Linnels Mill, Hexhamshire Low Quarter, Northumberland

Sample number	Sample location	Total rings*	Sapwood rings**	First measured ring date (AD)	Last heartwood ring date (AD)	Last measured ring date (AD)
Main mill; roof						
LNL-S01	East principal rafter, truss 1	82	11c (+2mm lost)	----	----	----
LNL-S02	West principal rafter, truss 1	63	h/s	----	----	----
LNL-S03	East principal rafter, truss 2	167	20C	1546	1692	1712
LNL-S04	West principal rafter, truss 2	170	17c (+2mm lost)	1541	1693	1710
LNL-S05	Collar, truss 2	NM	--	----	----	----
LNL-S06	West upper purlin, bay 1	NM	--	----	----	----
LNL-S07	West lower purlin, bay 2	71	9c (+5mm lost)	----	----	----
LNL-S08	East lower purlin, bay 2	57	18C	----	----	----
Main mill; machinery						
LNL-S09	Main beam	107	22c (+2mm lost)	----	----	----
LNL-S10	Centre post	129	--	----	----	----
LNL-S11	Spoke	110	--	----	----	----
LNL-S12	Spoke	118	--	----	----	----
LNL-S13	Spoke	112	--	----	----	----
LNL-S14	East-west beam over post (north)	NM	h/s	----	----	----
LNL-S15	East-west beam over post (south)	NM	h/s	----	----	----
Potentially primary						
LNL-S16	East-west floor beam (northernmost)	66	13c(+5mm lost)	----	----	----
LNL-S17	Lintel between main mill and east	58	h/s	1558	1615	1615
East outshot; pearl barley grinder						
LNL-S18	Left hand vertical post	61	h/s	----	----	----
LNL-S19	Right hand vertical post	49	h/s	----	----	----

Table 1: (cont)

LNL-S20	Horizontal beam	NM	--	----	----	----
LNL-S21	End beam	61	--	----	----	----

*NM = not measured

**h/s = heartwood/sapwood boundary is the last-measured ring

c = complete sapwood on timber, all or part lost during sampling with amount of sapwood lost in brackets

C = complete sapwood retained on sample, last-measured ring is the felling date

Table 2: Results of the cross-matching of site sequence LNLSSQ01 and relevant reference chronologies when the first-ring date is AD 1541 and the last-measured ring date is AD 1712

Reference chronology	*t*-value	Span of chronology	Reference
Staircase House, 30A & 31 Market Place, Stockport, Greater Manchester	8.7	AD 1489–1656	Howard *et al* 2003
Fell Close, Healeyfield, Consett, County Durham	7.7	AD 1496–1651	Arnold *et al* 2004
Ulnaby Hall, High Coniscliffe, Darlington, County Durham	6.4	AD 1493–1608	Hurford *et al* 2009
101 Meeting Street, Quorn, Leicestershire	6.4	AD 1489–1658	Arnold *et al* 2008
Pontefract Castle, Pontefract	6.2	AD 1507–1656	Arnold and Howard 2006
Bolsover Little Castle, Derbyshire	6.1	AD 1532–1749	Arnold *et al* 2003
Bentley Hall, Derby Lane, Hungry Bentley, near Ashbourne, Derbyshire	6.1	AD 1444–1675	Arnold *et al* 2009
17–19 St Mary's Chare, Hexham, Northumberland	5.8	AD 1536–1689	Arnold *et al* 2005

FIGURES

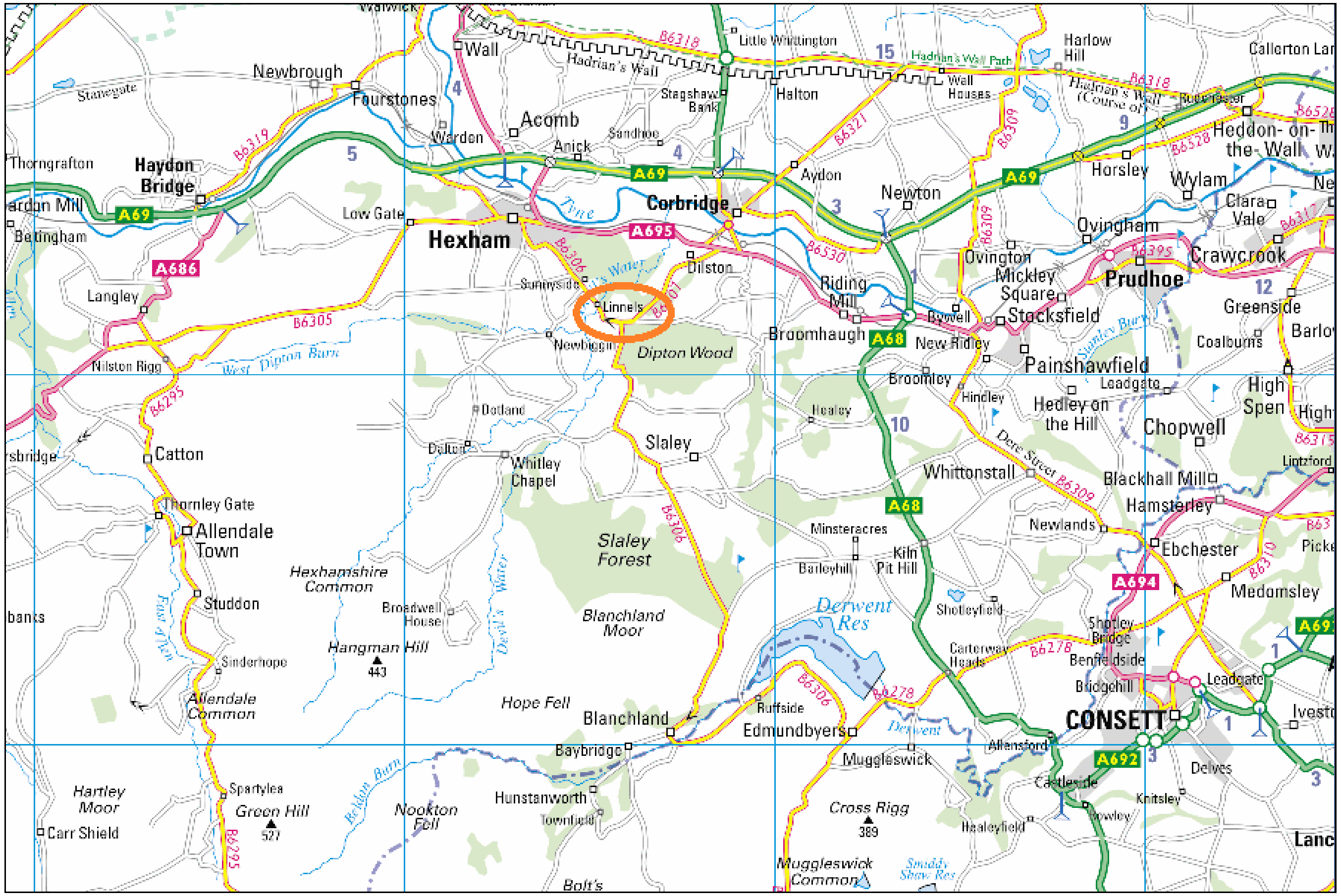


Figure 1: Map to show the general location of Linnels, circled. © Crown Copyright and database right 2013. All rights reserved. Ordnance Survey Licence number 100024900

