

GREAT BIDLACE, BRIDESTOWE, DEVON TREE-RING ANALYSIS OF TIMBERS SCIENTIFIC DATING REPORT

Alison Arnold and Robert Howard



Research Department Report Series 13-2011

**GREAT BIDLAKE,
BRIDESTOWE,
DEVON**

TREE-RING ANALYSIS OF TIMBERS

Alison Arnold and Robert Howard

NGR: SX 4947 8865

© English Heritage

ISSN 1749-8775

The Research Department Report Series incorporates reports from all the specialist teams within the English Heritage Research Department: Archaeological Science; Archaeological Archives; Historic Interiors Research and Conservation; Archaeological Projects; Aerial Survey and Investigation; Archaeological Survey and Investigation; Architectural Investigation; Imaging, Graphics and Survey, and the Survey of London. It replaces the former Centre for Archaeology Reports Series, the Archaeological Investigation Report Series and the Architectural Investigation Report Series.

Many of these are interim reports which 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 are advised to consult the author before citing these reports in any publication. Opinions expressed in Research Department 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

Extensive sampling was undertaken in the main house, the stable, and the threshing barn at Great Bidlake. This resulted in the construction of several site sequences, only two of which were successfully dated.

The first, GBDASQ01, contains six oak samples from the ceilings of the sitting room and the breakfast room, and spans the period AD 1489–1599. Interpretation of the sapwood suggests felling of the breakfast room joists in AD 1574 and the sitting room joists in AD 1599.

The second dated site sequence contains eight samples from the stable roof and one from the stable floor and spans the period AD 1681–1772. Another sample from the stable floor was individually dated to the period AD 1632–1752. Interpretation of the sapwood suggests felling of all of these timbers in AD 1772.

A further four oak site sequences and four pine site sequences remain undated.

CONTRIBUTORS

Alison Arnold and Robert Howard

ACKNOWLEDGEMENTS

Thanks are given to all at English Heritage's Scientific Dating Section for their invaluable support and assistance. Cathy Tyers, Sheffield University Dendrochronology Laboratory, co-ordinated the attempts by colleagues from elsewhere in northern Europe and North America to date the pine chronologies. Figures 4 and 5 were provided by Andrew Wood Chartered Architect. Thanks are also given to Stuart Blaylock, then of Exeter Archaeology, for arranging initial access and also for his on-site advice. The Laboratory would also like to thank the contractors on site, Good Roofing, who were universally helpful and extremely pleasant to work with.

ARCHIVE LOCATION

Devon HER
Historic Environment Service
Matford Offices
County Hall
Exeter
EX2 4QW

DATE OF INVESTIGATION

2007–10

CONTACT DETAILS

Alison Arnold and Robert Howard
Nottingham Tree-ring Dating Laboratory
20 Hillcrest Grove
Sherwood
Nottingham NG5 1FT
0115 960 3833
alisonarnold@tree-ringdating.co.uk
roberthoward@tree-ringdating.co.uk

CONTENTS

Introduction	1
Main (or central) range	1
East range	1
West range.....	2
Threshing Barn	2
Stable	3
Aims and Objectives	3
Sampling	3
Analysis and Results	4
Oak	4
Pine	5
Interpretation	5
Discussion	6
Bibliography.....	8
Data of Measured Samples	65
Appendix: Tree-Ring Dating	83
The Principles of Tree-Ring Dating	83
The Practice of Tree-Ring Dating at the Nottingham Tree-Ring Dating Laboratory.....	83
1. Inspecting the Building and Sampling the Timbers.	83
2. Measuring Ring Widths.....	88
3. Cross-Matching and Dating the Samples.....	88
4. Estimating the Felling Date.....	89
5. Estimating the Date of Construction.	90
6. Master Chronological Sequences.	91
7. Ring-Width Indices.	91
References.....	95

INTRODUCTION

The grade II* listed manor house Great Bidlake, Bridestowe, Devon (Figs 1–3; SX 4947 8865) is thought to be of sixteenth-century date with some seventeenth-century alterations, although it may have had somewhat earlier origins. It was extensively restored and remodelled in the mid-nineteenth century but retains much of the original fabric. The site of Great Bidlake was acquired by Ralph de Combe in AD 1268 and after subsequent marriages to the Bidlake family, this became the family name. In AD 1792, on the death of a Henry Bidlake, the estate passed into the Woolacombe family.

The original plan of the house is unknown; however, the principal front of the extant building faces north-east (north for the purpose of this report) and is basically E-shaped with a nineteenth-century wing and tower adjoining to the west (Figs 4 and 5).

The following information is based on the listed building description (<http://lbonline.english-heritage.org.uk/>).

Main (or central) range

There are two main rooms on the ground floor in this part of the house, marked 'dining room' and 'sitting room' on the plan (Fig 4). The original passage and adjoining lower room (dining room) were converted to one large entrance hall and a staircase was added in the tower at the rear of the former passage. The 'sitting room' is thought most likely to have been the Hall. The ceiling structure of this room consists of eight plain joists, evenly spaced (Fig 6). The roof over this central range was replaced in the nineteenth century in softwood. This roof consists of six trusses, with principal rafters crossed and nailed at the apex, king post, ridge, and with a single set of trenched purlins to each slope (Fig 7).

East range

To the east of the central range is a cross-wing which extends to the rear. Again, this range is divided into two main rooms on the ground floor; to the front, or north, is the breakfast room and to the rear the present kitchen. The ceiling structure of the breakfast room consists of eight, plain, evenly spaced ceiling joists (Fig 8). The ceiling of the kitchen has a massive cross beam with a hollow chamfer and run-out stops, and similar common joists (Fig 9). Within the roof of this cross-wing survive three oak trusses, thought to be sixteenth century. Two of these (Trusses 1 and 2) have chamfered archbraced collars with morticed apex, and a diagonal ridge (Fig 10). The third truss is considerably higher than the other two and of different construction but is believed to be contemporary. This truss has slightly curved feet, threaded purlins, and a morticed cranked collar, and has a similar apex to the others (Fig 11). The function of this room is not clear but, judging from the quality of the roof construction, appears to have been some sort of 'great chamber'.

In the seventeenth century an adjoining unheated rear wing was added in the angle behind the hall. The house does not then appear to have been significantly altered until the mid-nineteenth century at which time the lower end was heavily remodelled, with a long cross-wing, the west range, extending at the rear.

West range

At the west (or higher) end of the house a parallel cross wing was added in the mid-nineteenth century for service purposes; adjoined at the south of this cross-wing is a three-storey tower. The exterior of the house was also remodelled at this time.

The roof above this cross-wing is constructed in softwood with three different truss forms. Trusses 1 and 2 have principal rafters crossed at the apex and a plain king post (Fig 12). Truss 3 is similar except the king post has been cut off and it is constructed of reused timbers (Fig 13). Trusses 4–7 have principal rafters morticed into a jowled king post (Fig 14). All trusses have a collar, ridge, and two sets of trenched purlins.

During the ownership of Thomas Bidlake (who died in AD 1531), a description of the house mentions ‘the great parlour with its large chimneyplace, the Entry and Porch, and a room or 2 beyond that, and those with chambers over them, were already built and fully furnished’. Not only does this give us some indication of the form of the house at this time, it also demonstrates its importance, that at such an early date it had chimneys and a first floor. In the front wall of the house there is a reused mullion head with the date AD 1594 and the initials A.B. A first-floor window in the right-hand wing is inscribed with the initials I.B.W. and dated AD 1848; a reference to the Woolcombe family.

Threshing Barn

To the east-south-east of the house is a bank barn, with stone rubble walls with granite dressings, and a hipped slate roof (Fig 15). It is rectangular in plan with a row of sheds on the ground floor and two threshing floors above. It has two large doorways on the first floor located to the left and right of centre with elliptical stone arches. Alternating with these doorways are three circular pitching holes, the central one of which incorporates a date-stone of AD 1824. There were originally seven doorways on the ground floor with elliptical stone arches; four of these have since been converted to windows. The roof of the barn is constructed of softwood. It has 11 trusses, each one consisting of principal rafters, king post, struts running between king post and principal rafter, and tiebeam. There is a ridge and two sets of purlins to each slope (Fig 16).

Stable

To the north-east of the house is a two-storey outbuilding with stone rubble walls and a half-hipped slate roof (Fig 17). Rectangular in plan, it is now a single room but is thought likely to have originally been divided into stalls. The oak roof is of four trusses with each truss consisting of principal rafters and collars. There are three sets of purlins to each slope (Fig 18). The ground-floor ceiling frame has three main joists aligned east-west, with common joists between (Fig 19). The building is thought to date to the late-eighteenth century.

AIMS AND OBJECTIVES

Sampling and analysis by tree-ring dating was commissioned and funded by English Heritage. Francis Kelly of the South-West Regional Office requested the work to inform statutory advice in the context of programme of repairs. The east range roof appears to be the earliest surviving part of the complex, and it was hoped providing a construction date would confirm its early date. It would also show whether all three trusses were contemporary as thought, despite their difference in construction. Successful dating of the ceiling beams would demonstrate the date of these floors, whether they were secondary features, and their relationship to each other. The softwood roofs over the central range and the west range are known to have been constructed in the nineteenth century. However, it was hoped to confirm and potentially refine these dates whilst at the same time providing valuable data for English Heritage's on-going project into the dating of imported conifer timbers (Groves 2000), this being later material than has previously been analysed. Similar aims were the behind sampling of the threshing barn. The stable is of oak and thought to be late, therefore, by sampling this structure not only would we hopefully be able to provide a construction date for it but additionally gain important late data from the south west.

SAMPLING

A total of 119 core samples was taken from timbers of the house, the threshing barn, and the stable. Each sample was given the code GBD-A (for Great Bidlake) and numbered 01–119. Oak samples were taken from the breakfast room ceiling (GBD-A01–06), the kitchen ceiling (GBD-A07–18), from the sitting room ceiling (GBD-A19–25), the roof over the East range (GBD-A26–37), the roof over the West range (GBD-A62–4), and the roof and floor of the Stable (GBD-A101–119).

Pine samples were taken from the Central range roof (GBD-A38–55), the roof over the West range (GBD-A56–61 and GBD-A65–79), and from the roof and floor (GBD-A80–100) of the threshing barn. The positions of samples were noted at the time of sampling and have been marked on Figures 20–57. Further details relating to the samples can be found in Table I. Roof trusses and ceiling joists have been numbered from north to

south (East range, West range, threshing barn, breakfast room, kitchen, and dining room) or from east to west (Central range and stable).

ANALYSIS AND RESULTS

At this stage it was noticed that 16 of the oak samples and 10 of the pine samples had too few rings to make secure dating a possibility, and these samples were rejected prior to measurement. The remaining 93 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. The samples were then separated into oak or pine.

Oak

The remaining 43 oak samples were compared with each other by the Litton/Zainodin grouping procedure (see Appendix), resulting in 27 samples forming six groups.

Six samples matched and were combined at the relevant offset position to form GBDASQ01, a site sequence of 111 rings (Fig 58). This site sequence was then compared with a large number of relevant reference chronologies for oak where it was found to match at a first-ring date of AD 1489 and a last-ring date of AD 1599. The evidence for this dating is given by the *t*-values in Table 2.

Nine samples matched and were combined at the relevant offset position to form GBDASQ02, a site sequence of 92 rings (Fig 59). This site sequence was compared against the reference chronologies for oak where it was found to have a consistent match at a first-ring date of AD 1681 and a last-measured ring date of AD 1772. The evidence for this dating is given by the *t*-values in Table 3.

Two samples grouped and were combined to form GBDASQ03, a site sequence of 61 rings (Fig 60), six samples matched and were combined to form GBDASQ04, a site sequence of 174 rings (Fig 61), two further samples were combined to form GBDASQ05, a site sequence of 114 rings (Fig 62), and finally two samples grouped to form GBDASQ06, a site sequence of 57 rings (Fig 63). Attempts to date these four site sequences by comparing them against the relevant reference chronologies were unsuccessful and all remain undated.

Attempts were then made to date the remaining 16 ungrouped samples by individually comparing them against the reference material. This resulted in sample GBD-A116 being matched at a first-ring date of AD 1632 and a last-measured ring date of AD 1752. The evidence for this dating is given by the *t*-values in Table 4. The other oak samples could not be matched and remain undated.

Pine

The remaining 50 pine samples were compared with each other by the Litton/Zainodin grouping procedure, resulting in 43 samples forming four groups.

Firstly, 12 samples matched and were combined at the relevant offset positions to form GBDASQ07 (Fig 64), a site sequence of 130 rings. Secondly, five samples matched and combined to form GBDASQ08 (Fig 65), a site sequence of 126 rings. Eight samples grouped and were combined to form GBDASQ09 (Fig 66), a site sequence of 110 rings. Finally, 18 samples matched and were combined to form GBDASQ10 (Fig 67), a site sequence of 298 rings. Attempts to date these four site sequences and the remaining ungrouped pine samples by comparing them against a series of relevant reference chronologies from Europe and North America were unsuccessful and all samples remain undated.

INTERPRETATION

Analysis of 93 samples taken from timbers of the house, the threshing barn, and the stable has resulted in the construction of ten site sequences, only two of which have been dated.

The first, site sequence GBDASQ01, contains six samples, taken from the timbers of the ceilings of the Breakfast and Sitting rooms, and spans the period AD 1489–1599. Five of these samples have complete sapwood. Two of these samples, GBD-A01 and GBD-A05, both from the ceiling of the Breakfast Room, have the last-measured ring date of AD 1574, the felling date of the two timbers represented. The other three, all from the ceiling of the Sitting Room, have the last-measured ring date of AD 1599, again the felling date of the three timbers represented. The sixth sample, GBD-A20, again from the ceiling of the Sitting Room, does not have the heartwood/sapwood boundary ring and so a felling date cannot be given for it. However, its heartwood/sapwood boundary ring date is broadly contemporary with the other three dated samples from this ceiling, making it quite likely that this sample is also from a timber felled in AD 1599.

The second dated site sequence, GBDASQ02, contains nine samples from the stable, and spans the period AD 1681–1772. A tenth sample from the stable (GBD-A116) has been dated individually to the period AD 1632–1752. Five of these dated samples have complete sapwood and the last-measured ring date of AD 1772, the felling date of the five timbers represented. The remaining five dated samples from the stable have broadly contemporary heartwood/sapwood boundary ring dates which make it likely that they represent a single felling. The average heartwood/sapwood boundary ring date of these five samples is AD 1750 which allows an estimated felling date range to be calculated for the five timbers represented of AD 1769–90 (allowing for sample GBD-A104 having a last-measured ring date of AD 1768 with incomplete sapwood). This felling date range is

consistent with these five timbers from the roof and ceiling also having been felled in AD 1772.

Although the other site sequences are undated, it is possible, by looking at the relative heartwood/sapwood boundary ring position on the samples represented (where it exists) to comment on whether they suggest a single felling or not. Three of the samples in site sequence GBDASQ04 (Fig 61), have similar heartwood/sapwood boundary ring positions (with the other three not having this ring) suggesting they relate to a single felling, furthermore demonstrating contemporary construction for trusses 1 and 2 (Fig 61) of the East Range roof. It is unfortunate, that of the only two timbers considered potentially suitable for analysis from truss 3 of this roof, that only one was suitable for measurement and this sample did not match with those of the other two trusses. This might have allowed us to say whether this truss was contemporary with the other two trusses or if not, its relative date compared to them. It may be significant when considering whether all three trusses are contemporary, that the timbers of truss 3 had much fewer growth rings than those of trusses 1 and 2, although whether this is due to the timbers being from differing sources and/or dates, or whether this is due to other non-climatic conditions is not known.

Also undated is the pine site sequence of samples from the threshing barn roof and floor (GBDASQ10). Although the sapwood element of softwoods can vary to a far greater degree than with oak timbers, the relative heartwood/sapwood boundary ring positions of these samples in GBDASQ10 (Fig 67) are remarkably consistent and it does appear likely that the timbers utilised for the floor and roof are generally contemporary, probably representing a single phase of construction.

