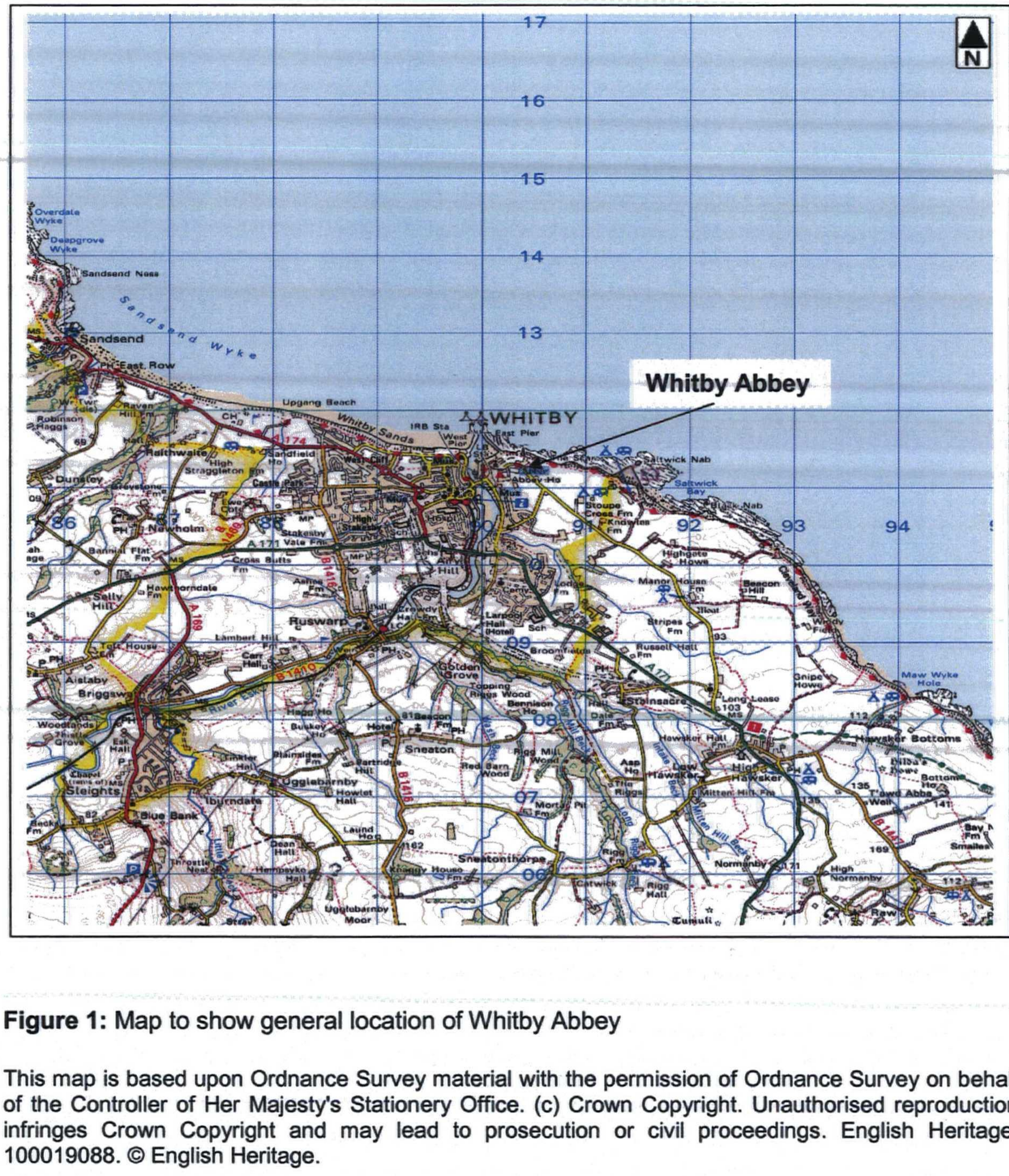


Figure 1: Map to show general location of Whitby Abbey

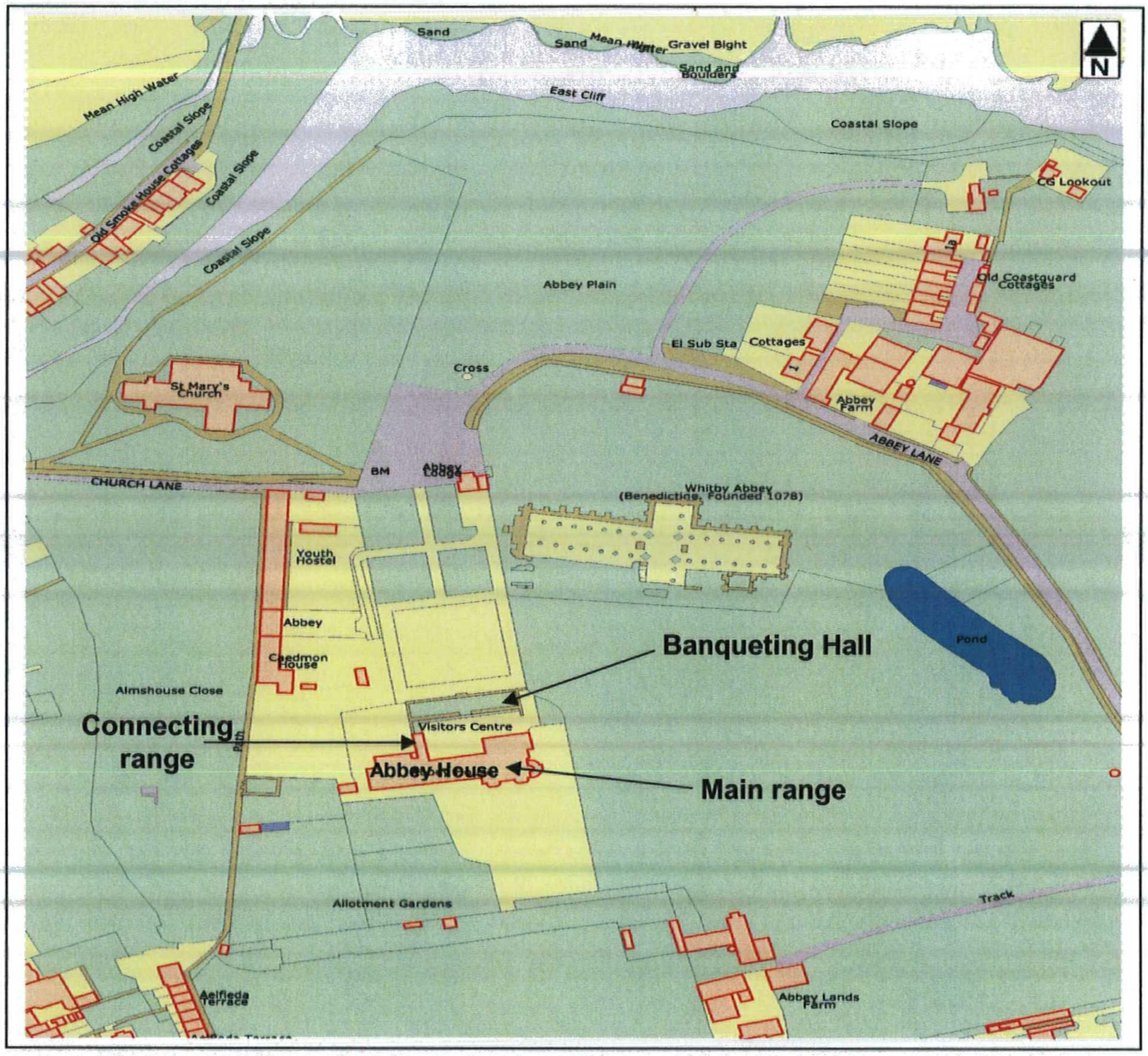


Figure 2: Map to show location of