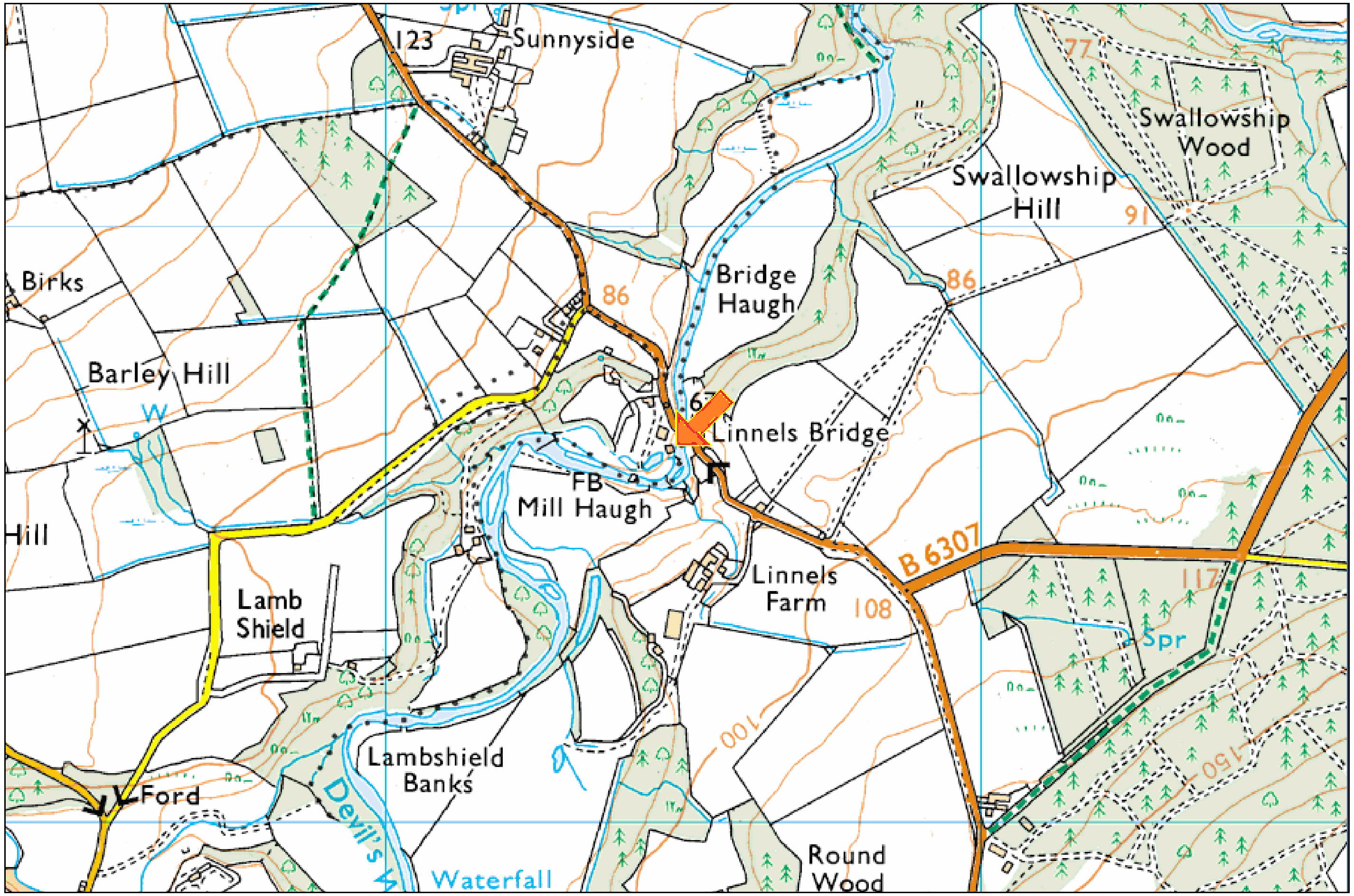


Figure 2: Map to show the general location of Linnels Mill, arrowed.

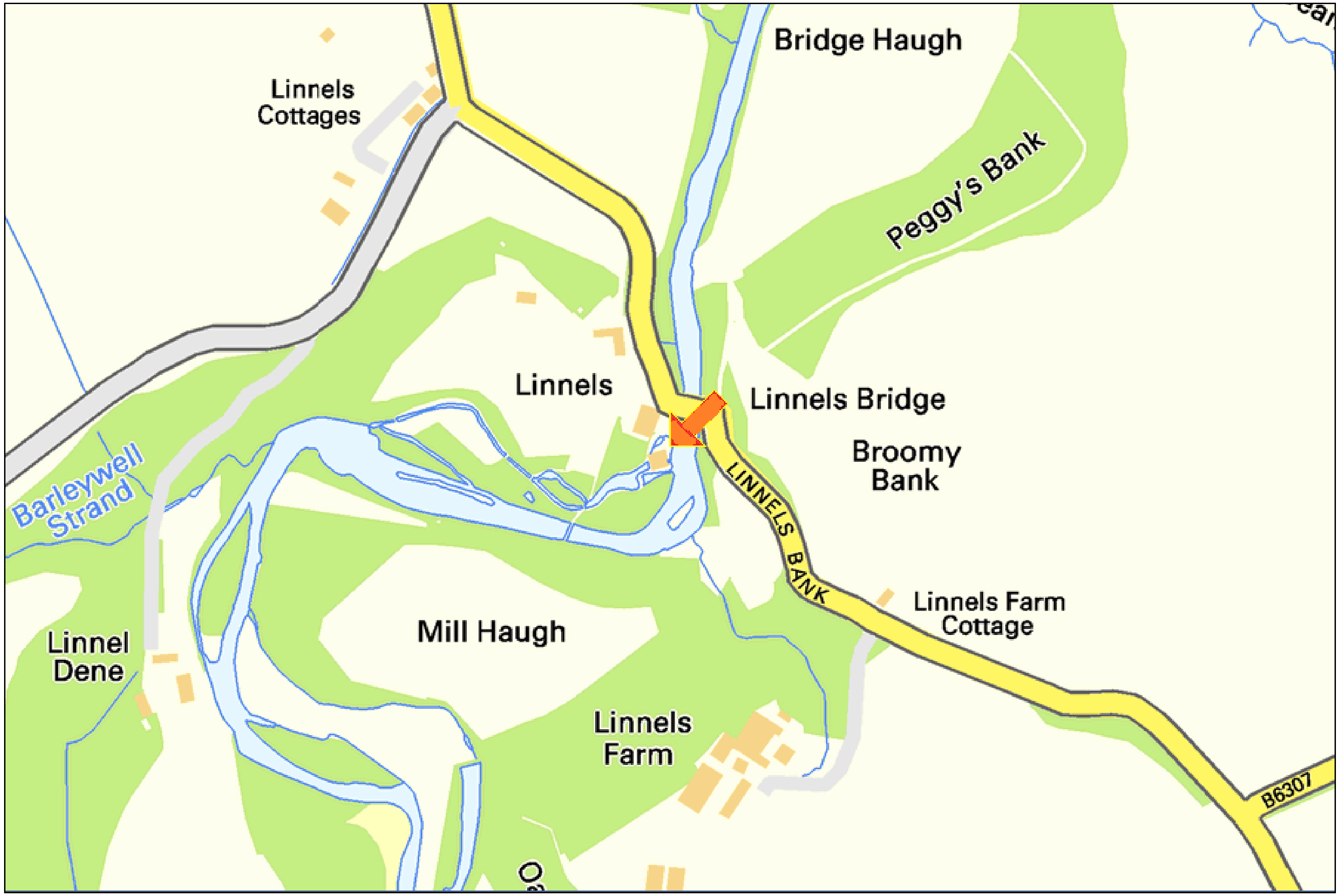


Figure 3: Map to show the location of Linnels Mill. © Crown Copyright and database right 2013. All rights reserved. Ordnance Survey Licence number 100024900