Site sequence GBDASQ07 contains samples from both the Central and West Range roofs. Again, on the evidence of the relative heartwood/sapwood boundary ring positions of those samples represented, it is possible to say that it is likely that both these roofs utilised timber felled at a similar time, suggesting contemporary construction (Fig 68).

DISCUSSION

Prior to tree-ring analysis being undertaken at Great Bidlake, the Central and East ranges were thought to be the earliest surviving parts of the building, dating to the sixteenth century. Although the roof over the Central range had been replaced in the nineteenth century; that over the East range was believed to be a survival of the sixteenth century. This East range roof contains three oak trusses, the two at the front of the range (Trusses 1 and 2) at one height and the third, located towards the rear of the range (Truss 3) at a different height, although it is possible that all three are contemporary. The West range roof is also believed to be a nineteenth-century structure. A description of the house during the ownership of Thomas Bidlake (who died AD 1531) shows that it had a first floor, in parts at least, by this period. The threshing barn incorporates a datestone of AD

1824, with the roof and floor frame being contemporary. Equally, the stable roof and floor were believed to date to late-eighteenth century.

Timbers from two ceilings, the sitting room in the Central range and the breakfast room in the East range have been successfully dated. Two timbers from the breakfast room ceiling have been dated to AD 1574 and three from the sitting room ceiling to AD 1599 (a fourth is likely to also have this felling date). This suggests that both these ceilings date to the second half of the sixteenth century, with the ceiling of the breakfast room being constructed some 25 years earlier than that of the sitting room. If this is the case and these two ceilings date to the latter part of the sixteenth century, then they cannot be those referred to in the description of pre- AD 1531. However, it may be that these ceilings were replacements for earlier ones. Alternatively, the 'chambers above' may refer to the rear of the cross-wing, now the kitchen on the ground floor and a bedroom on the first floor. It is unfortunate that no timbers from the ceiling in this part of the cross-wing could be dated.

Several of the roof timbers and two of the floor beams of the stable have been dated to a felling of AD 1772, with it likely that construction occurred in or soon after. This supports the late eighteenth-century date assigned to the structure and also confirms that the roof and floor are indeed contemporary.

None of the three sampled roofs of the house have been dated. This is perhaps understandable in the case of the Central and West range roofs, which are nineteenth-century pine structures, as very little research has as yet been undertaken on the dating of such late pine timbers. However, the oak roof over the East Range is also undated, despite six samples from trusses 1 and 2 of this roof grouping to form a site sequence. This site sequence is relatively well replicated and of a significant length which might usually be expected to have a good chance of successful dating. The fact that it is undated may be to do with the paucity of reference material from the south-west with which to cross-match it against. This situation is improving, helped to a large degree by an English Heritage and Devon County Council joint funded project in Devon (Groves 2005) and it is hoped that in the future, site sequences such as GBDASQ04, will be dated.

Dendrochronological dating of pine timbers in this country is still in its infancy and the fact that at Great Bidlake we have been unable to provide any dates for these timbers, despite the production of four well replicated and reasonably long site sequences, is disappointing but perhaps not unexpected given the lack of work undertaken on this type and date of material. Whether this is due to a lack of suitable reference chronologies against which to cross-match these site sequences or to irregularities in the growth patterns of the samples themselves is not known.

BIBLIOGRAPHY

- Arnold, A J, Howard, R E, and Litton, C D, 2003 *Tree-ring analysis of timbers from the roofs of the Lady Chapel north and south aisle, and the Choir south aisle, Worcester Cathedral*, Worcester, Centre for Archaeol Rep, **96/2003**
- Arnold, A J, Howard, R E, and Litton, C D, 2004a *Tree-ring analysis of timbers from Kibworth Harcourt Post Mill, Kibworth Harcourt, Leicestershire*, Centre for Archaeol Rep, **76/2004**
- Arnold, A J, Howard, R E, and Litton, C D, 2004b *Tree-ring analysis of samples from the roof of the 'Red Wing' Croome Court, Croome D'Abitot, near Upton upon Severn, Gloucestershire*, Centre for Archaeol Rep, **80/2004**
- Arnold, A J, Howard, R E, and Litton, C D, 2005 Tree-Ring Analysis of Timbers from Poltimore House, Poltimore, Devon, Centre for Archaeol Rep, **37/2005**
- Arnold, A, Howard, R, and Litton, C, 2006 *Exeter Cathedral, Exeter, Devon, Tree-ring analysis of timbers from the roof of the Chapel of St John The Baptists*, Res Dep Rep Ser, **62/2006**
- Arnold, A J and Howard, R E, 2007a *Tree-ring analysis of timbers from Treludick House, Egloskerry, Cornwall*, EH Res Dep Rep Ser, **63/2007**
- Arnold, A J and Howard, R E, 2007b *Tree-ring analysis of timbers from Trerithick House, Polyphant, Cornwall*, EH Res Dep Rep Ser, **94/2007**
- Arnold, A J and Howard, R E, 2007c *Leicester's Gatehouse, Kenilworth Castle, Kenilworth, Warwickshire; Tree-ring analysis of timbers*, Centre for Archaeol Rep, **8/2007**
- Bridge, M, 2005 *Tree-Ring Analysis of Timbers from Wolfeton Riding House, Charminster, Dorset*, Centre for Archaeol Rep, **55/2005**
- Groves, C, 2000 Belarus to Bexley and beyond: dendrochronology and dendroprovenancing of conifer timbers, *Vernacular Architect*, **31**, 59–66
- Groves, C, 2005 *Dendrochronological research in Devon: Phase I*, Centre for Archaeol Rep, **56/2005**
- Groves, C, 2006 *Leigh Barton, Churchstow, Devon: Scientific Dating Report - Tree-Ring Analysis of Timbers*, EH Res Dept Rep Ser, **10/2006**
- Howard, R E, Laxton, R R, and Litton, C D, 1999 *Tree-ring analysis of timbers from Bretby Hall, Bretby, Derbyshire*, Anc Mon Lab Rep, **43/99**

Howard, R E, Laxton, R R, and Litton, C D, 2000 *Tree-ring analysis of timbers from the buildings and living trees at Stoneleigh Abbey, Stoneleigh, Warwickshire*, Anc Mon Lab Rep, 80/2000

Howard, R, Litton, C, Arnold, A, Tyers, C, 2006 *Tree-ring analysis of timbers from Warleigh House, Tamerton Foliot, Bickleigh, South Hams, near Plymouth, Devon*, Res Dep Rep Ser, 38/2006

Miles, D W H, 2001 *The Tree-Ring Dating of the Skeleton Barn, Oakhouse Farm, Hampstead Norreys, Berkshire*, Centre for Archaeol Rep, 16/2001

Miles, D W H, 2002 *The Tree-Ring Dating of 8 Market Place, Shepton Mallet, Somerset*, Centre for Archaeol Rep, 4/2002

Miles, D H, and Bridge, M C, 2005 Tree-ring dates for Oxfordshire 1: List 168, *Vernacular Architect*, 36, 98–9

Miles, D, Haddon-Reece, D, and Roberts, E, 1996 Tree-ring dates for Hampshire 2: List 72, *Vernacular Architect*, 27, 97–102

Miles, D H, Worthington, M J, and Bridge, M C, 2004 Tree-ring dates for Somerset 6: List 156, *Vernacular Architect*, 35, 108–9

Tyers, I, 2001 *Tree-ring analysis of further buildings from the Clarendon Estate, Wiltshire*, ARCUS Rep, 429b

Table 1: Details of tree-ring samples from Great Bidlake, Bridestowe, Devon

Sample number	Sample location	Total rings*	Sapwood rings**	First measured ring date (AD)	Last heartwood ring date (AD)	Last measured ring date (AD)
<u>House: Oak timbers</u>						
East Range - breakfast room ceiling						
GBD-A01	Joist 2	42	15C	1533	1559	1574
GBD-A02	Joist 3	NM	--	---	---	---
GBD-A03	Joist 4	54	25C	---	---	---
GBD-A04	Joist 5	48	38C	---	---	---
GBD-A05	Joist 6	44	16C	1531	1558	1574
GBD-A06	Joist 7	63	13C	---	---	---
East Range - kitchen ceiling						
GBD-A07	North east-west beam	53	h/s	---	---	---
GBD-A08	Mid east-west beam	71	09	---	---	---
GBD-A09	West girding beam	55	h/s	---	---	---
GBD-A10	North joist 4	NM	--	---	---	---
GBD-A11	North joist 7	61	h/s	---	---	---
GBD-A12	North joist 14	NM	--	---	---	---
GBD-A13	South joist 7	56	h/s	---	---	---
GBD-A14	South joist 8	51	h/s	---	---	---
GBD-A15	South joist 9	NM	--	---	---	---
GBD-A16	South joist 10	53	h/s	---	---	---
GBD-A17	South joist 12	54	--	---	---	---
GBD-A18	South joist 14	NM	--	---	---	---
Central Range - sitting room ceiling						
GBD-A19	Joist 1	69	16	---	---	---
GBD-A20	Joist 2	78	18	1520	1579	1597
GBD-A21	Joist 3	NM	--	---	---	---
GBD-A22	Joist 4	89	23C	1511	1576	1599
GBD-A23	Joist 5	97	12C	1503	1587	1599
GBD-A24	Joist 6	111	48C	1489	1551	1599
GBD-A25	Joist 7	61	16C	---	---	---

East Range – roof

GBD-A26	East principal rafter, Truss 1	110	h/s	---	---	---
GBD-A27	West principal rafter, Truss 1	76	--	---	---	---
GBD-A28	East archbrace, Truss 1	69	--	---	---	---
GBD-A29	West archbrace, Truss 1	114	--	---	---	---
GBD-A30	East principal rafter, Truss 2	112	02	---	---	---
GBD-A31	West principal rafter, Truss 2	106	h/s	---	---	---
GBD-A32	East archbrace, Truss 2	101	--	---	---	---
GBD-A33	West archbrace, Truss 2	93	--	---	---	---
GBD-A34	West principal rafter, Truss 3	NM	--	---	---	---
GBD-A35	Collar, Truss 3	49	--	---	---	---
GBD-A36	East purlin, Truss 1-2	174	h/s	---	---	---
GBD-A37	West purlin, Truss 1-2	51	--	---	---	---

House: Pine timbers (except where noted)

Central Range – roof

GBD-A38	South principal rafter, Truss 1	69	35	---	---	---
GBD-A39	Collar, Truss 1	66	02	---	---	---
GBD-A40	North principal rafter, Truss 2	87	56	---	---	---
GBD-A41	South principal rafter, Truss 2	66	38	---	---	---
GBD-A42	Collar, Truss 2	105	68	---	---	---
GBD-A43	North principal rafter, Truss 3	63	42	---	---	---
GBD-A44	Collar, Truss 3	73	40	---	---	---
GBD-A45	North principal rafter, Truss 4	NM	--	---	---	---
GBD-A46	South principal rafter, Truss 4	NM	--	---	---	---
GBD-A47	Collar, Truss 4	NM	--	---	---	---
GBD-A48	North principal rafter, Truss 5	99	72	---	---	---
GBD-A49	South principal rafter, Truss 5	74	58	---	---	---
GBD-A50	Collar, Truss 5	80	56	---	---	---
GBD-A51	North principal rafter, Truss 6	62	16	---	---	---
GBD-A52	South principal rafter, Truss 6	NM	--	---	---	---
GBD-A53	Collar, Truss 6	NM	--	---	---	---
GBD-A54	South upper purlin, Truss 2-3	86	07	---	---	---

GBD-A55	North lower purlin, Truss 5-6	63	--	---	---	---	---
West Range – roof							
GBD-A56	East principal rafter, Truss 1	64	--	---	---	---	---
GBD-A57	West principal rafter, Truss 1	73	--	---	---	---	---
GBD-A58	Collar, Truss 1	65	10	---	---	---	---
GBD-A59	East principal rafter, Truss 2	111	40	---	---	---	---
GBD-A60	West principal rafter, Truss 2	100	25	---	---	---	---
GBD-A61	Collar, Truss 2	98	48	---	---	---	---
GBD-A62	East principal rafter, Truss 3 (reused oak)	NM	--	---	---	---	---
GBD-A63	West principal rafter, Truss 3 (reused oak)	NM	--	---	---	---	---
GBD-A64	Collar, Truss 3 (reused oak)	NM	--	---	---	---	---
GBD-A65	East principal rafter, Truss 4	66	01	---	---	---	---
GBD-A66	West principal rafter, Truss 4	NM	--	---	---	---	---
GBD-A67	Collar, Truss 4	NM	--	---	---	---	---
GBD-A68	East principal rafter, Truss 5	67	02	---	---	---	---
GBD-A69	West principal rafter, Truss 5	58	03	---	---	---	---
GBD-A70	King post, Truss 5	91	64	---	---	---	---
GBD-A71	Collar, Truss 5	NM	--	---	---	---	---
GBD-A72	East principal rafter, Truss 6	NM	--	---	---	---	---
GBD-A73	West principal rafter, Truss 6	60	--	---	---	---	---
GBD-A74	Collar, Truss 6	54	15	---	---	---	---
GBD-A75	East principal rafter, Truss 7	NM	--	---	---	---	---
GBD-A76	West principal rafter, Truss 7	56	21	---	---	---	---
GBD-A77	East upper purlin, Truss 2-3	62	--	---	---	---	---
GBD-A78	East upper purlin, Truss 4-5	92	33C	---	---	---	---
GBD-A79	East upper purlin, truss 6-7	71	19	---	---	---	---
<u>Threshing Barn: Pine timbers</u>							
Floor							
GBD-A80	Joist 2	205	51	---	---	---	---
GBD-A81	Joist 3	132	37	---	---	---	---
GBD-A82	Joist 4	207	47	---	---	---	---
GBD-A83	Joist 5	89	--	---	---	---	---

GBD-A84	Joist 6	209	117C	---	---	---
GBD-A85	Joist 7	100	27	---	---	---
GBD-A86	Joist 8	175	48	---	---	---
GBD-A87	Joist 9	175	08	---	---	---
GBD-A88	Joist 10	223	38	---	---	---
GBD-A89	Joist 11	131	12	---	---	---
Roof						
GBD-A90	East principal rafter, Truss 1	175	19	---	---	---
GBD-A91	East principal rafter, Truss 2	185	18	---	---	---
GBD-A92	East principal rafter, Truss 3	229	49	---	---	---
GBD-A93	East principal rafter, Truss 4	189	--	---	---	---
GBD-A94	West principal rafter, Truss 4	131	--	---	---	---
GBD-A95	West principal rafter, Truss 5	202	32	---	---	---
GBD-A96	Tiebeam, Truss 5	150	33	---	---	---
GBD-A97	East principal rafter, Truss 6	144	04	---	---	---
GBD-A98	West principal rafter, Truss 6	180	03	---	---	---
GBD-A99	East principal rafter, Truss 7	147	06	---	---	---
GBD-A100	West principal rafter, Truss 10	140	27	---	---	---
<u>Stable Barn: Oak timbers</u>						
Roof						
GBD-A101	North principal rafter, Truss 1	87	26	1681	1741	1767
GBD-A102	South principal rafter, Truss 1	85	31C	1688	1741	1772
GBD-A103	Collar, Truss 1	77	25C	1696	1747	1772
GBD-A104	North principal rafter, Truss 2	54	11	1715	1757	1768
GBD-A105	South principal rafter, Truss 2	53	17C	1720	1755	1772
GBD-A106	Collar, Truss 2	83	22C	1690	1750	1772
GBD-A107	North principal rafter, Truss 3	52	21C	1721	1751	1772
GBD-A108	South principal rafter, Truss 3	55	11	1706	1749	1760
GBD-A109	North principal rafter, Truss 4	NM	--	---	---	---
Floor						
GBD-A110	East-west beam 1	50	11	1716	1754	1765
GBD-A111	Joist 2, bay 2	45	h/s	---	---	---