Abbey House within the Abbey precincts

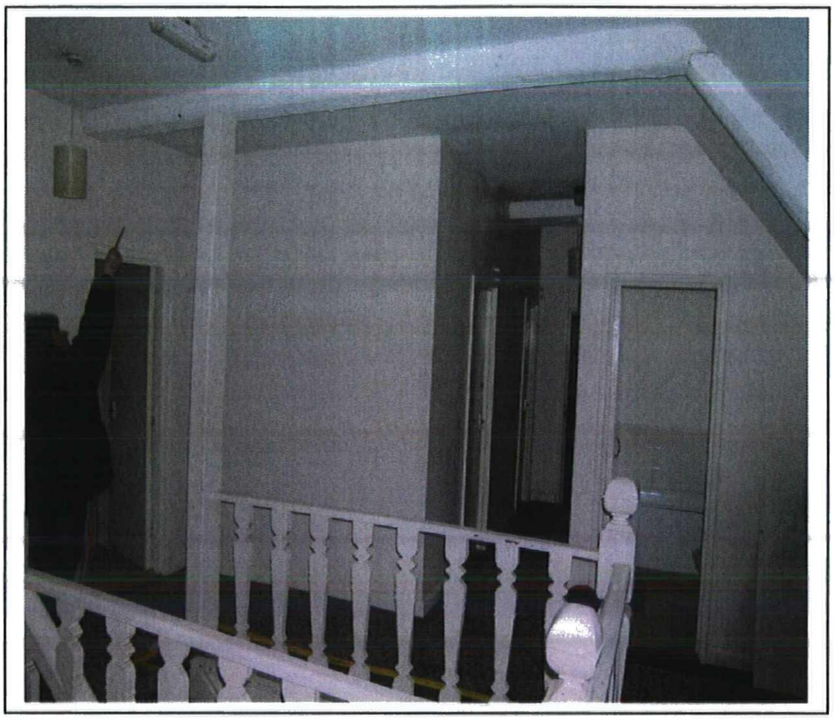


Figure 3a (top): View of a truss from the roof of the main range