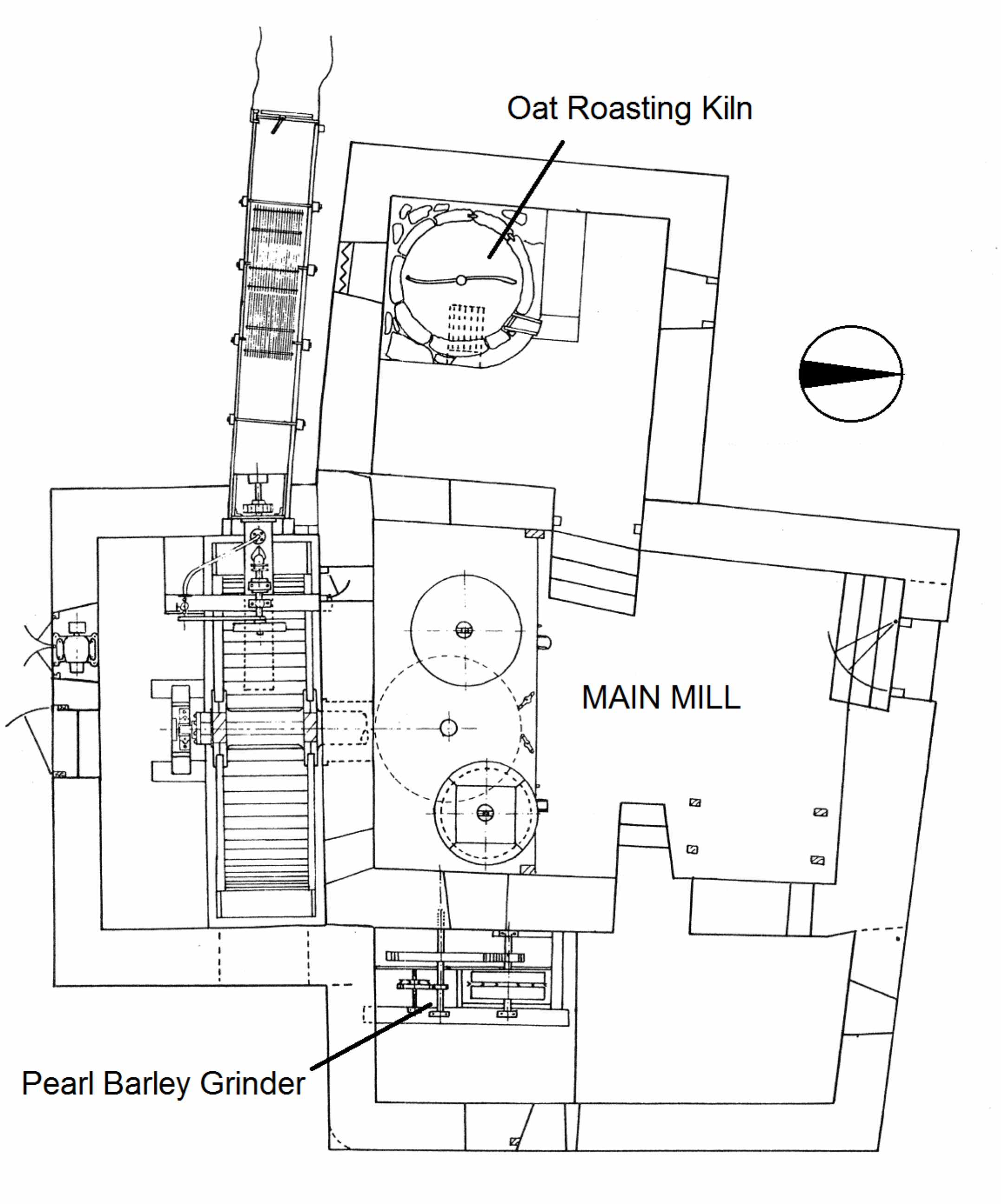


Figure 4: Linnels Mill, showing components (Adult Education Class, Univ of Newcastle Upon Tyne)

Figure 5: Linnels Mill; roof of the main building (photograph Alison Arnold)

Figure 6: Linnels Mill; pearl barley grinder (photograph Robert Howard)

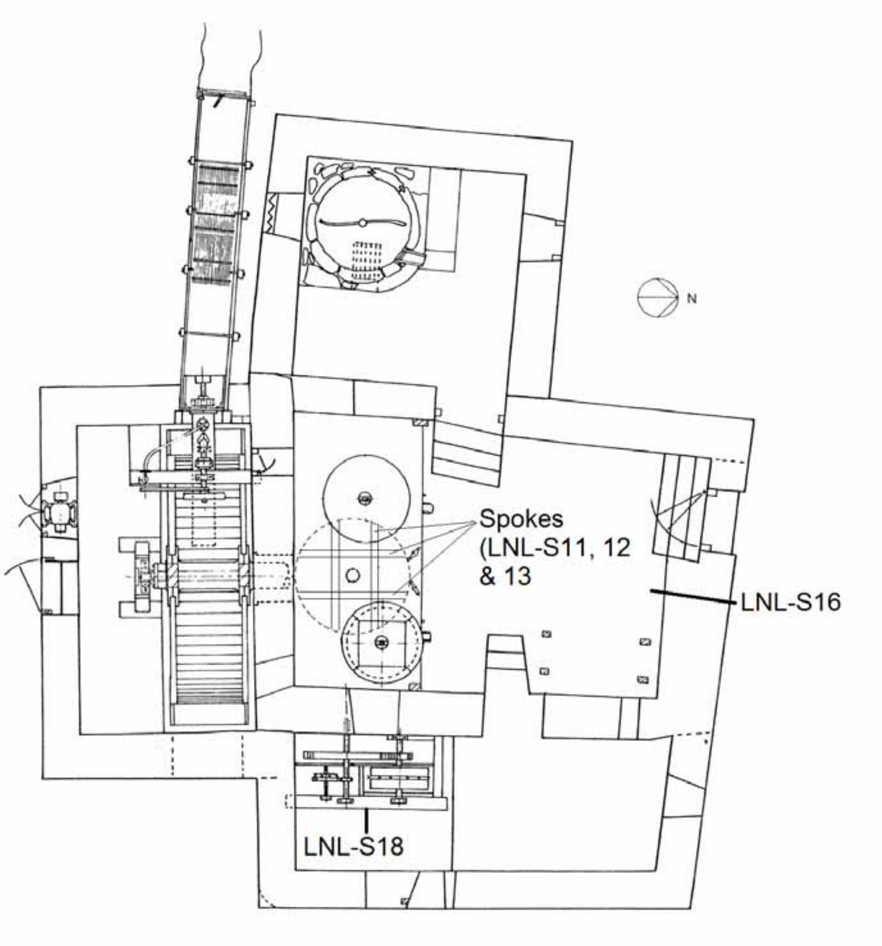


Figure 7: Ground-floor plan of Linnels Mill showing the location of samples LNL-S11–13, LNL-S16, and LNL-S18 (Adult Education Class, University of Newcastle upon Tyne)

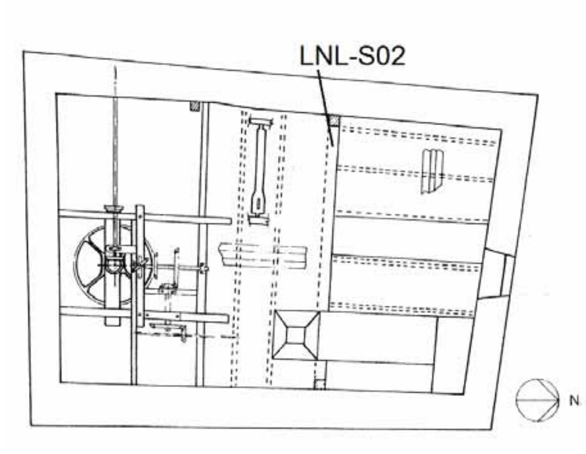


Figure 8: First-floor plan of Linnels Mill showing the location of sample LNL-S02 (Adult Education Class, University of Newcastle upon Tyne)

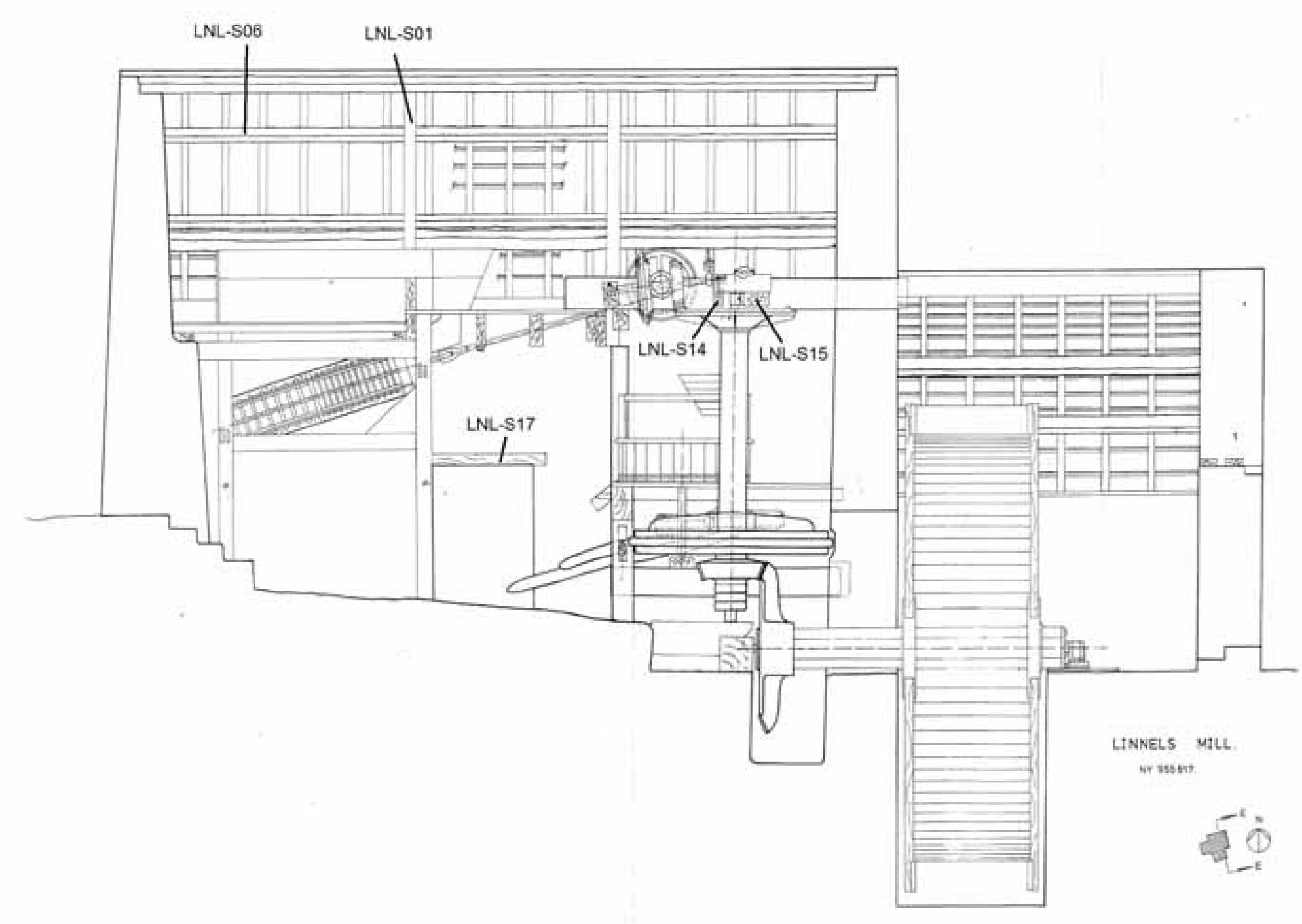


Figure 9: Section E-E of Linnels Mill showing the location of samples LNL-S01, LNL-S06, LNL-S14–15, and LNL-S17 (Adult Education Class, University of Newcastle upon Tyne)