GBD-A112	Joist 6, bay 2	NM	--	---	---	---
GBD-A113	Joist 9, bay 2	NM	--	---	---	---
GBD-A114	Joist 2, bay 3	60	04	---	---	---
GBD-A115	Joist 7, bay 3	NM	--	---	---	---
GBD-A116	Joist 8, bay 3	121	02	1632	1750	1752
GBD-A117	Joist 9, bay 4	52	--	---	---	---
GBD-A118	Joist 7, bay 4	NM	--	---	---	---
GBD-A119	Joist 8, bay 4	57	--	---	---	---

Table 2: Results of the cross-matching of site sequence GBDASQ01 and relevant reference chronologies when the first-ring date is AD 1489 and the last-ring date is AD 1599

Reference chronology	t-value	Span of chronology	Reference
Poltimore House, Poltimore, Devon	7.3	AD 1534–1725	Arnold <i>et al</i> 2005
Treludick House, Egloskerry, Cornwall	6.8	AD 1516–1630	Arnold and Howard 2007a
Leigh Barton, Churchstow, Devon	6.8	AD 1527–1605	Groves 2006
Trerithick House, Polyphant, Cornwall	6.6	AD 1503–1673	Arnold and Howard 2007b
8 Market Place, Shepton Mallet, Somerset	6.0	AD 1518–1677	Miles 2002
The Old Manor, Chawton, Hampshire	5.7	AD 1511–1592	Miles <i>et al</i> 1996
Wolfeton House, Charminster, Dorset	5.7	AD 1509–1585	Bridge 2005

Table 3: Results of the cross-matching of site sequence GBDASQ02 and relevant reference chronologies when the first-ring date is AD 1681 and the last-ring date is AD 1772

Reference chronology	t-value	Span of chronology	Reference
St John the Baptist Chapel, Exeter Cathedral, Devon	7.2	AD 1698–1805	Arnold <i>et al</i> 2006
Stoneleigh Abbey, Warwickshire	6.0	AD 1682–1753	Howard <i>et al</i> 2000
Skeleton Barn, Oakhouse Farm, Hampstead Norreys, Berkshire	5.8	AD 1722–1811	Miles 2001
Corfe Castle bellframe, Dorset	5.8	AD 1724–1780	Bridge pers comm.
Holnicote barn, Selworthy, Somerset	5.7	AD 1632–1823	Miles <i>et al</i> 2004
Warleigh House, Tamerton Foliot, Devon	5.5	AD 1671–1774	Howard <i>et al</i> 2006
Clarendon House granary, Wiltshire	5.5	AD 1675–1764	Tyers 2001

Table 4: Results of the cross-matching of sample GBD-A116 and relevant reference chronologies when the first-ring date is AD 1630 and the last-ring date is AD 1752

Reference chronology	t-value	Span of chronology	Reference
Buckland, Yelverton, Devon	7.3	AD 1677–1799	Morgan pers comm
Worcester Cathedral, Worcestershire	6.9	AD 1484–1772	Arnold <i>et al</i> 2003
Kibworth Harcourt Mill, Leicestershire	6.4	AD 1582–1773	Arnold <i>et al</i> 2004a
Croome Court, Worcestershire	6.2	AD 1639–1753	Arnold <i>et al</i> 2004b
Chastleton House, Chastleton, Oxfordshire	6.2	AD 1671–1788	Miles and Bridge 2005
Kenilworth Castle Gatehouse, Kenilworth, Warwickshire	6.1	AD 1623–1727	Arnold and Howard 2007c
Bretby Hall, Derbyshire	5.9	AD 1494–1719	Howard <i>et al</i> 1999



Figure 1: General location of Bridestowe, Devon (based on the Ordnance Survey map with permission of the Controller of Her Majesty's Stationery Office, ©Crown Copyright)

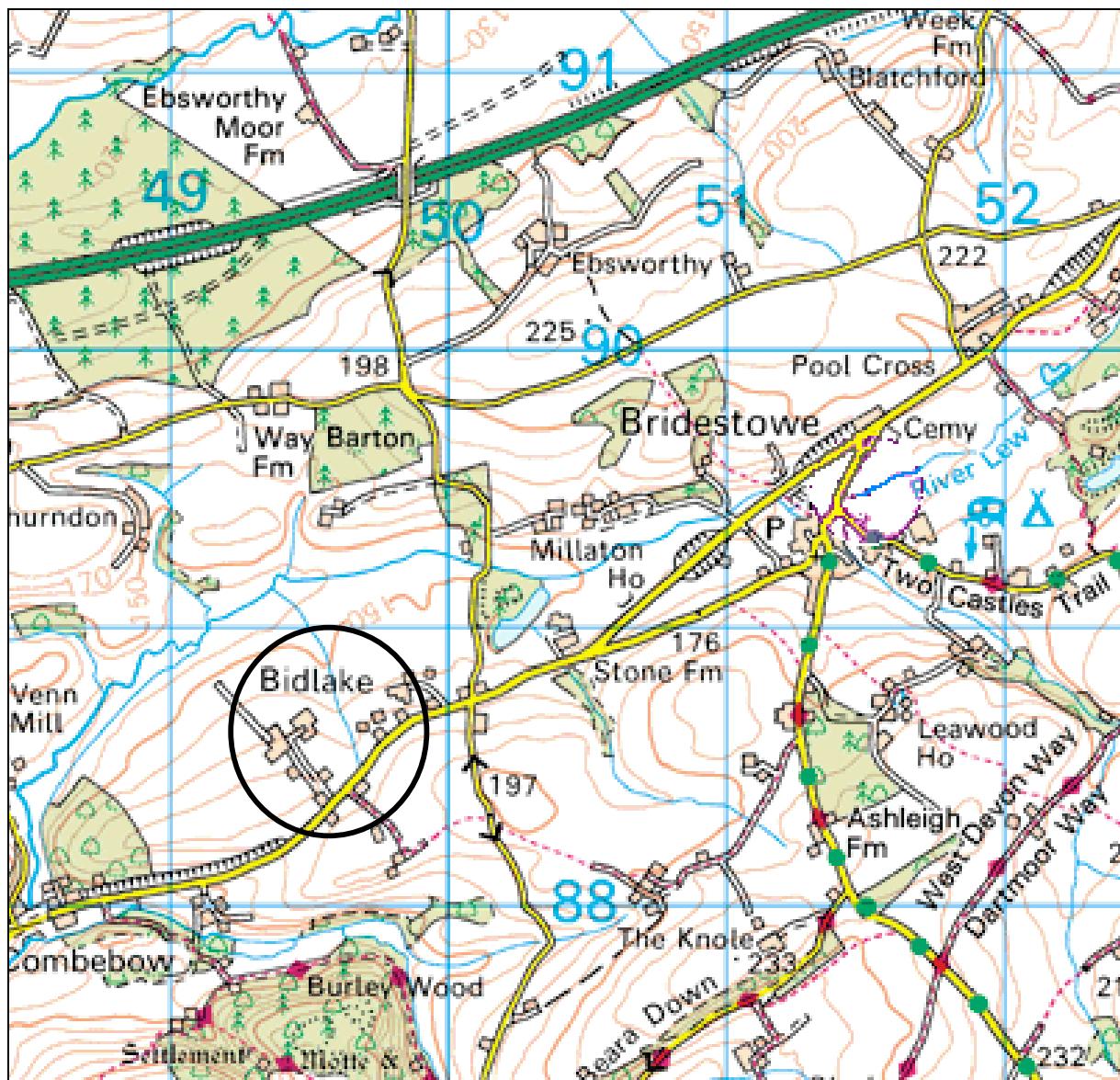


Figure 2: Map to show the general location of Great Bidlake (based on the Ordnance Survey map with permission of the Controller of Her Majesty's Stationery Office, ©Crown Copyright)

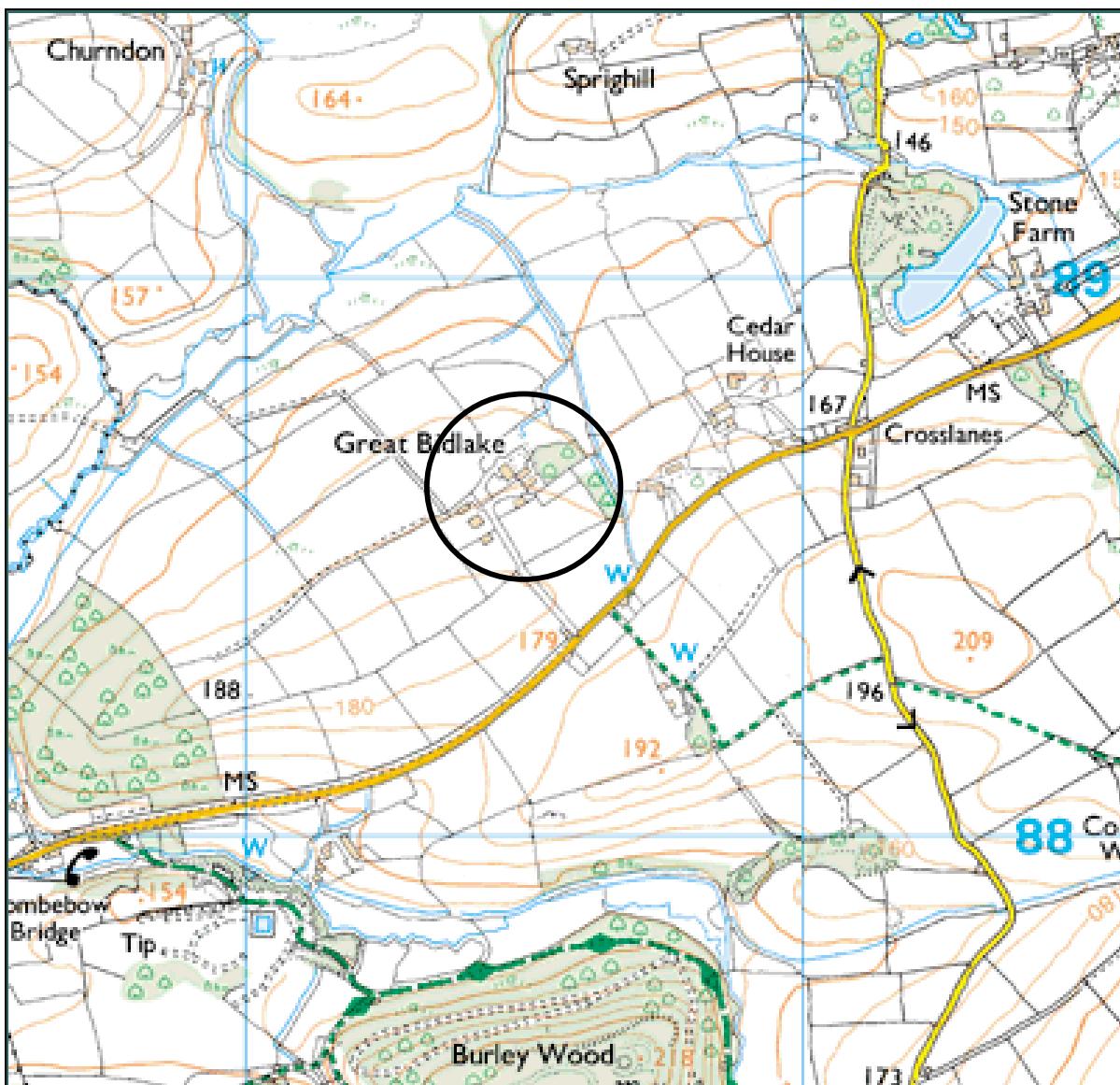


Figure 3: Map to show the location Great Bidlake (based on the Ordnance Survey map with permission of the Controller of Her Majesty's Stationery Office, ©Crown Copyright)