Figure 3b (bottom): View of a truss from the roof of the connecting range

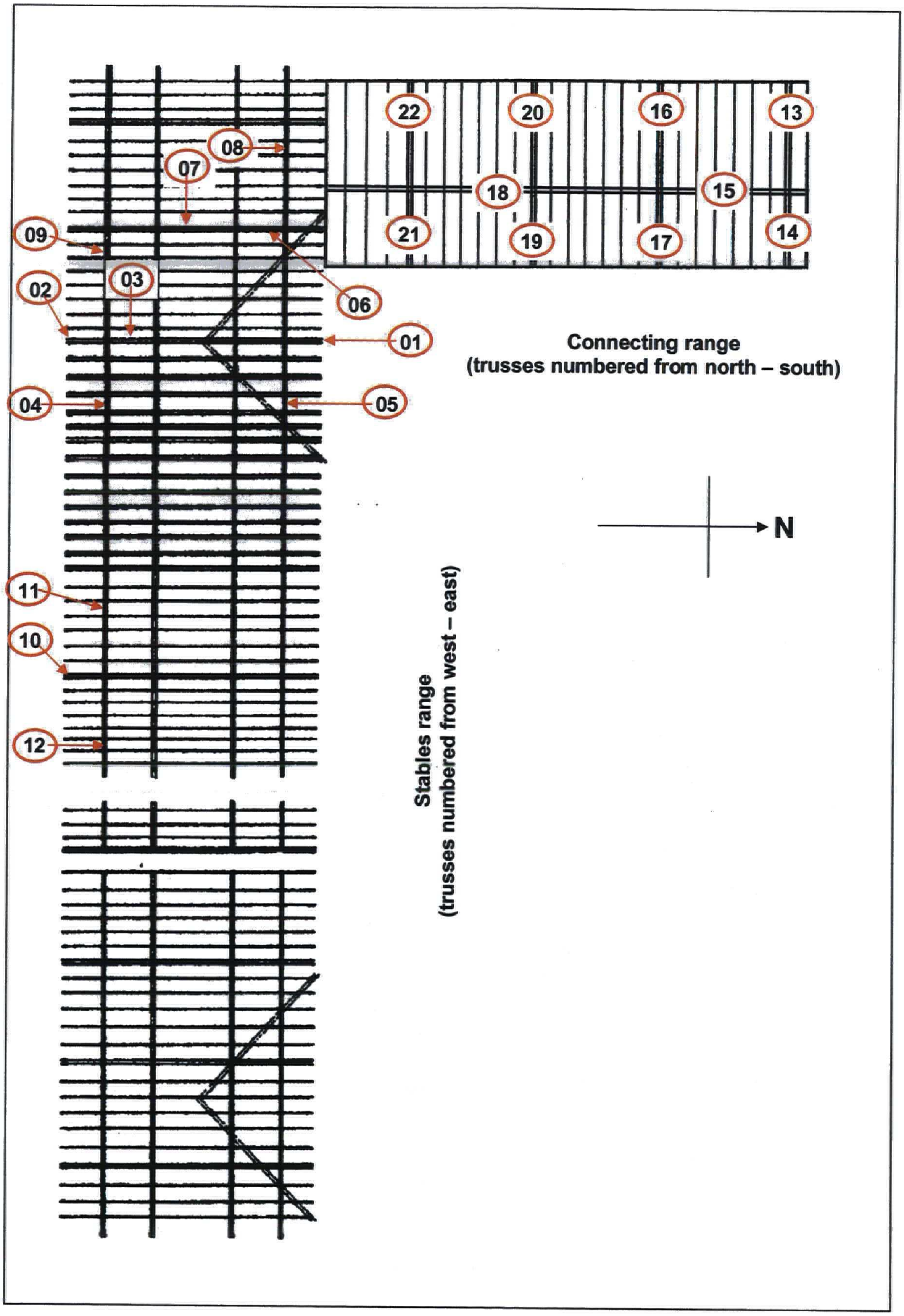
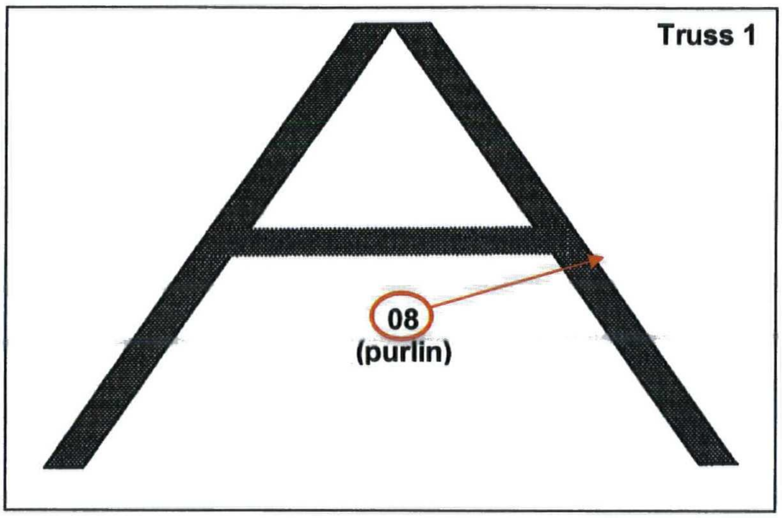
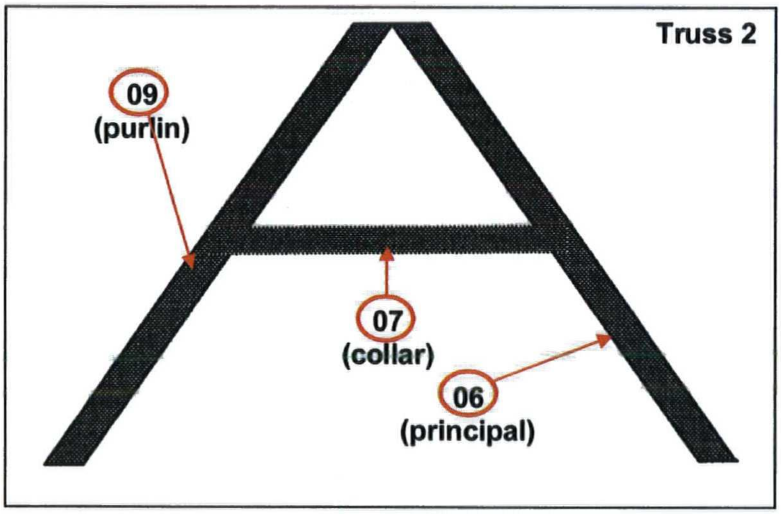