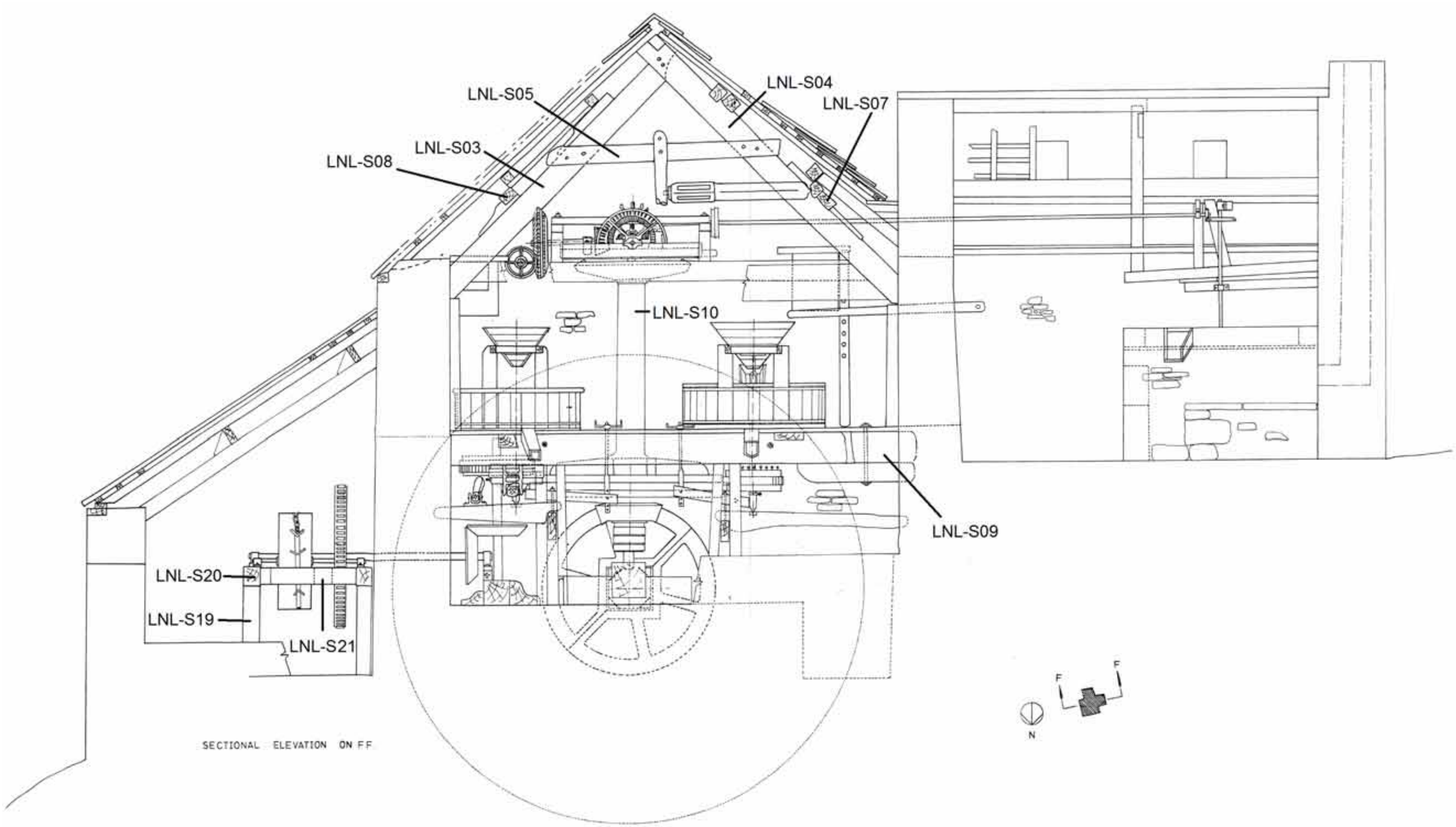


Figure 10: Section F-F of Linnels Mill showing the location of samples LNL-S03–05, LNL-S07–10, and LNL-S19–21 (Adult Education Class, University of Newcastle upon Tyne)