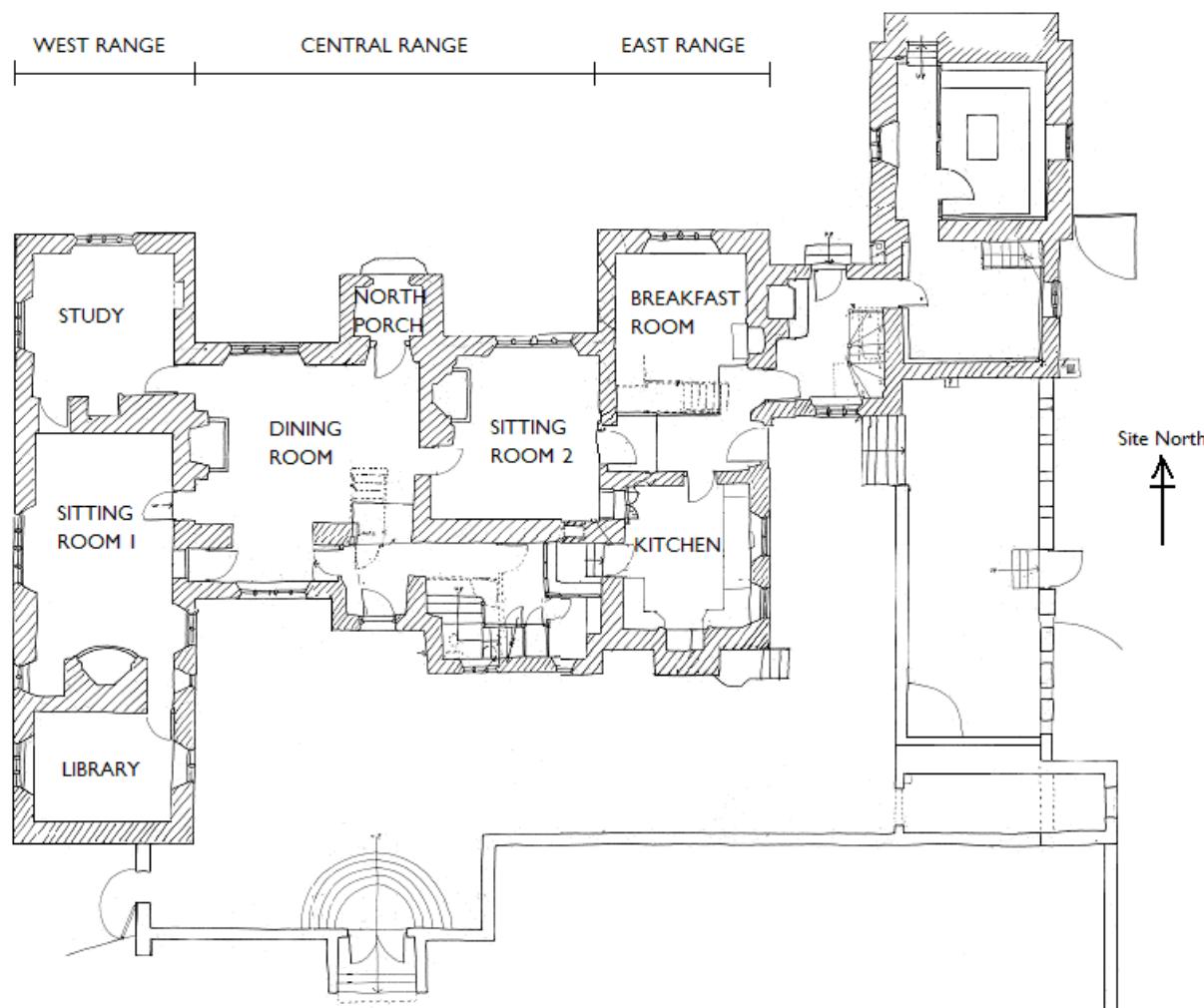


Figure 4: Ground-floor plan, provided by Andrew Wood Architect

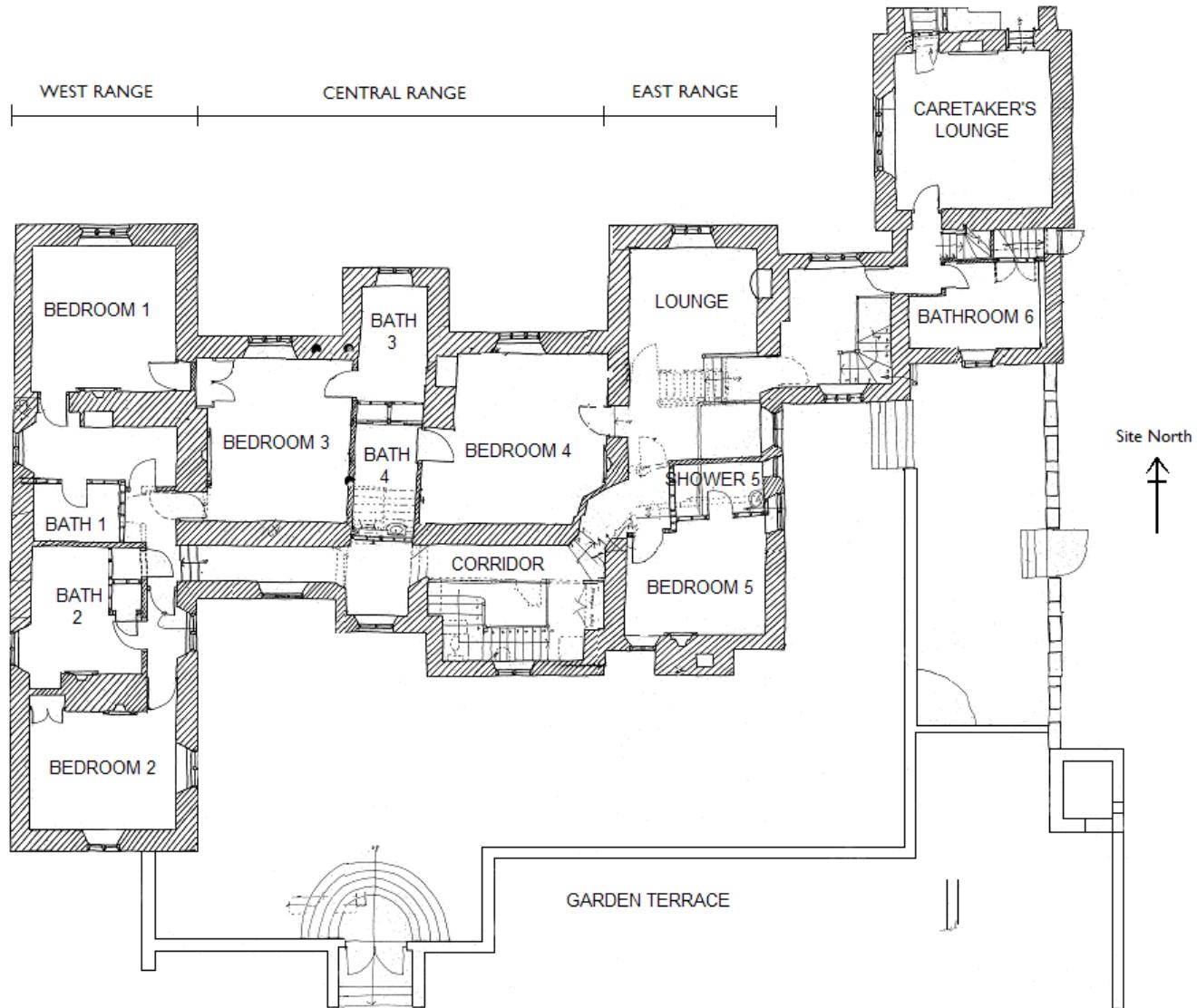


Figure 5: First-floor plan, provided by Andrew Wood



Figure 6: Central range; sitting room ceiling



Figure 7: Central range; roof taken from the south-west (truss 2 in foreground)



Figure 8: East range; breakfast room ceiling



Figure 9: East range; the kitchen ceiling



Figure 10: East range roof; trusses 1 and 2 (truss 2 in foreground, truss in gable end is false)



Figure 11: East Range; truss 3 (at above first-floor level), viewed from east



Figure 12: West range; truss 2 (from north)



Figure 13: West range; truss 3 (from the north)



Figure 14: West range; truss 4 (taken from the north)