Figure 4a: Plan to show location of samples from the roofs of the main and connecting ranges





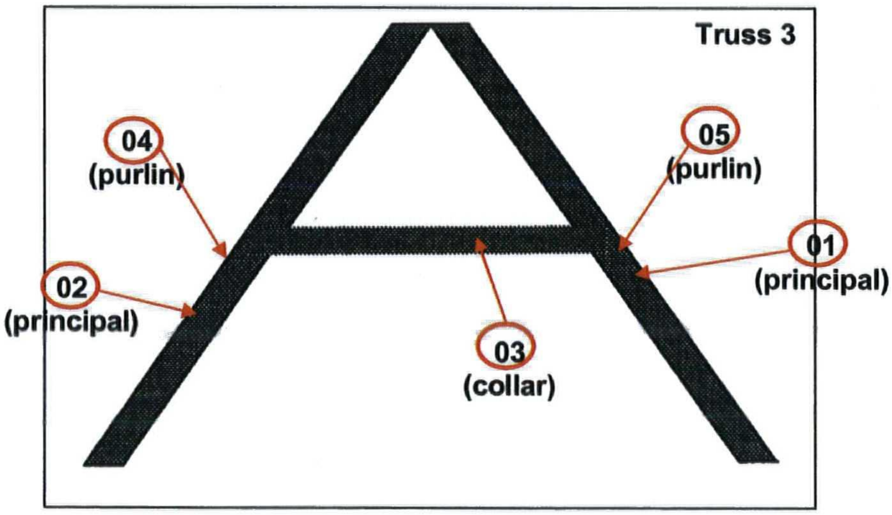
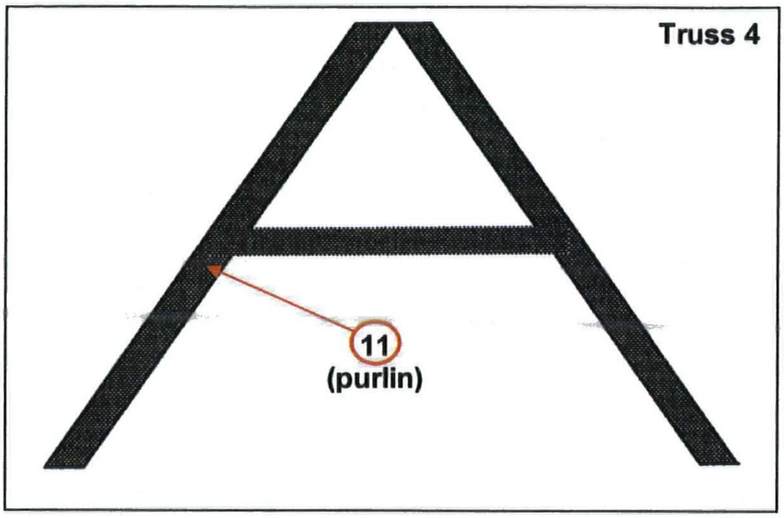
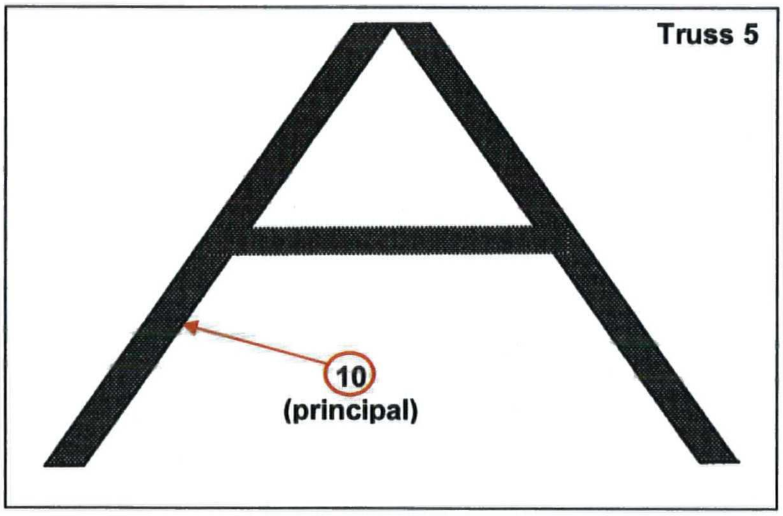


Figure 4bi: Main or stables range roof trusses to show sample locations (viewed from east looking west)