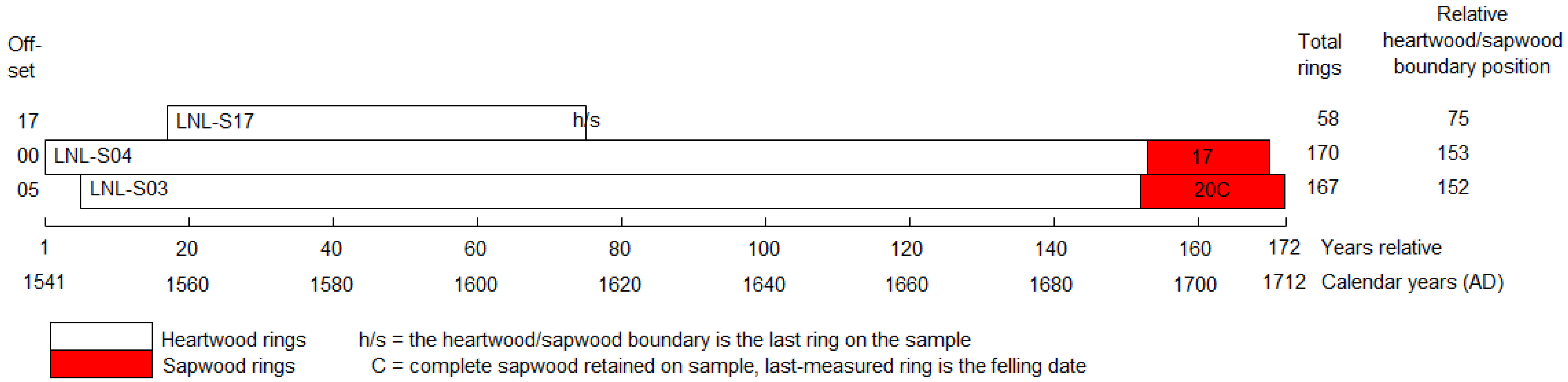


Figure 11: Bar diagram of samples in dated site sequence LNLSSQ01

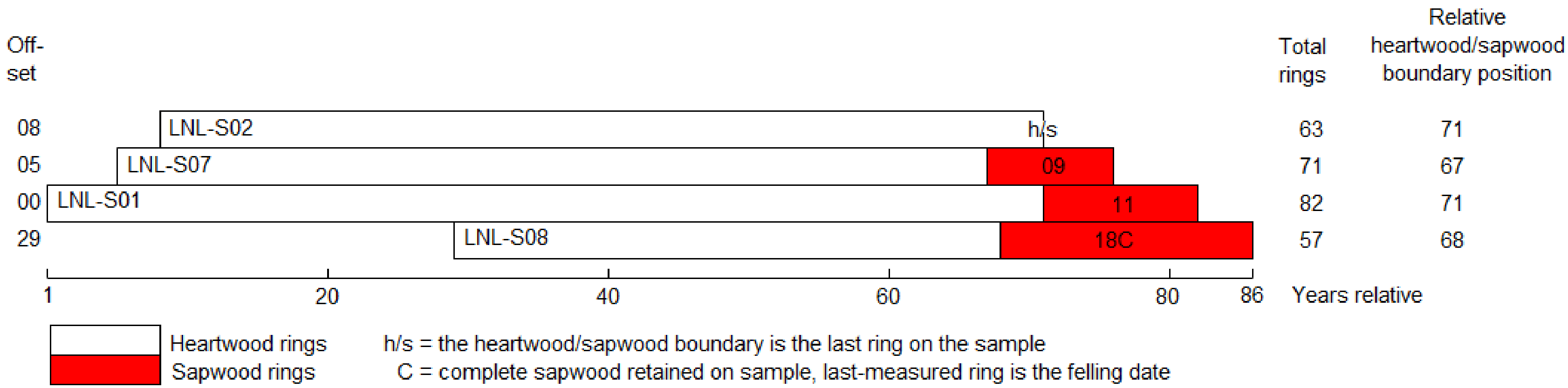


Figure 12: Bar diagram of samples in undated site sequence LNLSSQ02

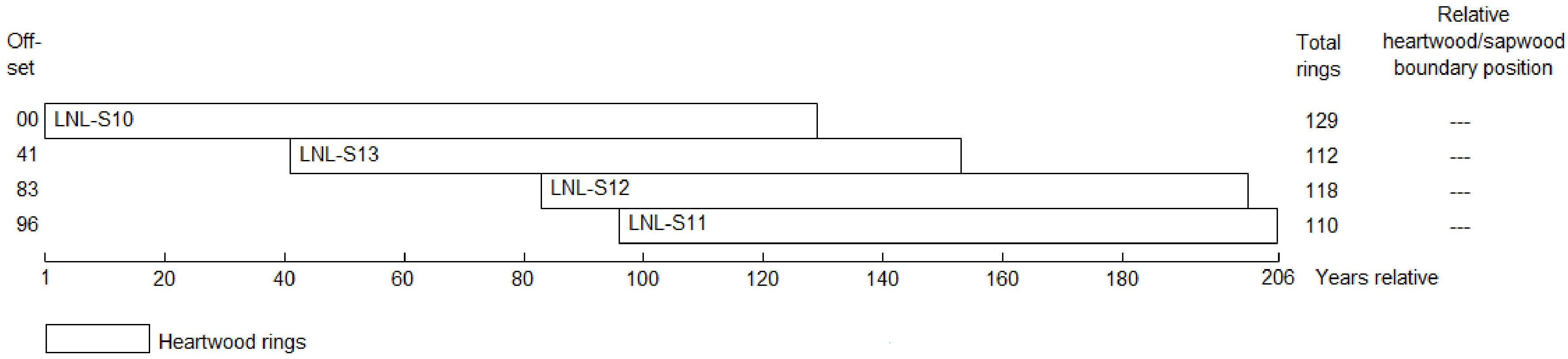


Figure 13: Bar diagram of samples in undated site sequence LNLSSQ03

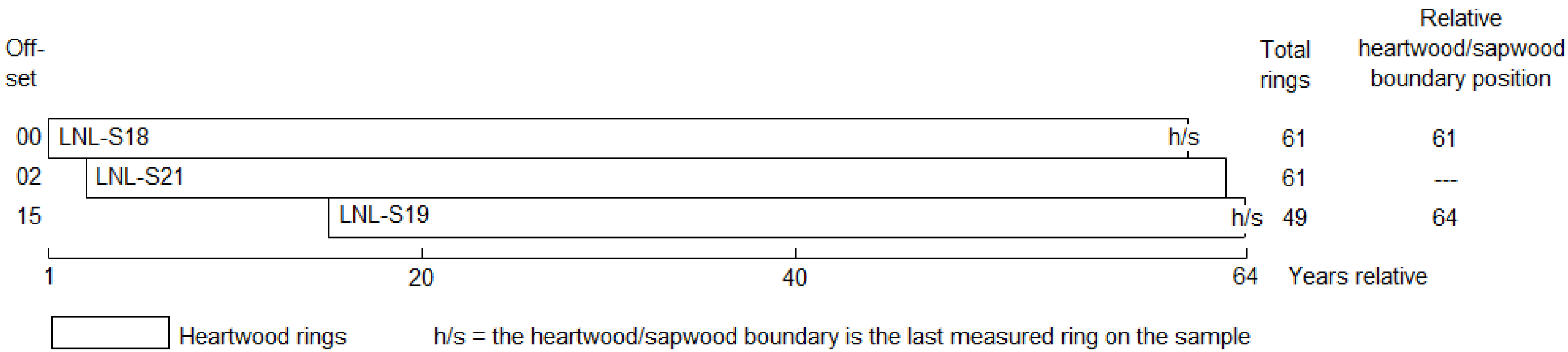


Figure 14: Bar diagram of samples in undated site sequence LNLSSQ04

DATA OF MEASURED SAMPLES

Measurements in 0.01mm units

```
LNL-S01A 82
 265 295 281 272 294 378 327 337 301 220 226 214 169 123 116 139 173 113  53  44
  33  39  45 112 138 209 226 229 195 208  97  31  28  45  34  59 113 196 244 169
 105 123 180 116 137 177 147 200 170 121 246 222 218 213 276 293 189 102  42  48
  70  88 130 125 139  89 122  71  81 111 204 149 138 152 171 158 124  90 115 117
 114 140
LNL-S01B 82
 236 283 287 247 311 382 300 338 308 223 231 192 175 136 101 142 179 106  66  54
  31  30  59 103 130 215 232 225 189 204  99  32  32  27  35  65 112 184 257 170
  99 127 180 116 134 172 149 192 177 119 250 220 221 213 276 290 194 102  46  48
  51 106 126 127 138 109 115  78  71 118 205 158 141 136 148 161 130 101 113 107
 125 133
LNL-S02A 63
 242 278 316 308 430 343 273 279 326 239 155  91  55  95 114 149 201 222 234 201
 204 177 123  50  60  77  65  99 178 153 177 146 189 214 237 151 152 217 204 208
 142 148 222 198 241 223 217 221 181 114  65  70 101 148 144 129 106  96  94  88
  56 123 101
LNL-S02B 63
 240 278 318 316 448 348 273 282 333 242 149  98  52  87 117 150 191 212 228 202
 194 174 118  53  59  72  67 111 177 149 171 151 187 220 235 149 152 215 199 203
 141 148 217 211 233 218 217 222 189  94  67  73  97 149 141 124 107 100  97  82
  62  97  88
LNL-S03A 167
 100 128 153 151 139 144 123 140 141 196 164 106 122 215 148 218 150 238 246 191
 161 109 166 265 261 211 147 220 243 224 237 169 193 194 213 200 139 196 157 121
 294 209 131 176 141 132 179 174 200 209 163 176 181 164 167 173 151 161 135 103
 149 134 139 128 116  95 115  91  93  65  75  93 128 107 108  78  72  75  85  64
  71 114  87 123  71  48  89  75  61  91  64  64  67  59  69  90  59  55  60  79
  93  74  66  74  50  71  62  70  65  83  78  66  75  76  67  79  88  83  90  87
  56  58  62  73  79  76  80  82  73  60  64  68  89  88  56  54  59  65  84  76
  84  76  84  93  59  60  59  70  60  54  76  81  76  46  55  67  48  48  54  74
  60  64  59  46  50  59  79
LNL-S03B 167
  92 126 150 163 138 150 140 135 144 206 176 112 125 216 149 233 141 225 247 189
 160 112 164 271 265 216 150 226 246 217 241 164 193 203 213 208 140 198 155 121
 293 210 138 172 143 130 176 180 202 210 156 175 182 159 163 183 148 160 145  90
 150 145 141 119 122  92 110  88  98  66  68 100 124 109 114  68  73  80  86  59
  81 113  82 124  69  52  87  84  64  93  63  63  72  58  69  95  56  58  65  74
  88  75  89  61  57  76  80  47  73  77  79  97  69  66  53  81  83  90  85  81
  71  63  50  70  84  73  76  84  71  63  66  71  88  80  54  67  73  69  87  67
  74  76  84 102  67  67  59  63  50  66  77  77  79  50  62  56  48  49  48  76
  50  65  66  38  53  63  51
LNL-S04A 170
 106 113 135 134 173 108 130 180 114 118 122 132 146 155 204 196 123 162 186 131
 175 153 202 179 135 129  93 113 180 220 186 160 198 204 195 228 123 143 159 154
 145 106 126 103 101 207 159 104 128 115  93 119 107 138 171 141 185 129 139 156
 147 117 124 110  82 132 106 141 119 127  61  67  72  53  44  46  44  75  83  89
  48  73  60  49  44  42  32  50  87  48  49  37  59  44  52  53  53  46  42  50
```