Figure 15: Threshing barn



Figure 16: Threshing barn; roof



Figure 17: Stable



Figure 18: Stable, roof



Figure 19: Stable, floor frame

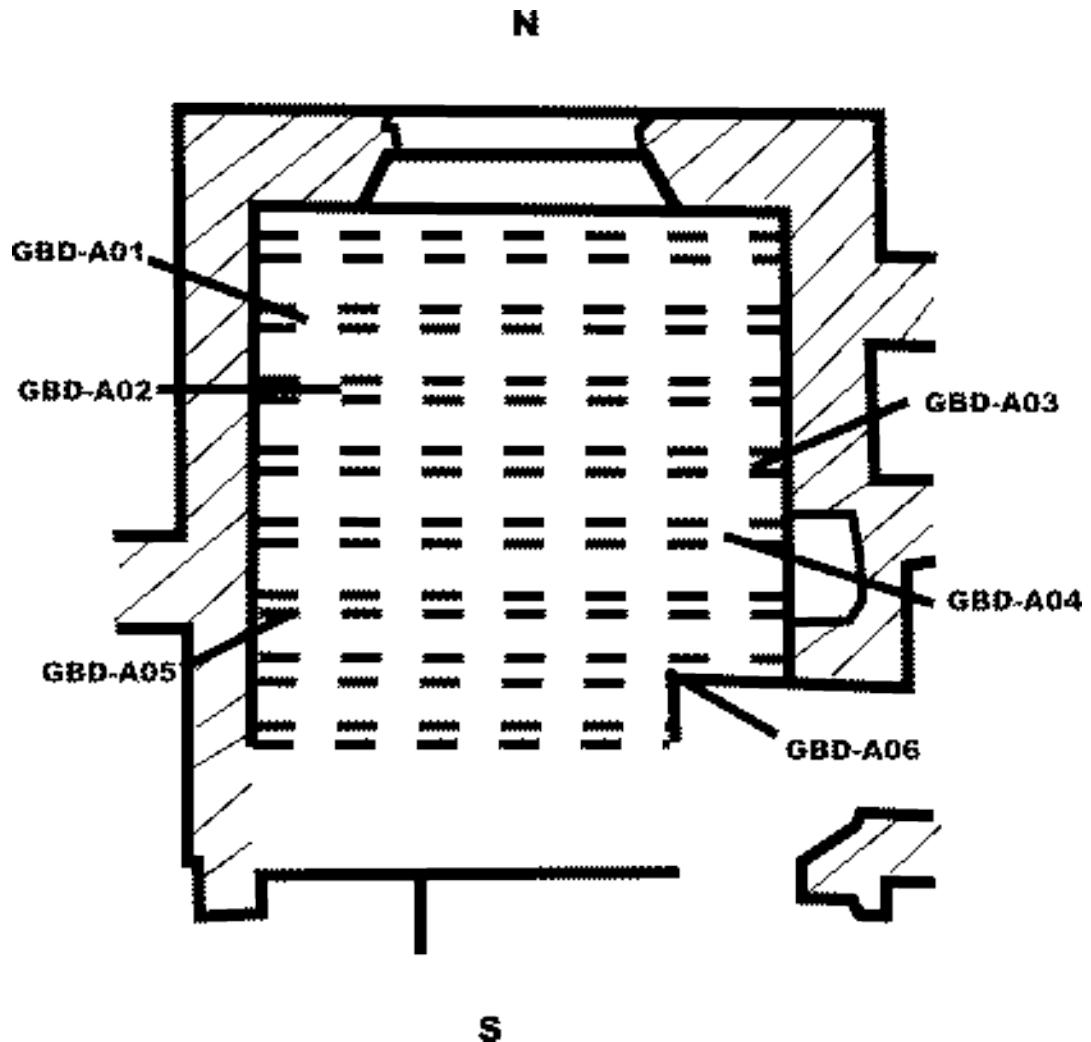


Figure 20: Breakfast room, showing the location of samples GBD-A01–6

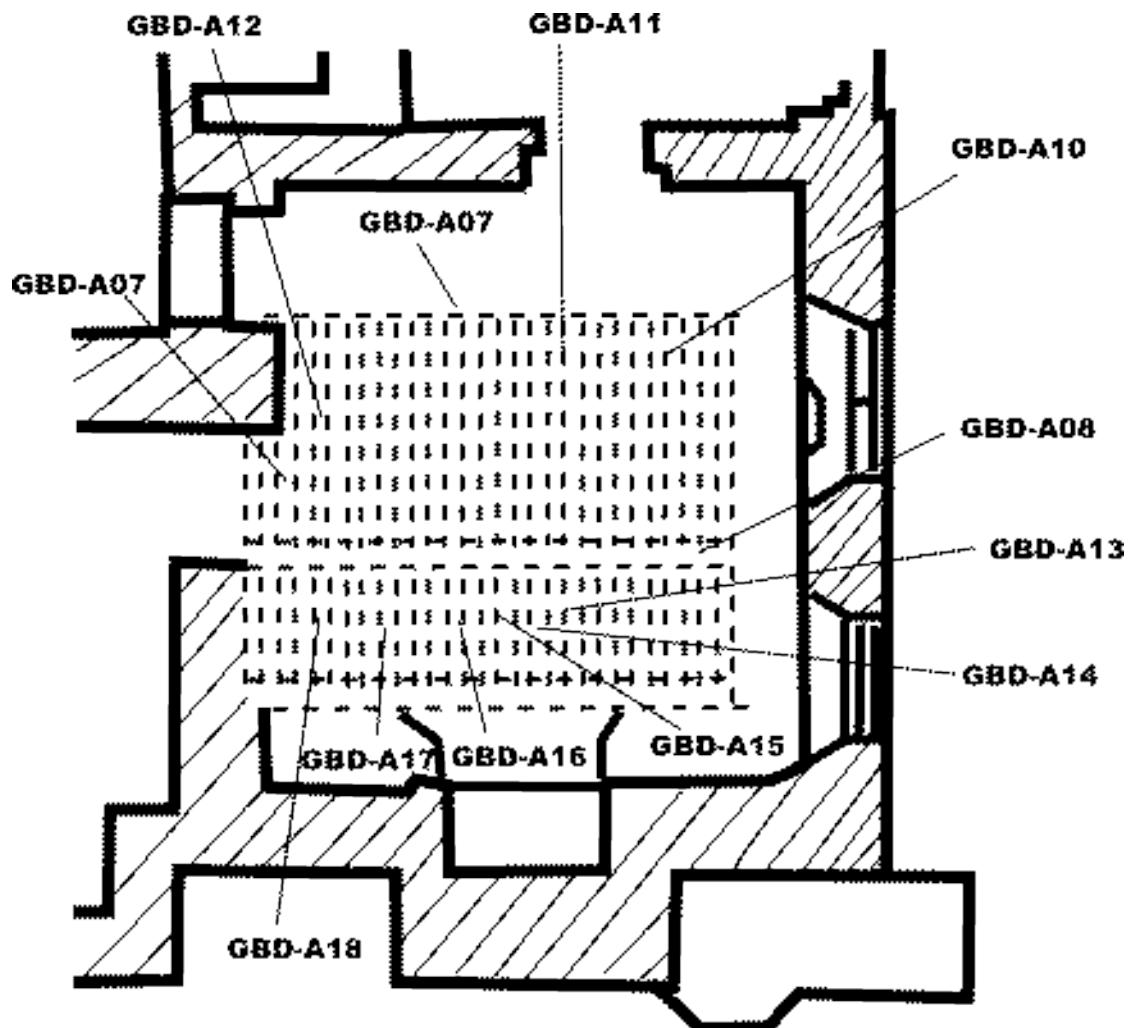


Figure 21: Kitchen, showing the location of samples GBD-A07–18

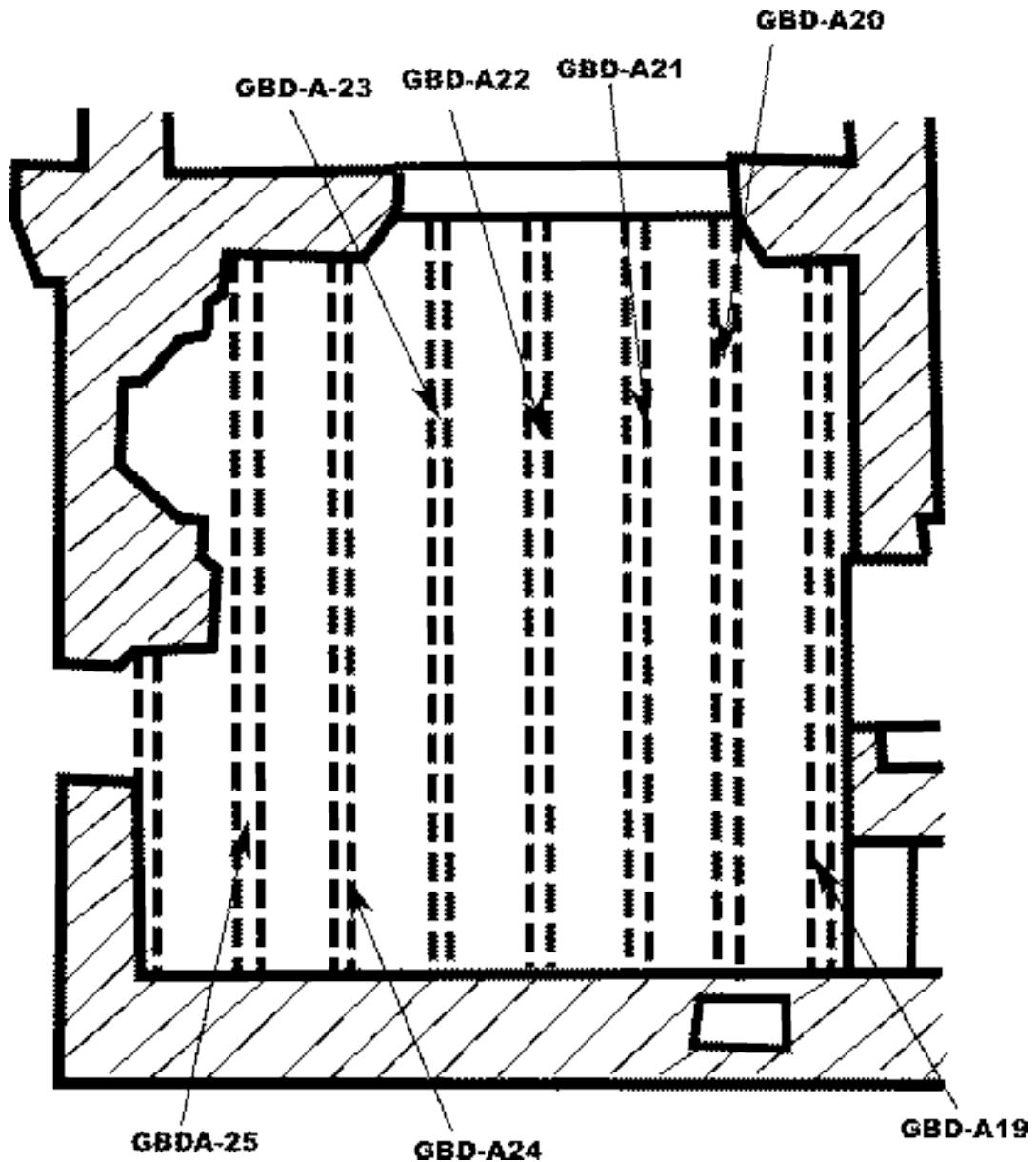


Figure 22: Sitting room, showing the location of samples GBD-A19–25

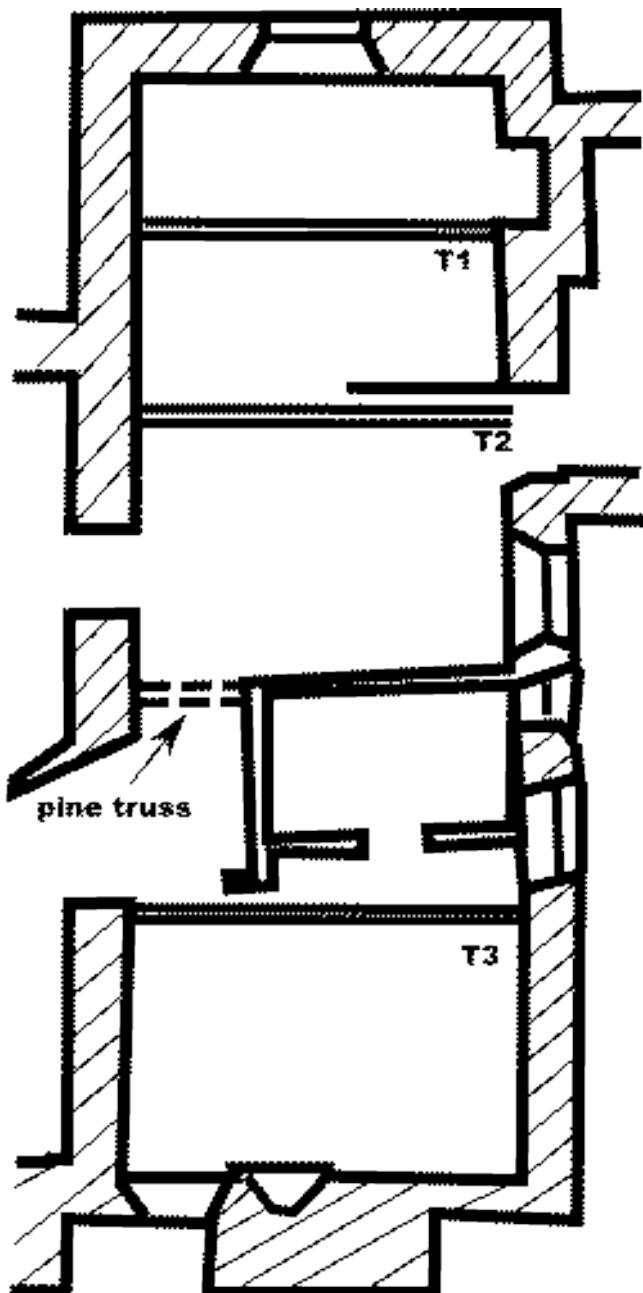


Figure 23: *East range; plan, showing the approximate position of trusses*

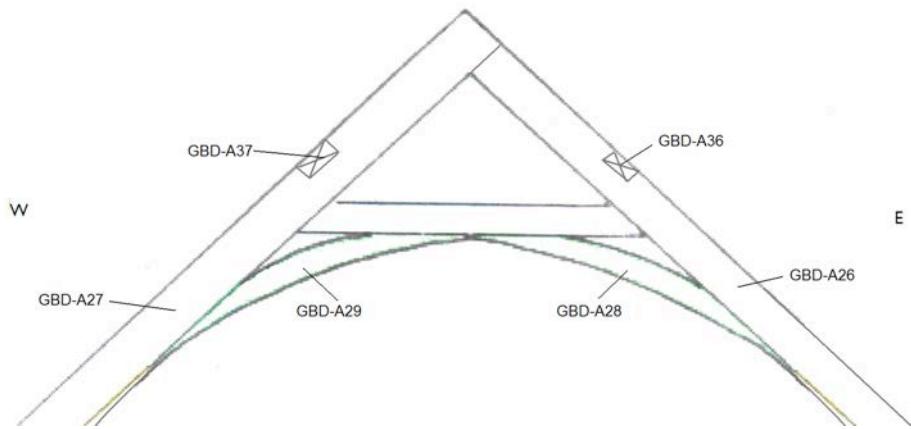


Figure 24: East range; sketch drawing of truss 1, showing the location of samples GBD-A26–29, GBD-A36 and GBD-A37

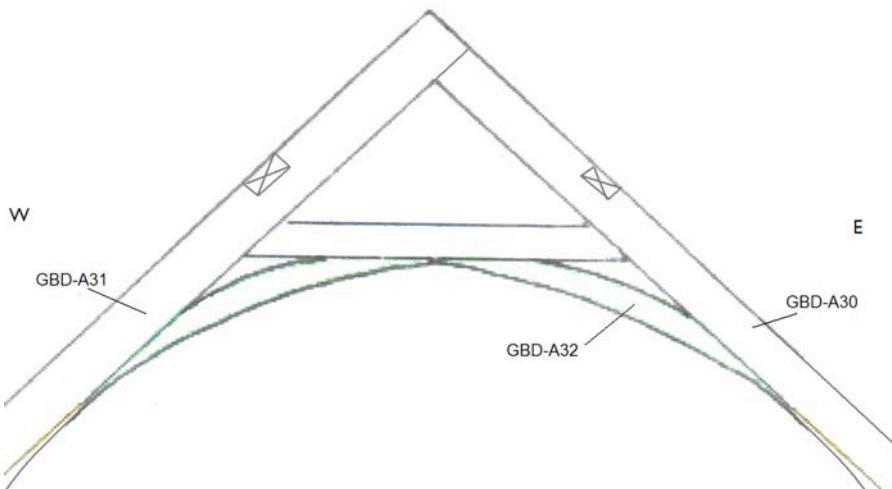


Figure 25: East range; sketch drawing of truss 2, showing the location of samples GBD-A30–32

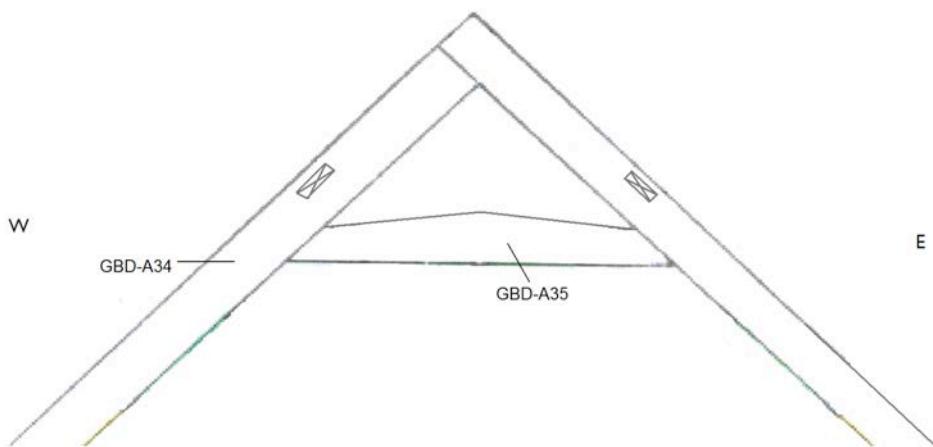


Figure 26: East range; sketch drawing of truss 3, showing the location of samples GBD-A34 and GBD-A35

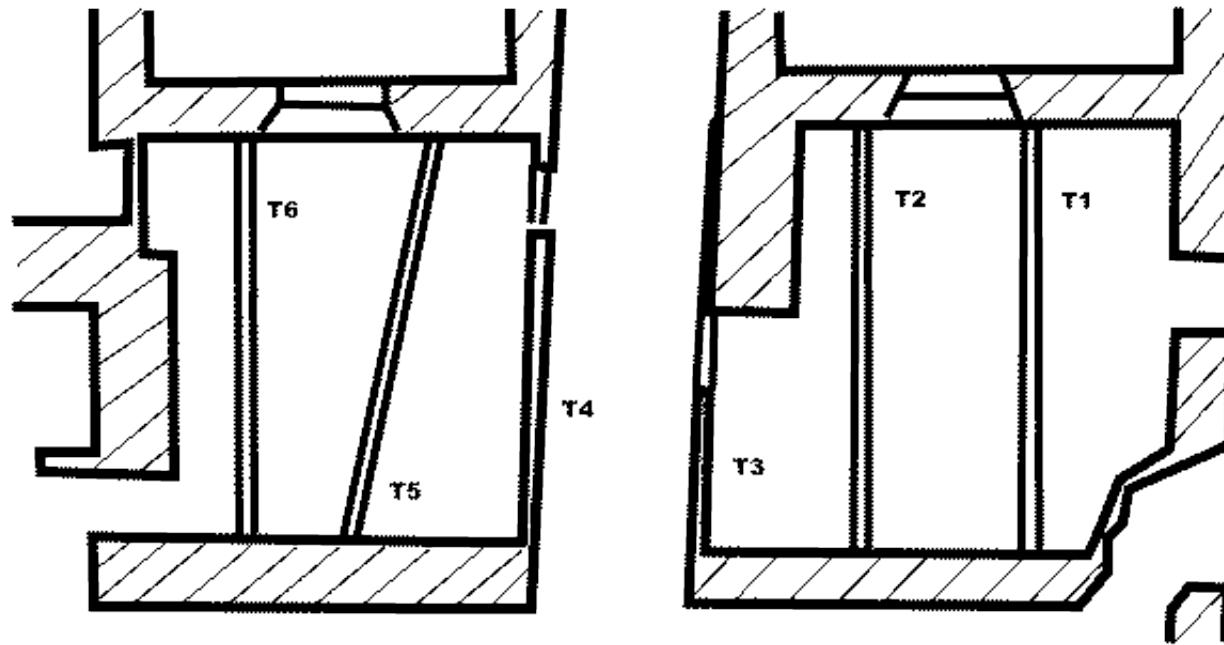


Figure 27: Central range; plan, showing the approximate position of roof trusses

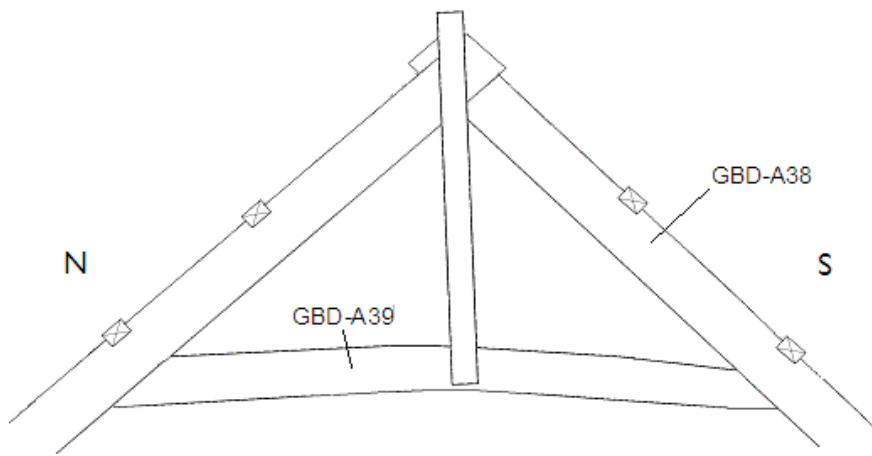


Figure 28: Central range; sketch of truss 1, showing the location of samples GBD-A38 and GBD-A39

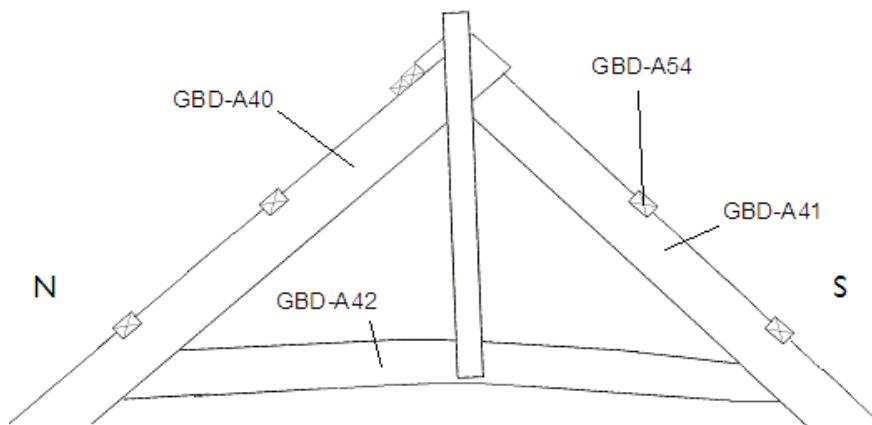


Figure 29: Central range; sketch of truss 2, showing the location of samples GBD-A40–42 and GBD-A54

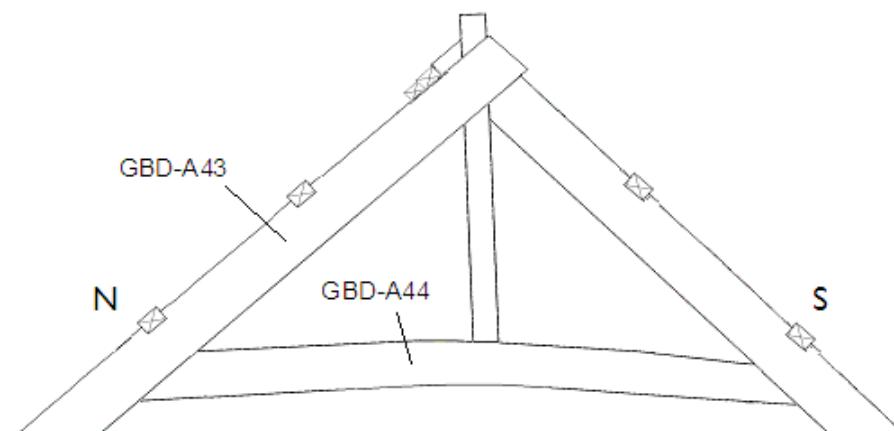


Figure 30: Central range; sketch of truss 3, showing the location of samples GBD-A43 and GBD-A44

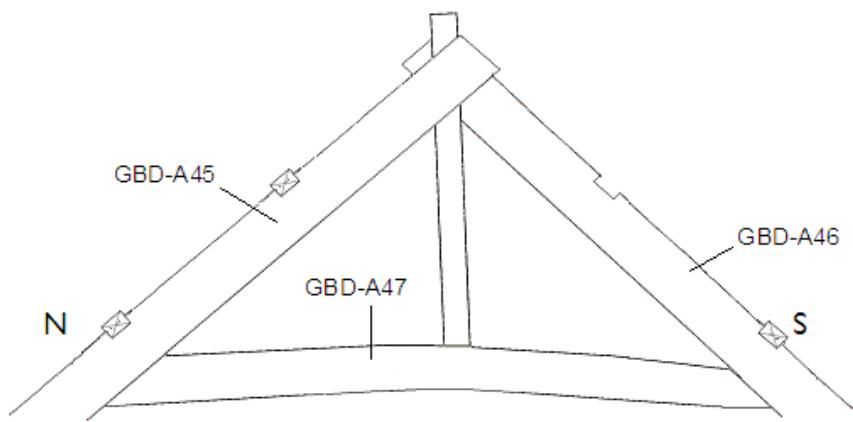


Figure 31: Central range; sketch of truss 4, showing the location of samples GBD-A45–7