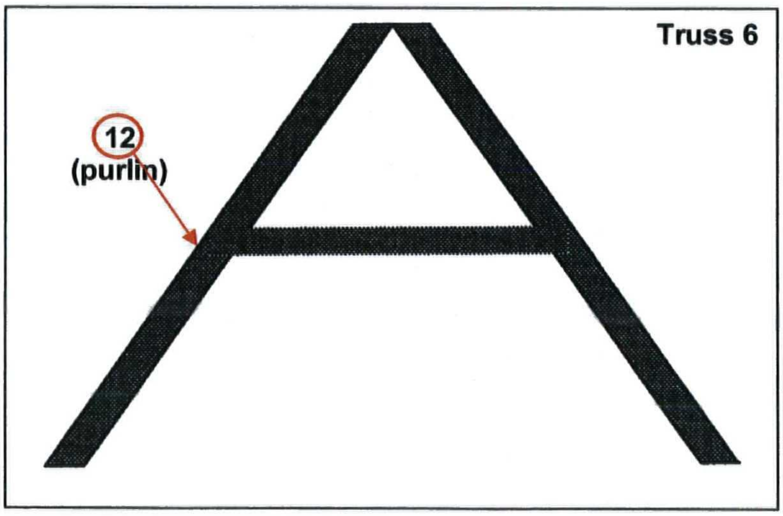


Figure 4bii: Main or stables range roof trusses to show sample locations (viewed from east looking west)

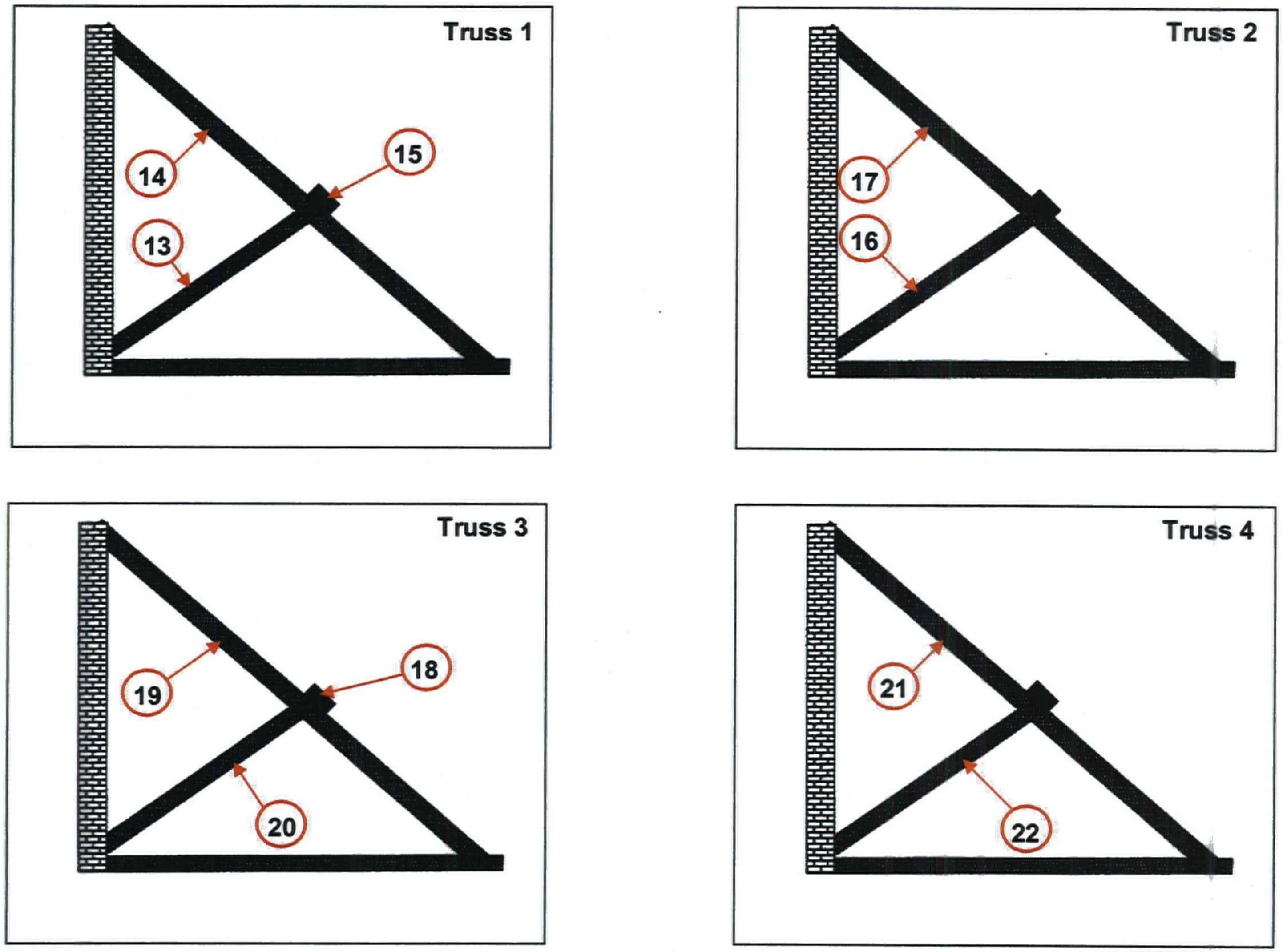


Figure 4c: Roof trusses of the connecting range showing sample positions (trusses viewed from the south looking north)