80 50 44 50 53 72 53 69 77 57 71 68 65 81 76 105 77 59 63 78
100 82 90 70 78 57 43 56 60 80 69 60 81 70 46 50 49 82 64 46
56 78 39 46 46 51 48 43 60 48 35 38 39 33 28 49 60 39 31 40
32 34 32 30 47 33 39 42 76 70
LNL-S04B 142
89 123 137 152 172 108 123 180 118 124 116 128 151 151 208 188 130 162 187 134
173 149 200 182 137 125 97 120 171 215 184 168 190 204 200 220 128 140 163 151
150 100 136 106 96 212 155 107 136 116 94 128 105 132 177 137 175 151 139 146
147 110 128 111 89 126 107 139 117 129 66 60 66 58 53 37 46 79 91 84
61 68 58 58 41 40 46 50 85 57 43 48 50 44 55 56 54 52 47 44
87 46 41 39 59 71 61 68 76 56 71 68 72 90 78 102 81 60 63 69
95 88 90 77 67 61 45 60 56 64 69 67 88 59 62 39 55 74 72 51
55 71
LNL-S07A 71
137 129 139 303 297 250 171 77 92 96 134 140 90 48 42 51 54 70 106 111
122 156 112 102 100 68 39 77 83 70 126 213 188 224 178 244 242 219 107 147
178 118 192 181 230 225 172 212 175 228 209 143 70 30 60 81 131 92 114 96
86 51 63 61 105 148 117 138 186 145 113
LNL-S07B 71
89 133 140 304 287 261 165 73 103 90 133 140 89 60 43 41 65 65 100 111
108 163 101 100 99 66 35 78 86 61 136 216 192 242 154 232 241 221 102 147
170 122 192 182 218 232 164 217 175 236 206 133 76 39 52 72 147 95 120 95
85 55 58 72 103 144 123 142 190 142 133
LNL-S08A 57
114 134 45 116 110 115 209 312 306 416 289 244 190 268 174 174 151 119 201 182
167 190 131 132 135 151 137 96 72 31 34 52 112 82 84 67 60 50 53 66
107 125 147 184 169 128 87 42 39 33 37 47 72 73 97 63 94
LNL-S08B 57
107 135 46 116 101 119 194 311 296 429 271 227 207 251 191 163 165 124 197 187
163 203 117 141 116 148 125 109 71 42 31 47 103 79 89 75 53 56 46 57
103 131 153 176 173 122 96 34 27 36 39 50 67 75 89 75 88
LNL-S09A 107
218 186 201 247 236 186 141 209 164 165 183 224 250 191 248 196 203 202 164 225
266 238 229 246 226 179 181 138 150 155 136 152 214 167 239 238 243 255 196 181
275 252 247 174 176 191 196 148 99 88 82 56 54 67 54 68 92 95 116 115
126 147 207 190 250 240 230 199 171 134 98 121 176 188 178 136 193 155 135 134
124 110 146 231 168 204 186 202 185 181 135 99 115 93 90 109 136 174 142 139
146 149 174 144 126 146 190
LNL-S09B 107
222 189 190 251 255 192 144 210 161 165 190 250 278 200 243 198 211 195 163 225
254 240 219 244 223 188 181 139 149 152 140 151 211 170 254 239 240 262 197 183
273 251 243 175 180 179 201 152 100 87 82 56 54 61 54 69 81 105 113 117
127 149 212 188 229 229 243 196 170 140 88 122 169 184 181 145 186 153 137 136
118 116 144 239 170 209 179 203 182 182 135 100 117 89 90 106 140 171 140 137
138 153 170 158 137 138 177
LNL-S10A 129
118 84 41 44 71 97 93 106 115 83 168 136 155 135 103 153 99 63 58 38
44 23 40 59 75 51 191 99 69 92 100 116 106 111 91 67 94 96 108 85
75 91 72 86 79 81 71 49 68 62 50 48 39 61 49 38 21 34 55 48
27 29 36 43 35 33 33 44 33 22 36 35 49 48 46 36 45 65 39 51
47 42 51 36 49 34 52 39 63 37 45 65 37 37 48 67 73 88 65 67
90 99 136 103 132 121 97 104 117 79 77 73 69 79 100 98 94 109 113 135
114 117 125 128 119 110 109 140 118

LNL-S10B 129
119 83 44 39 71 97 96 105 122 84 167 138 153 139 101 143 105 62 56 48
31 30 34 53 75 47 192 99 71 101 90 112 102 101 92 65 85 94 108 81
79 93 72 86 80 82 68 55 68 59 53 45 42 61 50 36 24 37 47 48
31 32 40 38 34 33 32 49 29 21 35 36 51 47 49 39 43 54 46 62
48 39 49 37 51 33 47 53 61 32 44 62 41 41 45 65 74 86 64 73
94 96 123 108 137 114 98 107 117 86 77 78 63 84 94 111 85 113 119 125
113 114 116 130 129 101 111 144 112
LNL-S11A 110
54 75 58 48 49 82 106 123 145 84 83 79 93 75 67 81 53 61 79 70
52 40 66 70 69 71 80 104 112 96 65 101 77 92 98 93 72 84 104 88
87 108 90 78 118 110 112 90 138 159 141 120 107 118 126 88 157 115 71 88
80 74 100 70 63 80 120 105 112 122 74 96 63 82 92 91 74 73 75 49
44 39 27 37 37 44 35 36 34 27 49 57 56 63 56 58 85 60 80 82
79 83 104 68 74 63 70 71 69 68
LNL-S11B 110
66 65 48 55 70 92 126 116 101 91 72 86 86 71 61 77 52 58 70 66
111 49 61 79 69 69 77 102 88 97 68 98 72 85 98 83 71 75 104 82
92 104 87 72 113 115 111 82 143 151 140 120 113 152 113 89 111 109 72 86
85 77 84 75 66 77 120 105 109 118 67 93 71 76 91 88 74 73 68 49
38 40 29 38 35 39 36 28 43 25 51 60 51 64 54 57 69 63 80 82
75 81 95 92 65 62 70 70 68 69
LNL-S12A 118
56 95 88 103 94 110 63 65 85 55 104 73 74 91 104 78 137 158 132 120
113 121 112 80 110 134 102 69 73 66 96 131 161 172 228 198 180 152 193 165
187 142 151 112 152 134 150 142 111 90 92 112 103 91 150 130 172 209 186 154
129 166 167 144 103 143 114 147 111 137 153 81 109 111 117 116 106 89 125 126
113 163 156 156 153 79 106 135 103 87 76 72 42 37 60 52 41 53 51 49
46 55 56 51 67 64 89 88 85 110 92 97 109 94 108 106 101 87
LNL-S12B 118
50 101 81 106 91 105 65 69 72 65 99 72 74 74 92 80 94 138 127 122
114 116 117 87 106 140 98 67 62 75 85 138 183 175 240 187 177 146 189 165
176 144 152 111 152 139 150 141 112 88 92 112 107 89 152 131 171 206 191 151
131 168 168 148 111 144 111 142 101 131 156 81 106 115 113 118 106 86 126 128
113 161 152 156 156 81 103 132 98 88 75 73 47 35 58 50 43 53 50 49
45 55 58 51 65 64 86 84 87 115 85 100 100 102 114 110 99 125
LNL-S13A 112
24 141 103 119 108 101 100 114 111 99 100 89 105 81 94 59 63 56 49 52
62 56 74 60 51 54 75 70 51 57 76 71 52 68 55 63 59 55 52 76
51 44 46 73 46 67 75 72 83 80 120 111 121 139 116 194 124 104 92 127
209 238 193 158 142 115 115 130 108 92 77 102 102 129 223 193 172 167 142 152
152 150 127 138 172 185 175 150 148 142 135 102 109 138 107 114 154 143 146 227
220 164 134 174 196 187 141 164 129 147 88 117
LNL-S13B 112
100 125 119 129 106 91 100 118 108 105 90 93 103 81 90 63 57 61 55 51
54 62 72 58 62 52 66 71 55 58 67 71 71 74 54 66 55 52 59 74
51 48 44 80 56 64 80 73 74 86 123 110 122 138 112 197 121 106 76 131
201 242 191 156 163 111 115 136 107 90 78 104 100 134 228 182 195 159 143 144
160 153 121 137 172 182 168 159 145 133 128 92 107 128 104 114 146 155 137 233
219 167 131 179 192 184 140 167 116 152 92 122
LNL-S16A 66
348 334 300 360 319 184 244 246 201 88 93 89 134 152 217 166 201 223 224 264
181 148 139 115 189 206 160 101 112 106 133 167 169 130 158 143 157 143 190 180