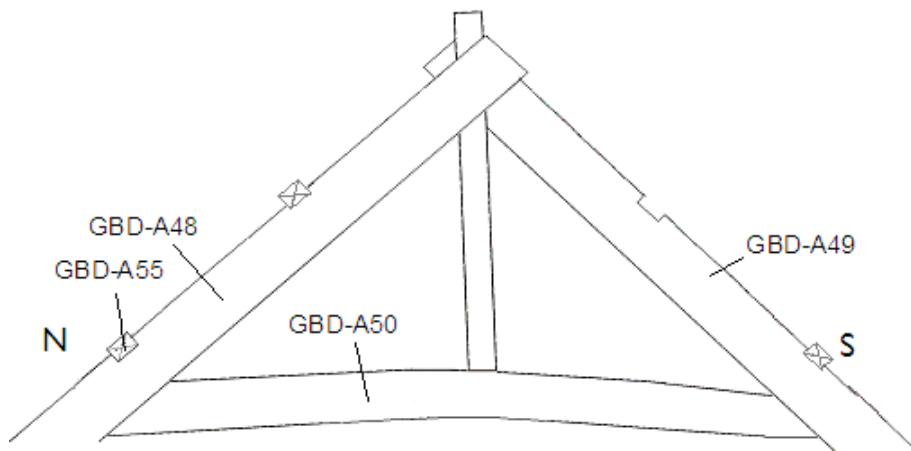


Figure 32: Central range; truss 5 (based on sketch of truss 4), showing the location of samples GBD-A48–50

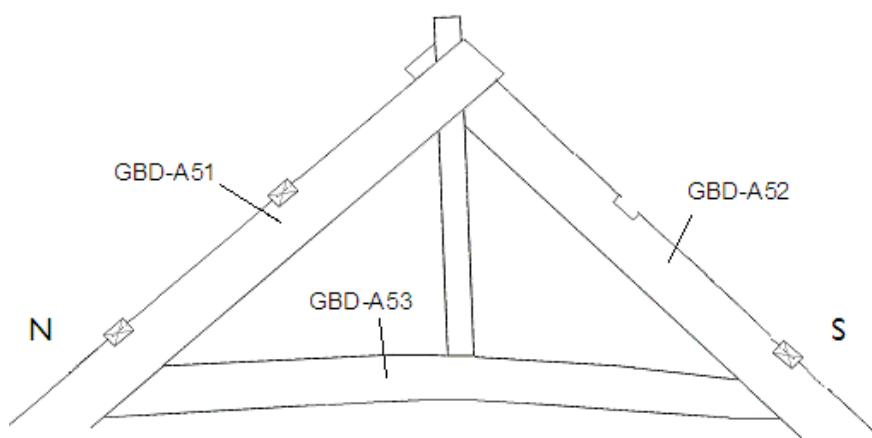


Figure 33: Central range; truss 6 (based on sketch of truss 4), showing the location of samples GBD-A51–3

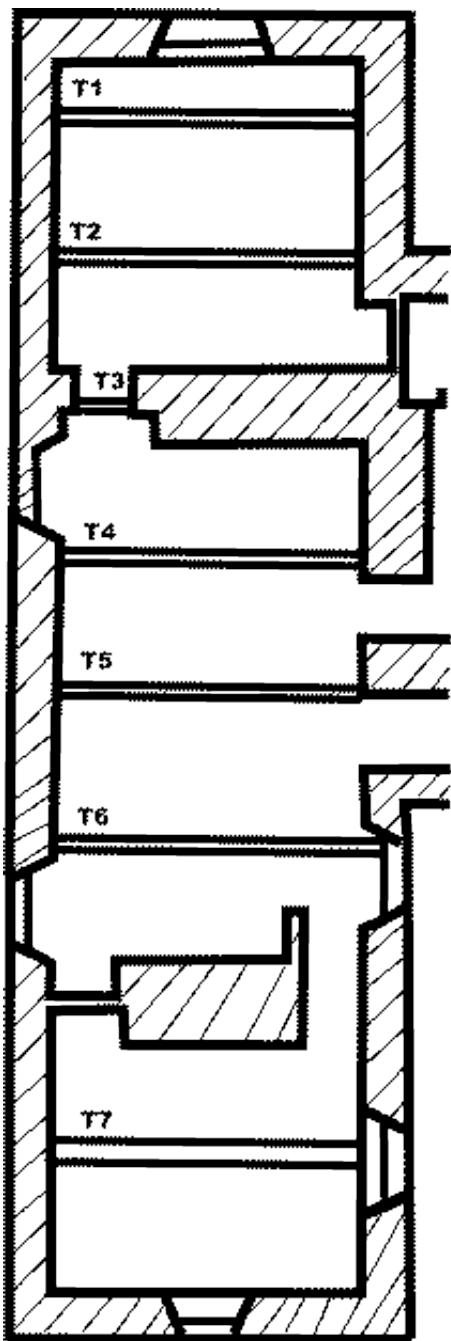


Figure 34: West range; plan, showing approximate position of roof trusses

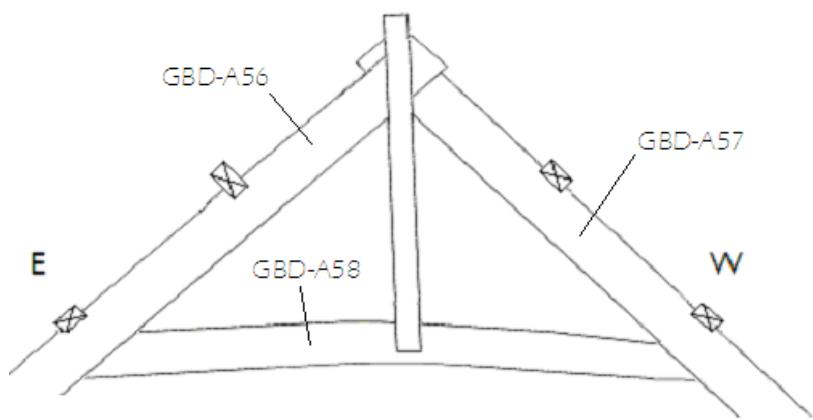


Figure 35: West range; sketch of truss 1, showing the location of samples GBD-A56–8

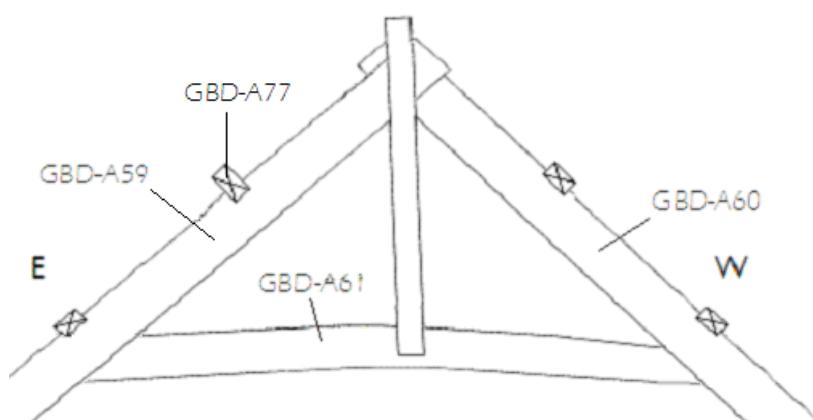


Figure 36: West range; sketch of truss 2, showing the location of samples GBD-A59–61 and GBD-A77

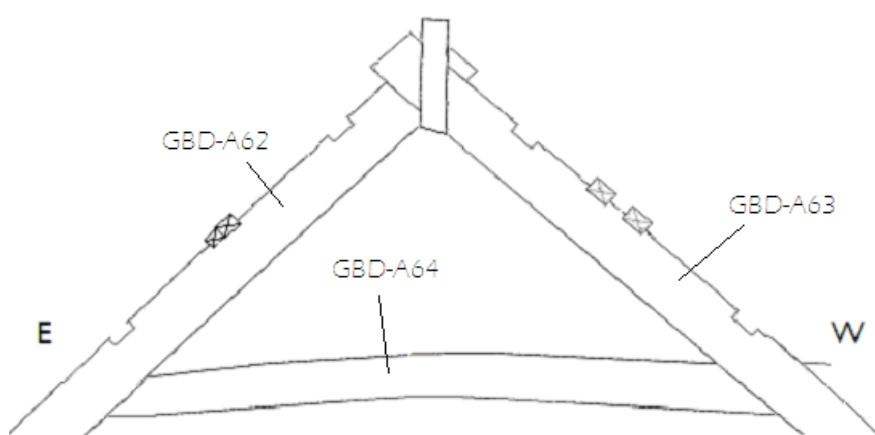


Figure 37: West range; sketch of truss 3, showing the location of samples GBD-A62–4

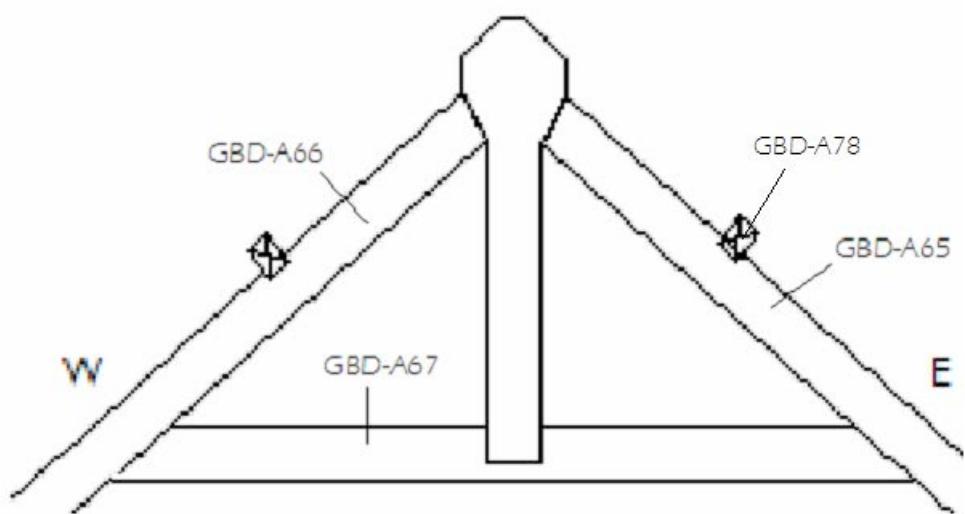


Figure 38: West range; sketch of truss 4, showing the location of samples GBD-A65–7

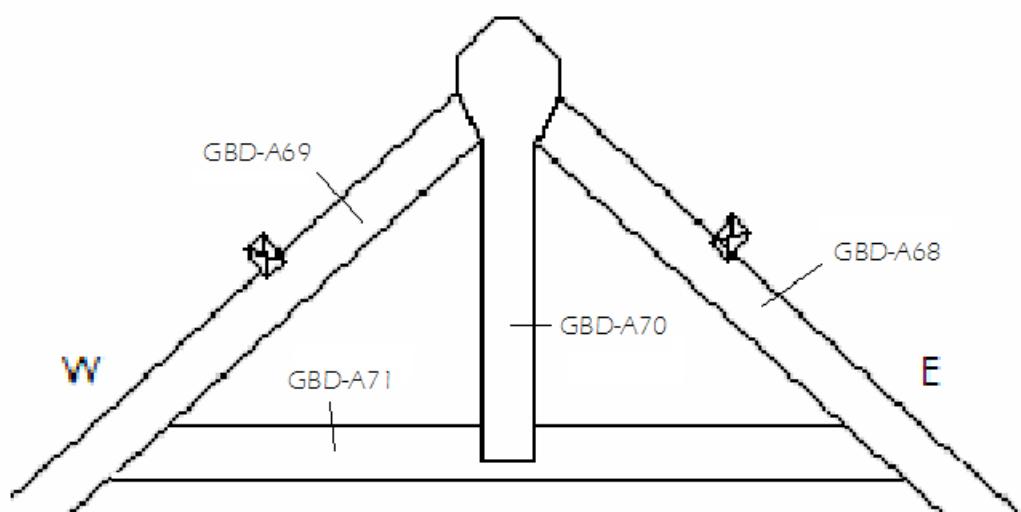


Figure 39: West range; sketch of truss 5, showing the location of samples GBD-A68–71

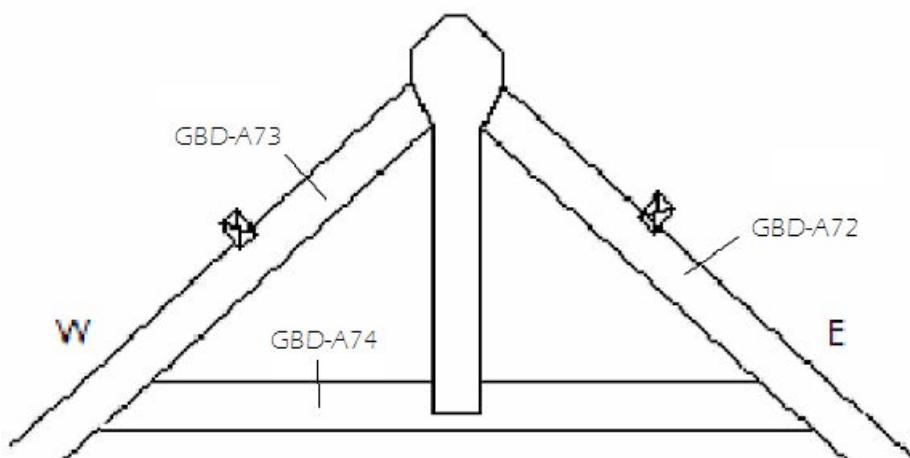


Figure 40: West range; sketch of truss 6, showing the location of samples GBD-A72–4

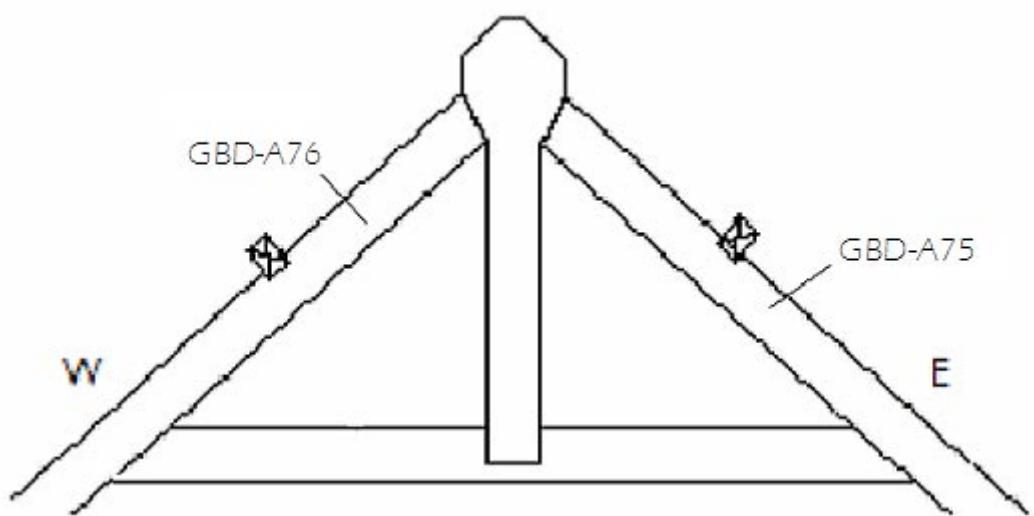


Figure 41: West range; sketch of truss 7, showing the location of samples GBD-A75 and GBD-A76