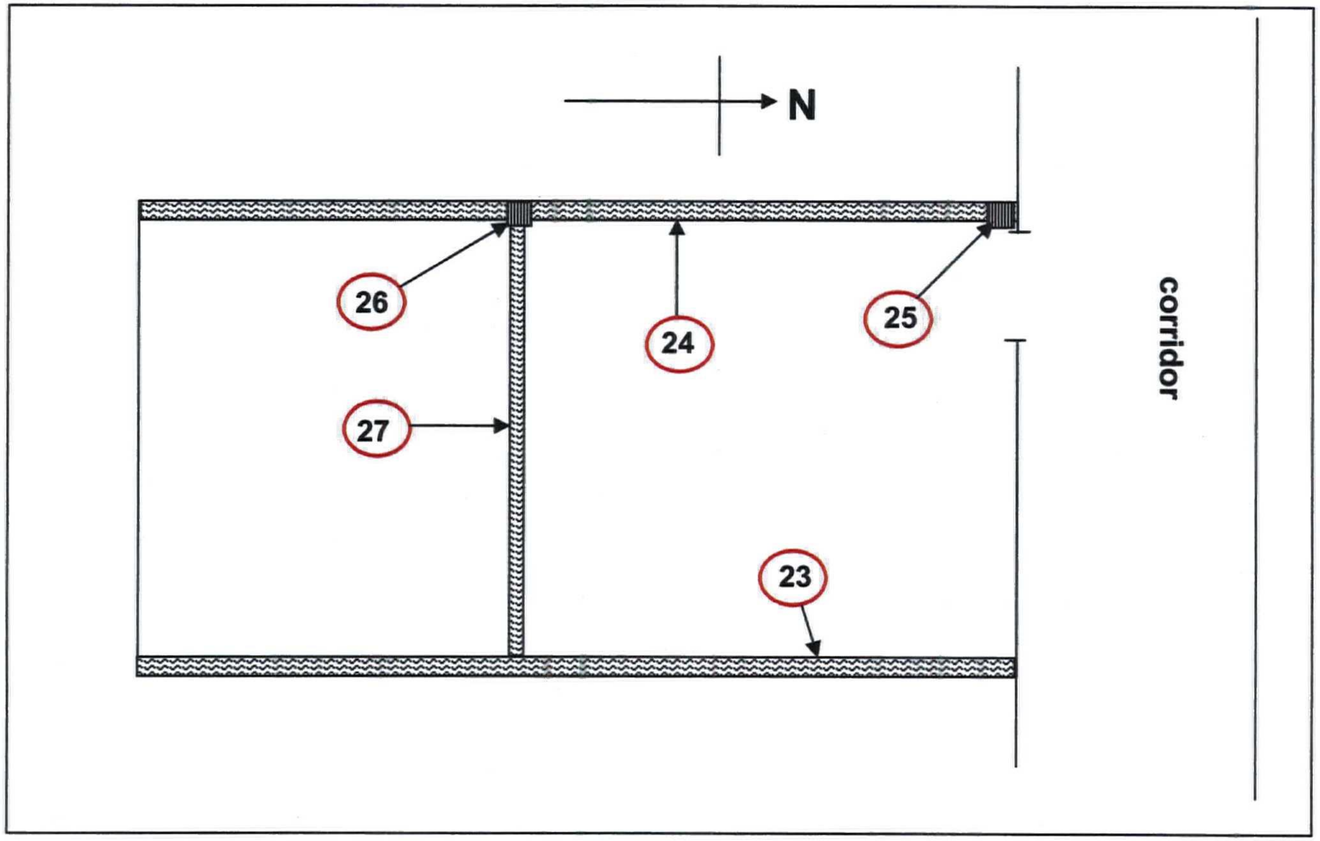


Figure 4d: Plan of the basement to show location of samples from the oak timbers

Figure 5: Bar diagram of the samples in site chronology WITBSQ01

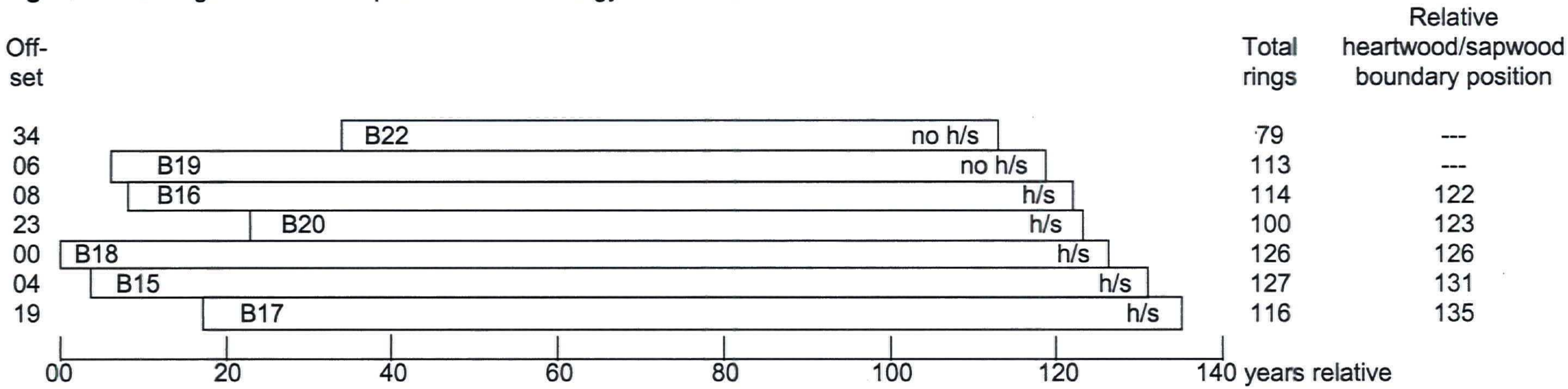
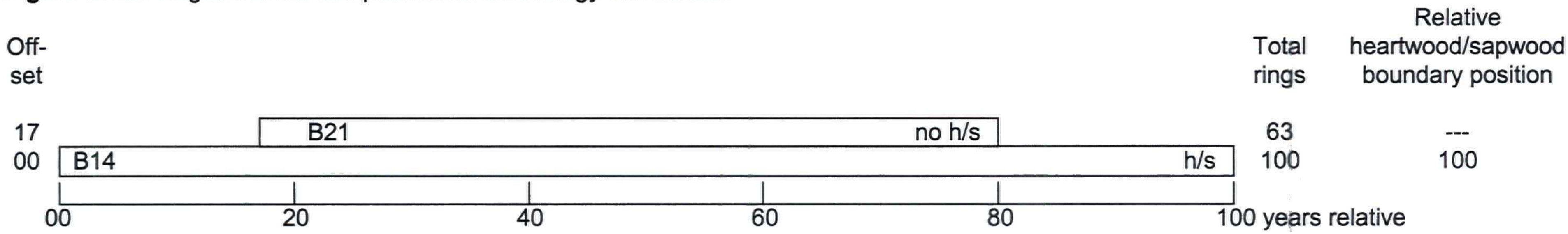


Figure 6: Bar diagram of the samples in site chronology WITBSQ02



white bars = heartwood rings