132 158 140 125 143 92 122 114 78 56 52 84 92 144 103 80 74 71 55 66
73 108 148 94 115 198
LNL-S16B 58
266 311 312 250 128 133 154 170 206 239 184 207 259 264 261 190 169 152 137 195
210 152 120 111 95 109 133 124 110 134 90 107 110 128 158 113 129 119 89 136
89 106 122 97 81 93 119 135 230 114 116 106 89 62 77 97 115 184
LNL-S17A 58
280 374 495 371 313 399 306 225 191 212 260 285 345 358 317 251 273 261 292 183
196 189 176 144 100 115 155 112 152 152 88 131 102 75 113 135 132 117 85 72
67 36 43 44 36 48 61 63 111 125 99 102 135 96 145 134 151 134
LNL-S17B 58
299 358 486 372 300 401 304 229 183 200 259 307 338 357 323 244 276 262 299 185
191 193 176 152 99 115 142 113 142 132 100 115 107 67 100 133 139 110 77 64
74 37 49 32 41 46 69 72 96 116 103 98 134 91 140 138 135 123
LNL-S18A 61
189 272 247 265 259 253 213 177 160 188 177 203 152 100 67 69 113 141 130 168
171 108 136 110 90 72 85 166 175 213 185 213 195 185 225 221 229 199 158 192
124 114 113 112 112 193 152 85 48 83 108 193 262 145 137 124 105 53 39 60
70
LNL-S18B 61
164 241 234 237 253 236 209 172 167 181 165 194 162 95 74 63 111 149 136 187
167 105 135 104 96 73 83 161 186 208 183 220 202 175 232 215 227 200 162 197
126 109 113 100 114 182 152 76 46 93 130 192 252 143 138 115 98 43 45 62
80
LNL-S19A 49
169 310 301 289 321 399 336 361 314 310 303 291 375 339 365 326 336 313 294 333
293 288 268 297 311 227 279 253 218 213 308 280 200 131 240 269 309 351 257 250
223 177 147 88 109 139 196 264 158
LNL-S19B 49
165 308 291 296 328 398 336 367 315 315 305 274 363 334 374 330 335 312 276 309
285 294 268 298 292 241 273 271 220 198 312 277 214 124 249 278 303 361 258 247
221 178 144 99 107 137 188 274 159
LNL-S21A 61
256 431 387 345 349 304 235 227 219 341 332 256 232 173 260 249 227 220 221 167
215 179 180 162 168 201 170 163 136 100 96 156 172 158 164 124 190 212 210 228
180 194 150 216 174 184 130 156 144 199 204 217 227 198 215 126 90 178 211 262
352
LNL-S21B 61
273 459 378 346 343 304 236 229 221 339 304 261 227 176 267 247 230 229 226 165
203 183 175 146 157 212 163 164 138 105 100 146 171 161 164 125 188 208 219 221
196 203 145 220 180 166 136 157 145 181 220 208 226 187 210 135 86 168 213 262
338

APPENDIX: TREE-RING DATING

The Principles of Tree-Ring Dating

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

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

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

1. Inspecting the Building and Sampling the Timbers. Together with a building historian the timbers in a building are inspected to try to ensure that those sampled are not reused or later insertions. Sampling is almost always done by coring into the timber, which has the great advantage that we can sample in situ timbers and those judged best to give the date of construction, or phase of construction if there is more than one in the building. The timbers to be sampled are also inspected to see how many rings they have. We normally look for timbers with at least 70 rings, and preferably more. With fewer rings than this, 50 for example, sequences of widths become difficult to match to a unique

position within a master sequence of ring widths and so are difficult to date (Litton and Zainodin 1991). The cross-section of the rafter shown in Figure A2 has about 120 rings; about 20 of which are sapwood rings – the lighter rings on the outside. Similarly the core has just over 100 rings with a few sapwood rings.

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

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

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

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

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

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

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

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

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

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

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

It is standard practice in our Laboratory first to cross-match as many as possible of the ring-width sequences of the samples in a building and then to form an average from them. This average is called a site sequence of the building being dated and is illustrated in Figure A5. The fifth bar at the bottom is a site sequence for a roof at Lincoln Cathedral and is constructed from the matching sequences of the four timbers. The site sequence width for each year is the average of the widths in each of the sample sequences which has a width for that year. Thus in Fig A5 if the widths shown are 0.8mm for C45, 0.2mm for C08, 0.7mm for C05, and 0.3mm for C04, then the corresponding width of the site sequence is the average of these, 0.55mm. The actual sequence of widths of this site sequence is stored on the computer. The reason for creating site sequences is that it is usually easier to date an average sequence of ring widths with a master sequence than it is to date the individual component sample sequences separately.

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

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

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

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

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

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

5. Estimating the Date of Construction. There is a considerable body of evidence collected by dendrochronologists over the years that oak timbers used in buildings were not seasoned in medieval or early modern times (English Heritage 1998; Miles 1997, 50–5). Hence, provided that all the samples in a building have estimated felling-date ranges broadly in agreement with each other, so that they appear to have been felled as a group, then this should give an accurate estimate of the period when the structure was built, or soon after (Laxton et al 2001, fig 8; 34–5, where 'associated groups of fellings' are discussed in detail). However, if there is any evidence of storage before use, or if there is evidence the oak came from abroad (eg Baltic boards), then some allowance has to be made for this.