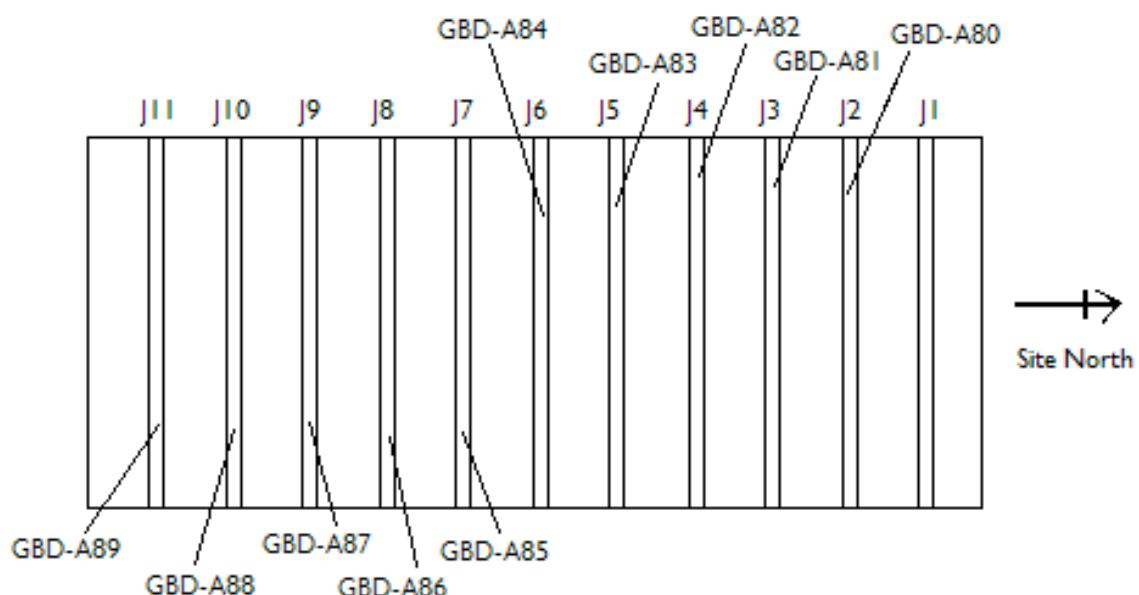


Figure 42: Threshing barn; sketch plan of ground floor, showing the location of samples GBD-A80–9



Figure 43: Threshing barn; sketch plan of first floor, showing the location of roof trusses

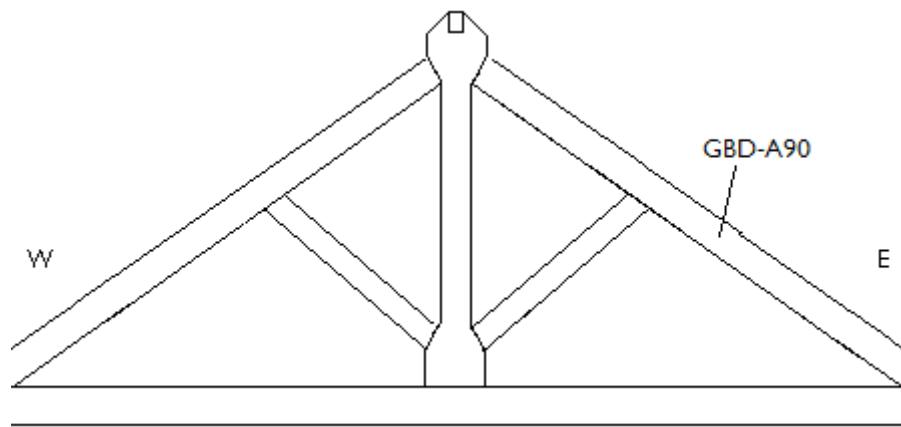


Figure 44: Threshing barn; sketch of truss 1, showing the location of sample GBD-A90

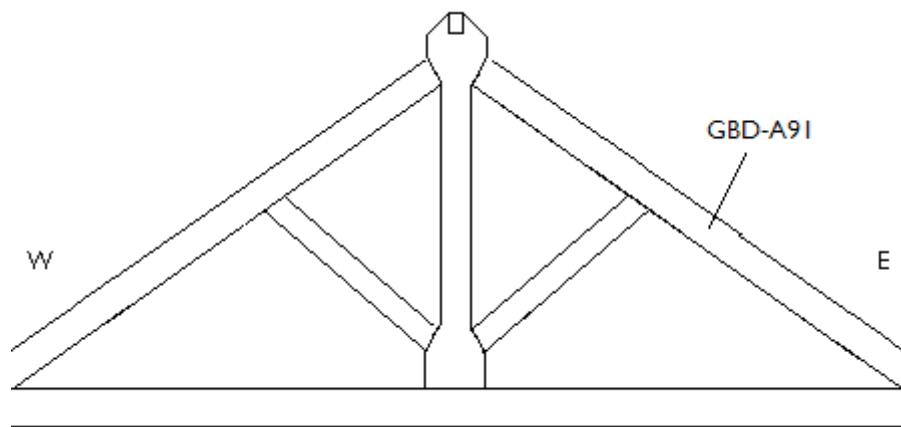


Figure 45: Threshing barn; sketch of truss 2, showing the location of sample GBD-A91

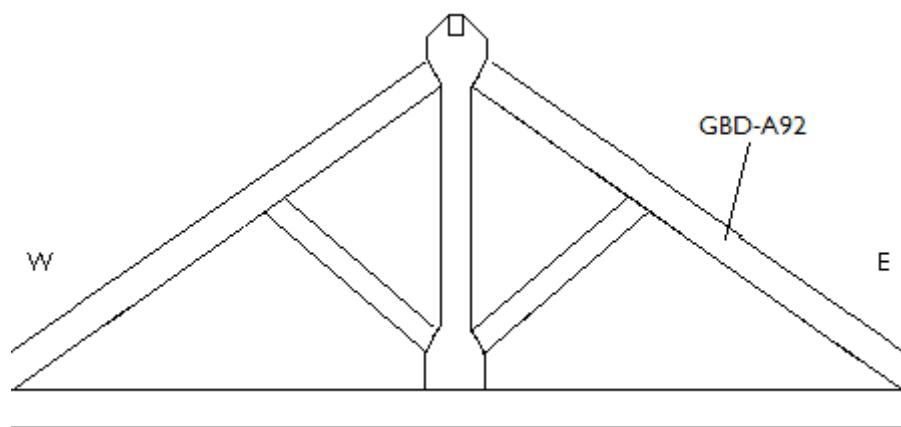


Figure 46: Threshing barn; sketch of truss 3, showing the location of sample GBD-A92

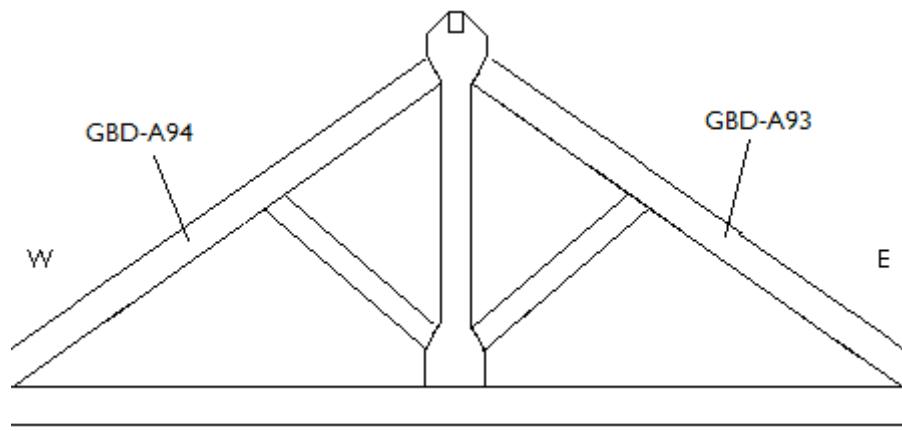


Figure 47: Threshing barn; sketch of truss 4, showing the location of samples GBD-A93 and GBD-A94

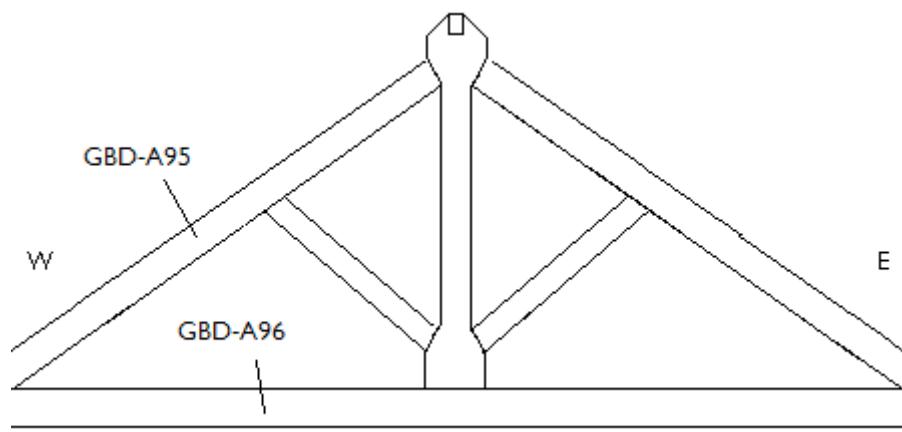


Figure 48: Threshing barn; sketch of truss 5, showing the location of samples GBD-A95 and GBD-A96

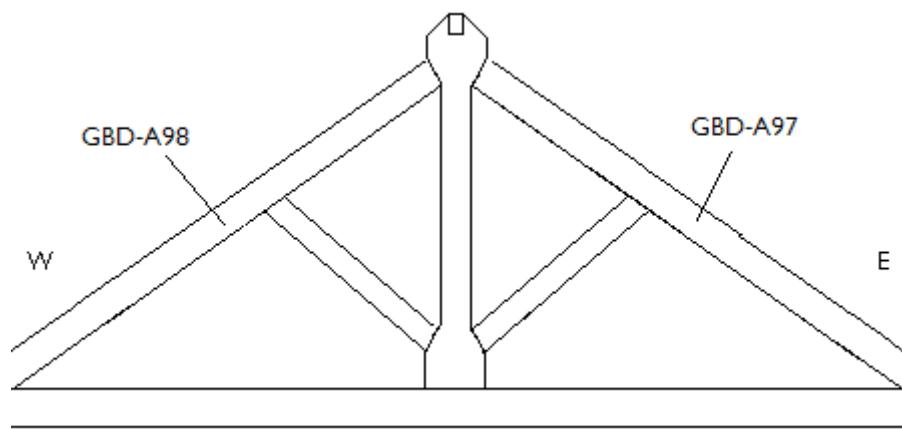


Figure 49: Threshing barn; sketch of truss 6, showing the location of samples GBD-A97 and GBD-A98

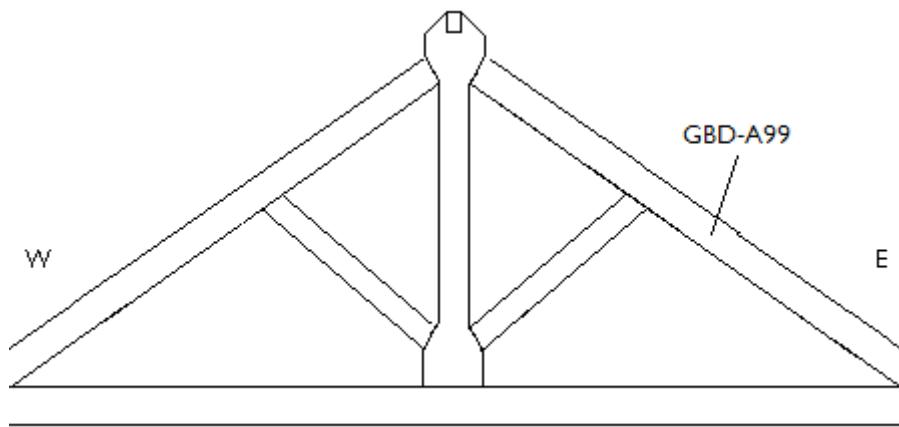


Figure 50: Threshing barn; sketch of truss 7, showing the location of sample GBD-A99

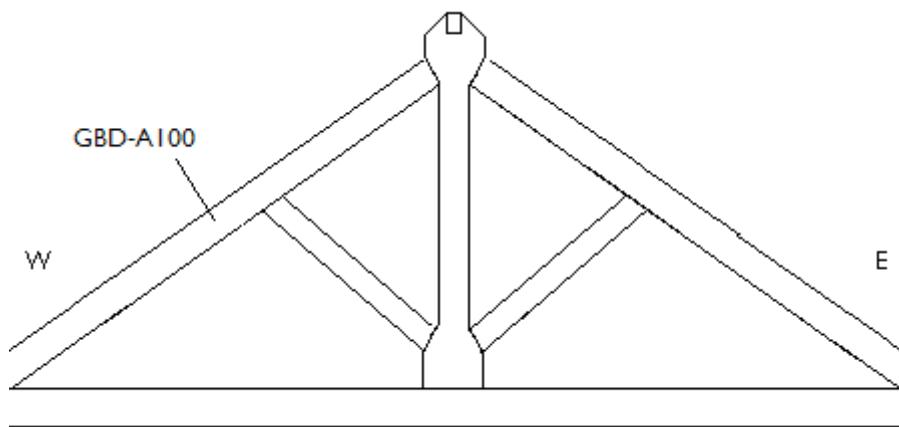


Figure 51: Threshing barn; sketch of truss 10, showing the location of sample GBD-A100

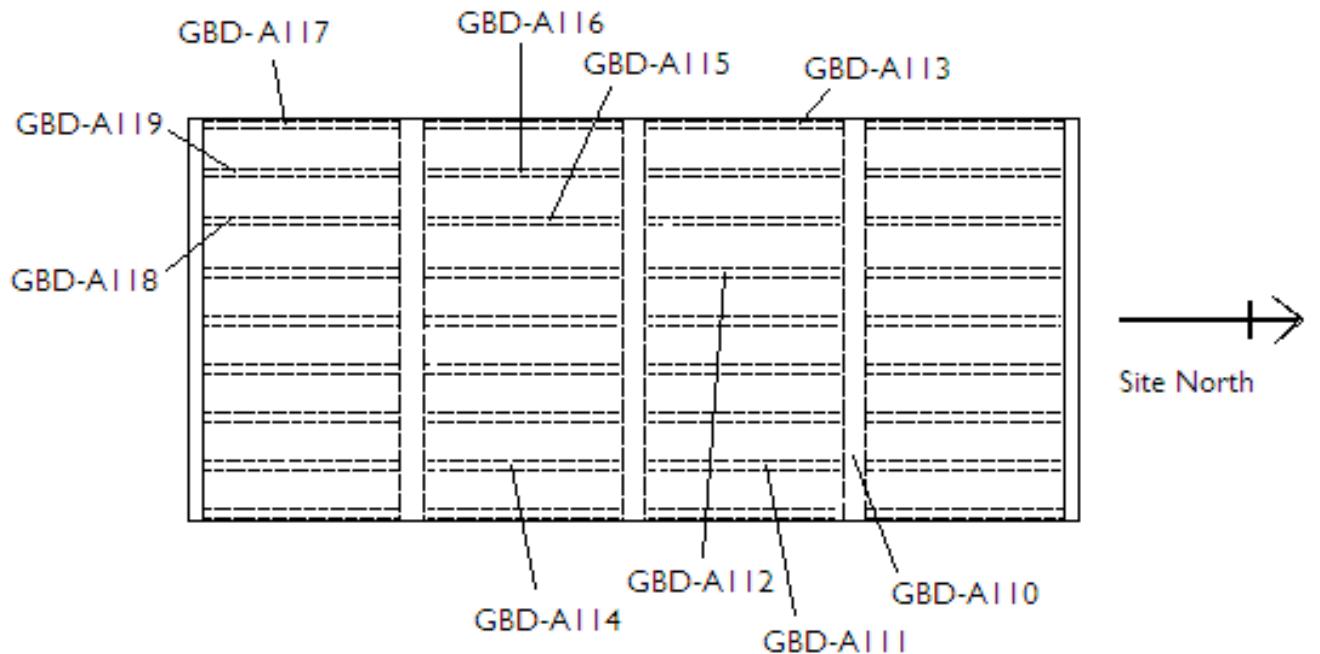


Figure 52: Stable; sketch plan of first-floor frame, showing the location of samples GBD-A110–19