h/s = the heartwood/sapwood boundary is the last ring on the sample

Figure 7: Bar diagram of the samples in site chronology WITBSQ03

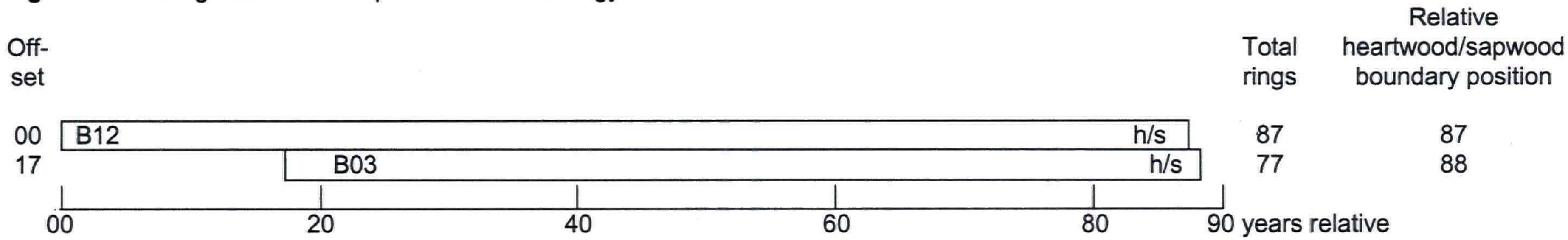
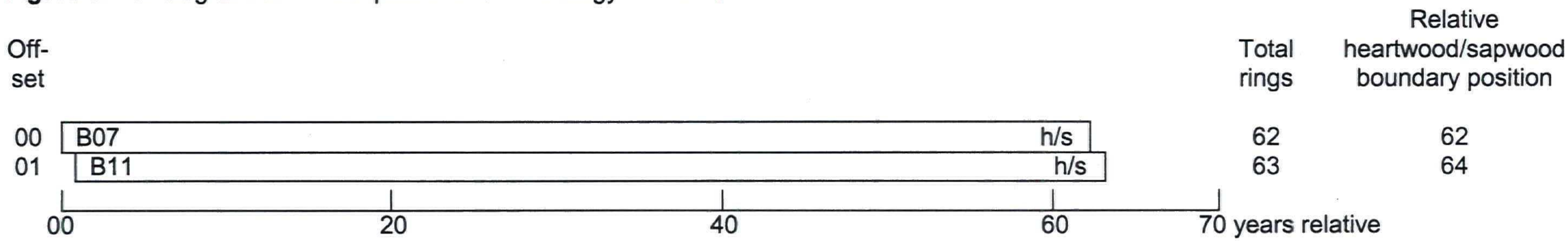


Figure 8: Bar diagram of the samples in site chronology WITBSQ04



white bars = heartwood rings
h/s = the heartwood/sapwood boundary is the last ring on the sample