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

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

t-value/offset Matrix

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

Bar Diagram

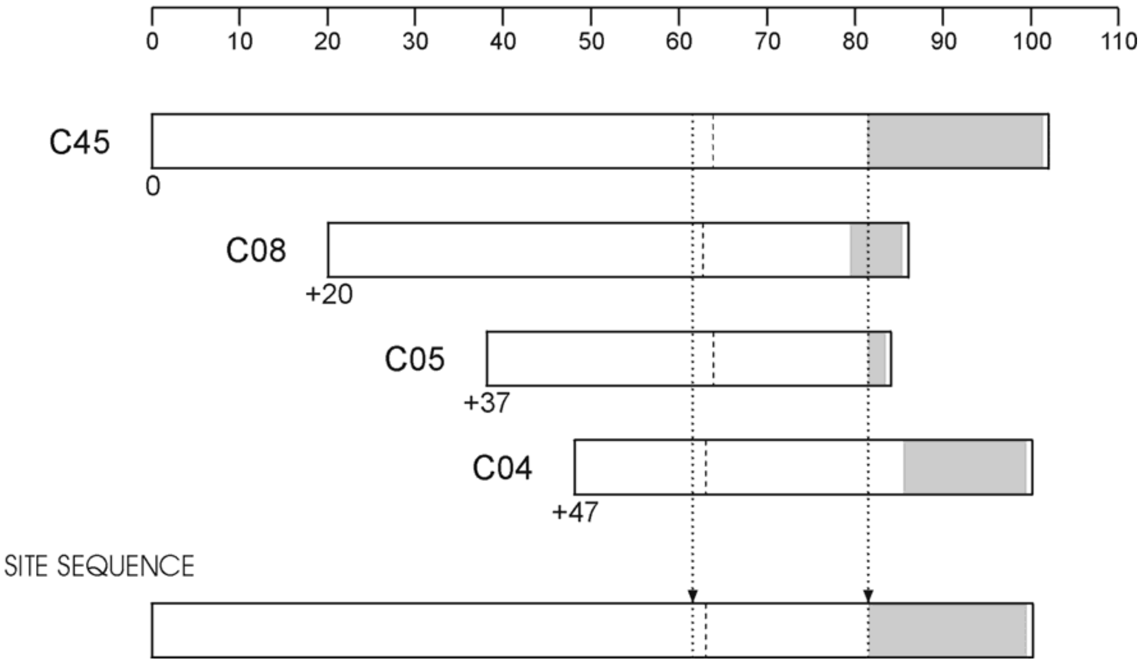


Figure A5: Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them

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

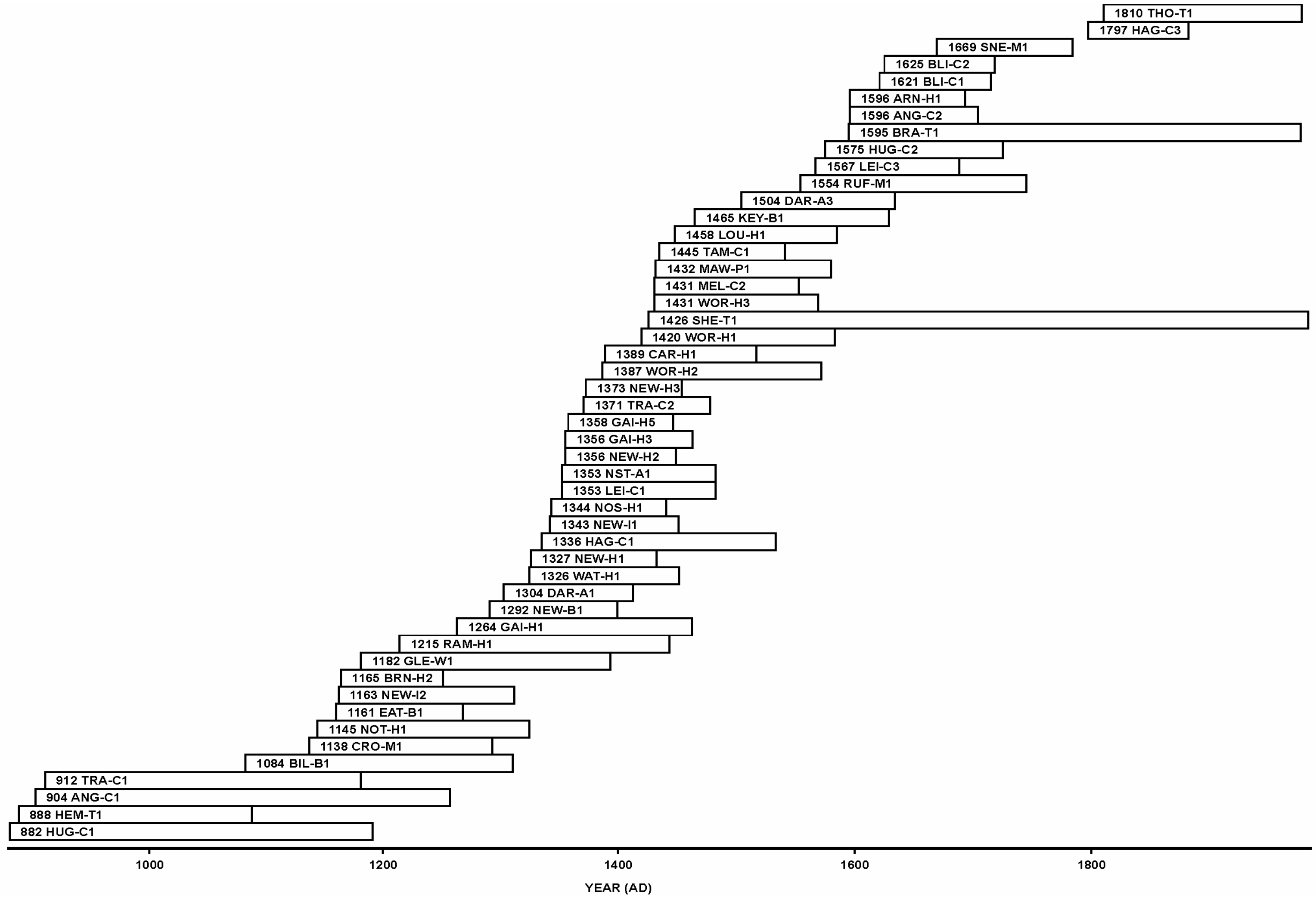
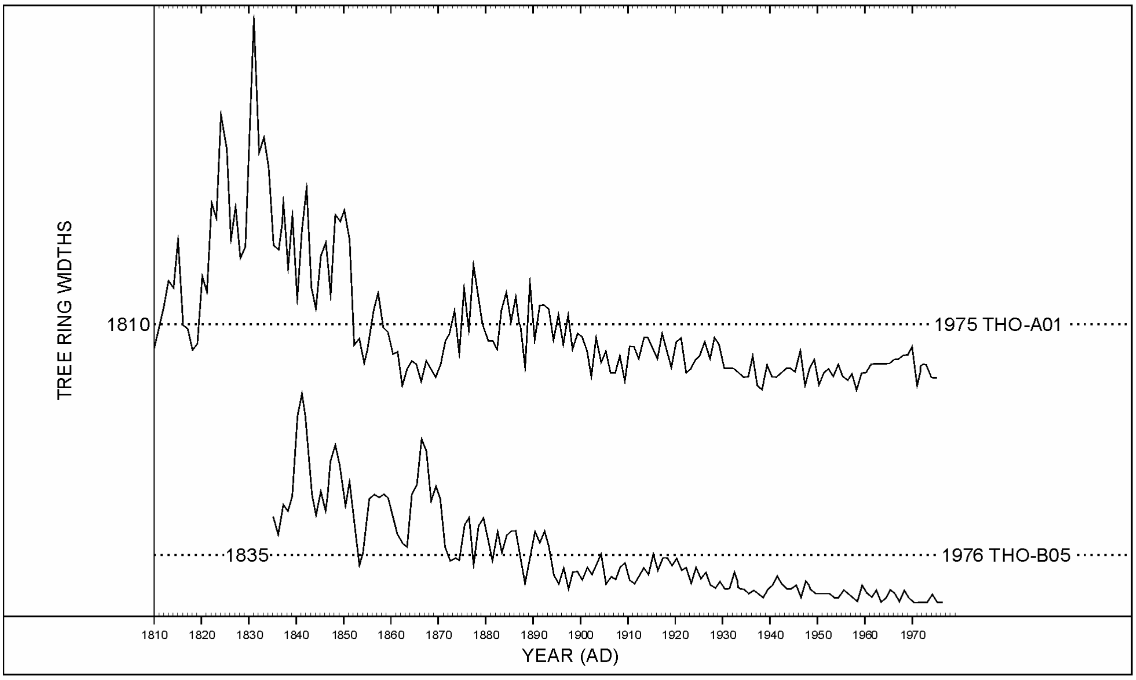


Figure A6: Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87

(a)



(b)

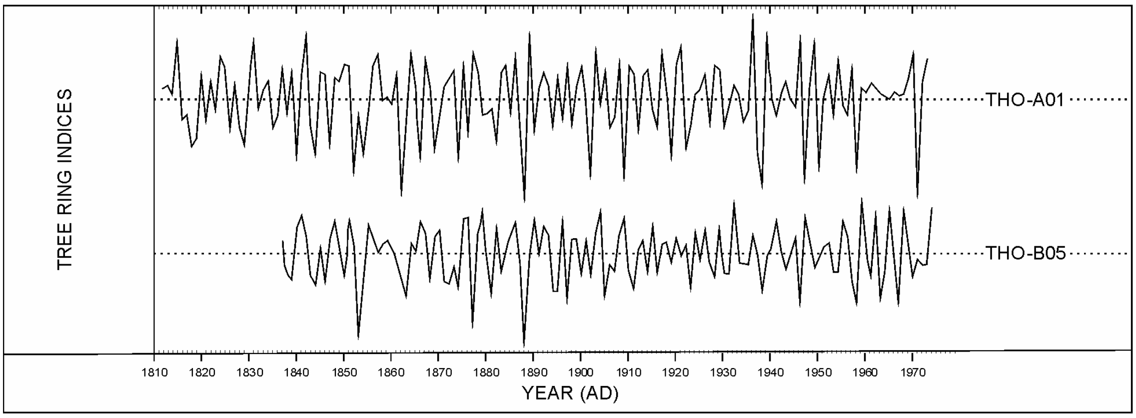


Figure A7 (a): The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known

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

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

The growth trends have been removed completely

References

Baillie, M G L, and Pilcher, J R, 1973 A simple cross-dating program for tree-ring research, Tree-Ring Bull, 33, 7–14

English Heritage, 1998 Dendrochronology: Guidelines on Producing and Interpreting Dendrochronological Dates, London

Hillam, J, Morgan, R A, and Tyers, I, 1987 Sapwood estimates and the dating of short ring sequences, Applications of tree-ring studies, BAR Int Ser, 3, 165–85

Howard, R E, Laxton, R R, Litton, C D, and Simpson, W G, 1984–95 Nottingham University Tree-Ring Dating Laboratory results, Vernacular Architect, 15–26

Howard, R E, Laxton, R R, Litton, C D, and Simpson, W G, 1992 List 44 no 17 - Nottingham University Tree-Ring Dating Laboratory: tree-ring dates for buildings in the East Midlands, Vernacular Architect, 23, 51–6

Hughes, M K, Milson, S J, and Legett, P A, 1981 Sapwood estimates in the interpretation of tree-ring dates, J Archaeol Sci, 8, 381–90

Laxon, R R, Litton, C D, and Zainodin, H J, 1988 An objective method for forming a master ring-width sequence, P A C T, 22, 25–35

Laxton, R R, and Litton, C D, 1988 An East Midlands Master Chronology and its use for dating vernacular buildings, University of Nottingham, Department of Archaeology Publication, Monograph Series III

Laxton, R R, and Litton, C D, 1989 Construction of a Kent master dendrochronological sequence for oak, AD 1158 to 1540, Medieval Archaeol, 33, 90–8

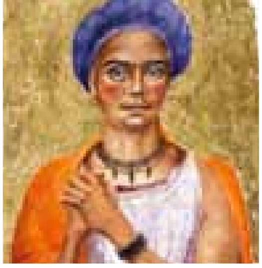
Laxton, R R, Litton, C D, and Howard, R E, 2001 Timber: Dendrochronology of Roof Timbers at Lincoln Cathedral, Engl Heritage Res Trans, 7

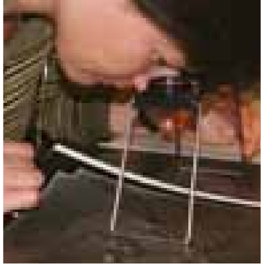
Litton, C D, and Zainodin, H J, 1991 Statistical models of dendrochronology, J Archaeol Sci¸18, 29–40

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

Pearson, S, 1995 The Medieval Houses of Kent, an Historical Analysis, London

Rackham, O, 1976 Trees and Woodland in the British Landscape, London


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

ENGLISH HERITAGE

ISSN 2046-9799 (Print)
ISSN 2046-9802 (Online)