Data of measured oak samples – measurements in 0.01 mm units

WIT-B23A 87
246 159 348 160 100 192 149 169 285 232 161 160 217 166 203 188 195 182 202 171
159 159 137 95 66 38 48 38 59 69 90 138 120 109 134 123 104 99 133 100
90 93 99 125 110 132 114 137 101 109 125 122 125 150 135 74 80 72 125 104
103 107 121 152 125 80 110 161 124 94 82 80 106 90 94 93 85 90 87 48
63 45 58 52 77 58 78
WIT-B23B 87
285 148 329 223 140 213 142 185 295 228 172 155 219 173 192 189 193 176 206 195
147 163 149 89 62 41 43 38 57 66 90 148 102 122 135 129 109 102 123 107
96 90 110 110 130 124 110 151 107 109 128 118 127 169 123 100 63 76 107 109
130 92 129 152 113 97 102 139 115 118 82 84 116 95 97 88 88 92 55 60
74 48 64 55 72 57 80
WIT-B24A 73
183 220 248 215 148 162 149 271 252 254 196 151 91 74 98 161 214 167 176 128
89 134 122 139 164 251 196 189 167 159 220 194 147 146 181 160 126 89 116 176
149 142 135 128 150 210 185 156 170 224 212 260 211 179 176 147 120 128 148 192
169 213 176 159 201 181 144 144 112 132 160 110 135
WIT-B24B 73
195 213 237 241 250 144 146 265 250 287 186 151 66 81 81 160 206 158 167 121
89 121 144 160 191 291 166 191 148 189 227 193 145 138 205 157 124 103 114 190
157 150 133 143 149 223 169 177 167 235 212 232 208 158 188 157 125 118 125 217
176 205 174 161 193 171 154 143 106 138 152 115 140
WIT-B25A 105
165 188 251 240 169 136 85 107 141 132 165 142 122 130 111 123 132 117 40 40
24 44 55 61 61 85 89 125 82 97 93 55 55 83 93 64 112 114 91 96
114 93 79 57 44 22 47 97 88 117 135 94 118 69 40 72 89 80 107 124
162 152 200 213 182 145 154 83 54 121 179 162 133 131 156 107 127 76 60 77
48 57 74 61 63 65 102 83 92 45 52 114 142 141 123 211 169 84 41 60
54 73 118 162 126
WIT-B25B 105
174 192 252 245 171 146 89 104 145 135 160 141 124 139 110 115 169 49 45 51
30 48 65 63 41 98 92 77 102 117 104 45 59 85 94 73 116 113 105 92
124 72 92 55 34 36 42 89 88 108 104 114 105 85 51 80 90 78 85 145
159 155 201 218 204 189 170 85 61 127 197 157 149 118 158 106 133 71 60 74
56 55 76 56 69 60 103 60 79 60 44 84 133 128 133 207 169 91 43 37
52 88 126 164 126
WIT-B26A 62
433 513 361 478 321 199 120 251 255 242 379 246 294 106 163 172 230 188 147 204
91 216 120 117 96 100 79 44 26 36 55 49 59 64 45 115 139 167 154 103
90 99 128 147 166 140 179 207 107 83 149 180 141 150 125 132 131 136 123 164
167 152
WIT-B26B 62
426 517 350 496 326 206 117 252 255 240 380 236 296 122 157 167 243 192 146 217
104 217 115 136 81 114 53 53 31 41 45 62 65 51 55 95 144 158 160 99
93 96 131 155 163 132 194 203 106 100 145 164 160 137 151 119 136 97 121 170
171 156

WIT-B27A 139
54 61 60 61 84 69 87 90 102 137 91 107 155 112 111 135 59 116 78 53
50 83 81 73 74 103 83 75 83 105 143 100 122 118 95 85 134 101 105 117
101 164 78 113 134 95 58 86 100 133 151 132 118 159 106 146 145 120 103 153
84 72 107 68 114 53 38 83 116 91 139 99 97 106 123 105 112 125 103 116
136 119 90 139 99 105 124 132 100 107 113 95 105 103 81 66 106 89 75 130
73 86 92 82 78 44 53 56 91 89 86 104 118 134 94 85 97 78 86 97
120 111 61 63 88 130 79 92 73 73 98 79 99 126 116 102 91 71 64
WIT-B27B 139
63 59 78 56 94 73 82 91 95 137 132 95 157 119 114 128 61 110 89 57
70 93 61 84 74 116 80 70 107 96 139 104 118 96 126 102 145 115 100 117
110 177 86 126 138 95 57 90 95 133 157 149 107 155 121 140 139 125 118 145
84 91 100 86 106 59 43 76 127 83 137 102 94 101 133 104 105 138 86 116
155 113 97 130 97 109 143 123 84 118 106 111 84 111 82 85 101 89 69 124
79 90 86 71 65 64 44 60 85 82 93 100 107 136 78 88 81 84 97 99
126 107 60 73 77 123 98 74 74 84 100 86 89 130 113 108 92 69 82

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 1988). 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 1 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 1, 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 2 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 to 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 2; it is about 15cm long and 1cm 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 1: 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 determined by counting back from the outside ring, which grew in 1976.

Figure 2: Cross-section of a rafter showing the presence of sapwood rings in the left hand corner, the arrow is pointing to the heartwood/sapwood boundary (H/S). Also a core with sapwood; again the arrow is pointing to the H/S. The core is about the size of a pencil.

Figure 3: Measuring ring widths under a microscope. The microscope is fixed while the sample is on a moving platform. The total sequence of widths is measure 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 4: 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.