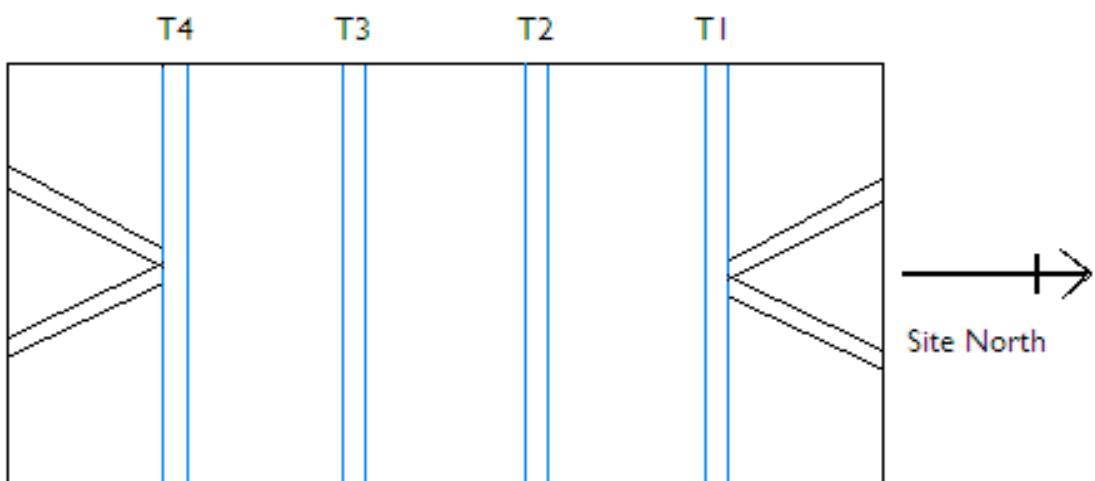


Figure 53: Stable; sketch plan of the roof, showing the approximate position of trusses

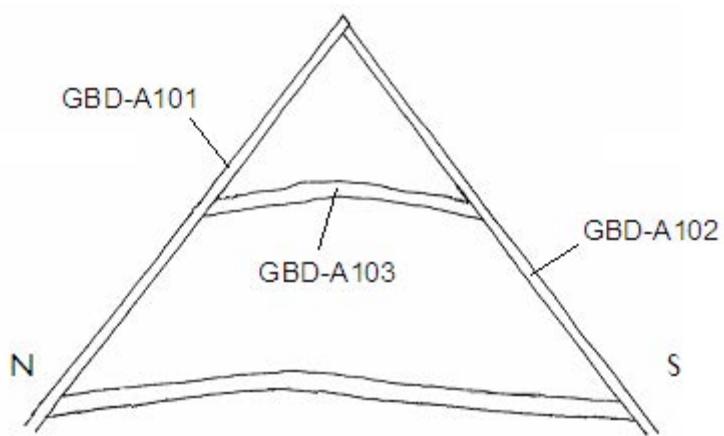


Figure 54: Stable; sketch of truss 1, showing the location of samples GBD-A101–3

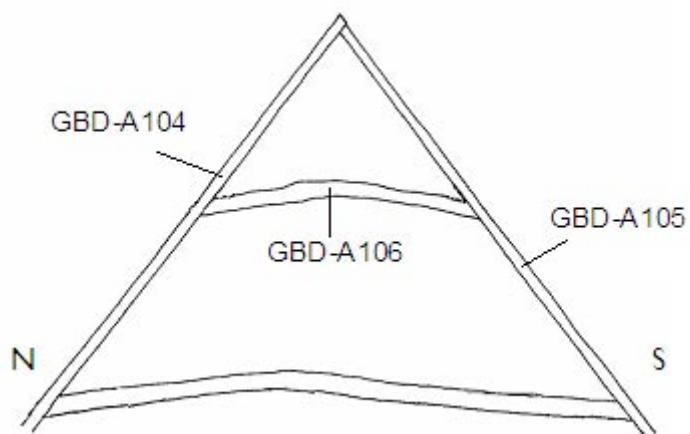


Figure 55: Stable; sketch of truss 2, showing the location of samples GBD-A104–6

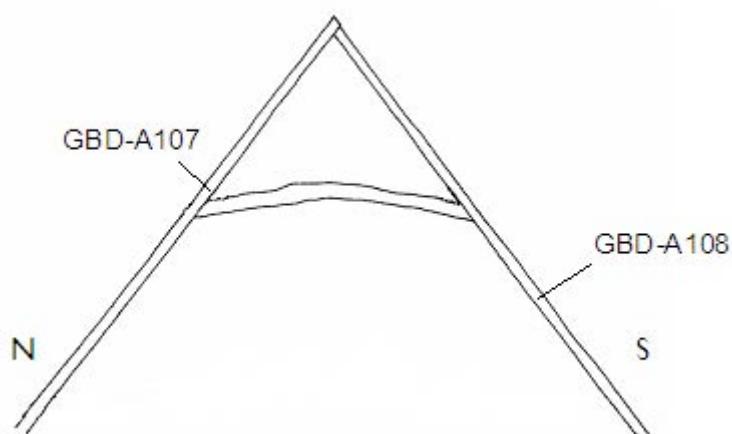


Figure 56: Stable; sketch of truss 3, showing the location of samples GBD-A107 and GBD-A108

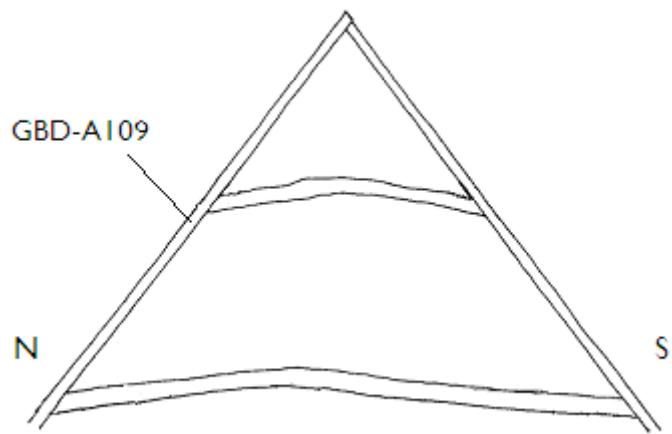
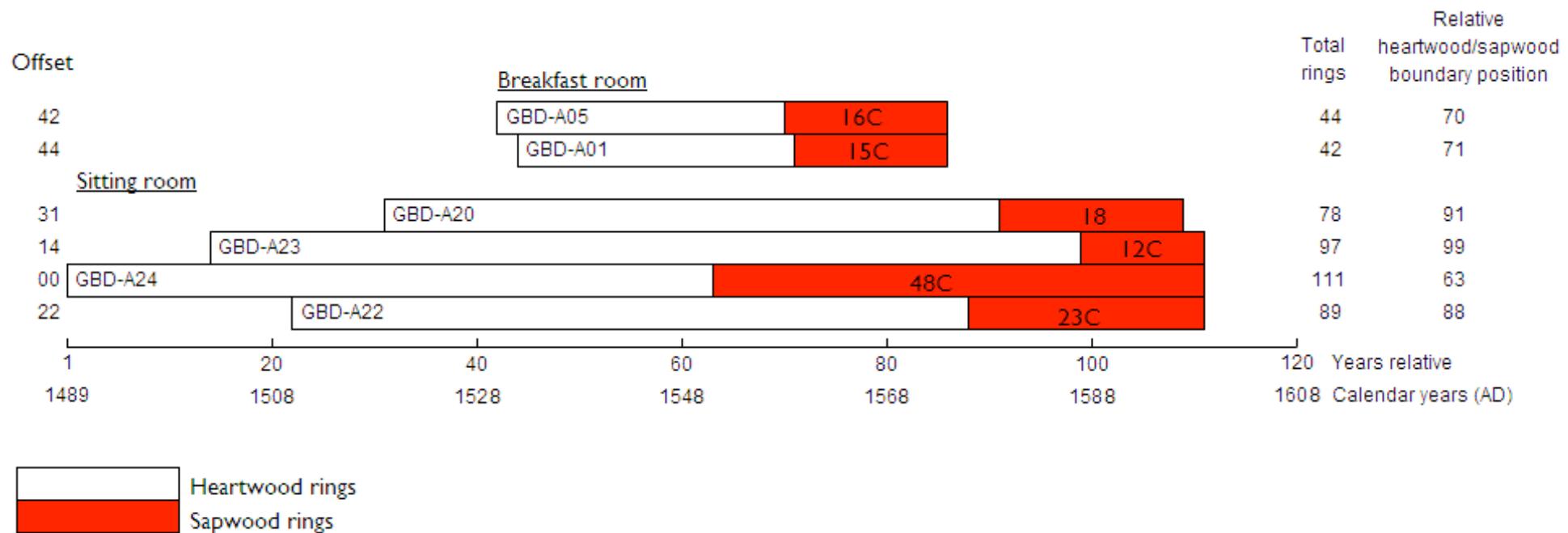
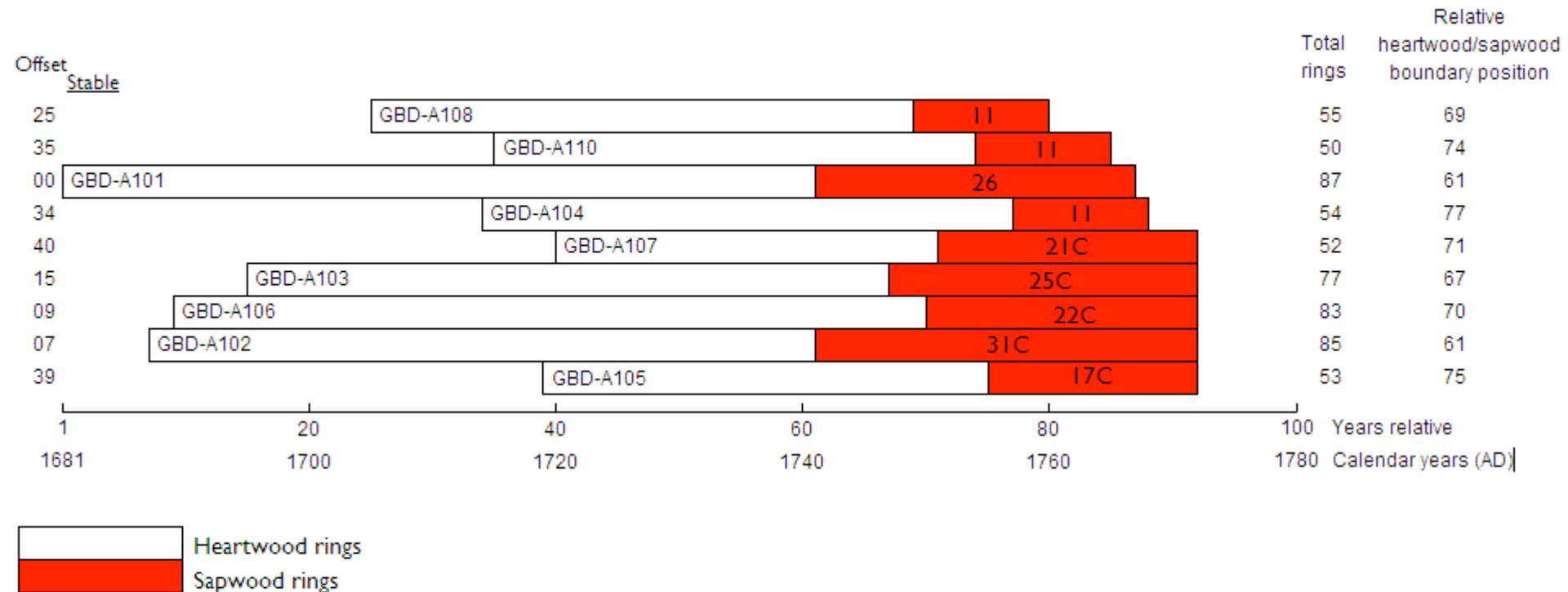


Figure 57: Stable; sketch of truss 4, showing the location of sample GBD-A109



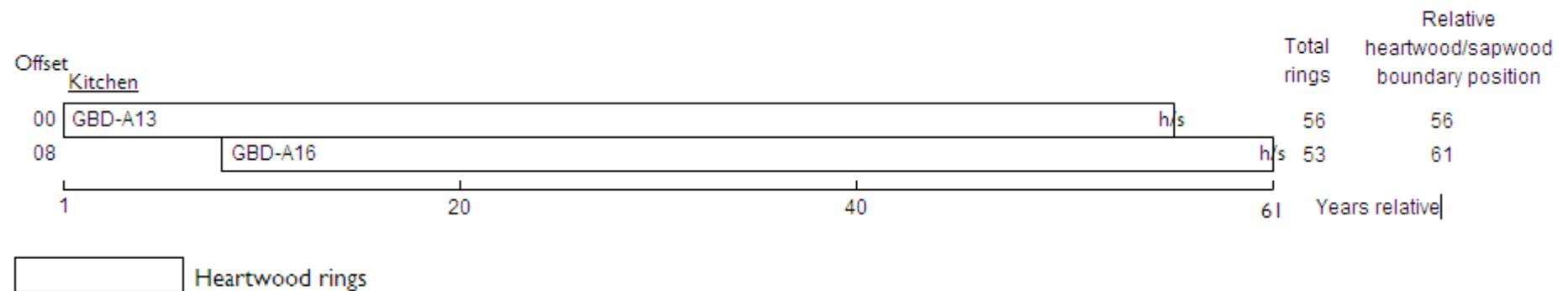
C = complete sapwood retained on the sample, last-measured ring is the felling date.

Figure 58: Bar diagram of samples in site sequence GBDASQ01



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

Figure 59: Bar diagram of samples in site sequence GBDASQ02



h/s = the heartwood/sapwood boundary ring is the last-measured ring on the sample.

Figure 60: Bar diagram of samples in undated site sequence GBDASQ03

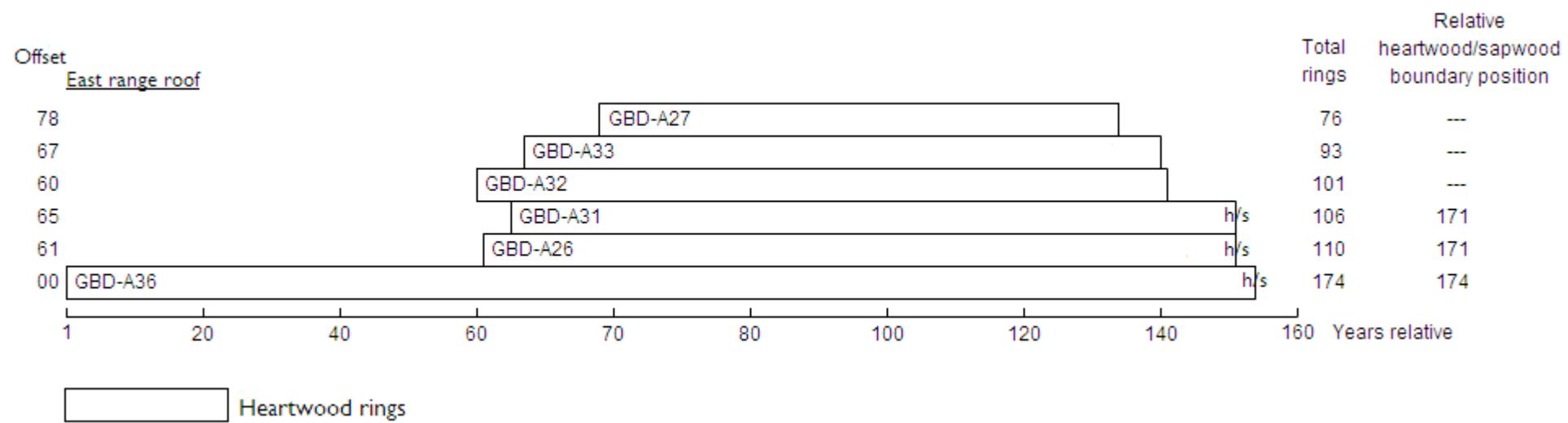


Figure 61: Bar diagram of samples in undated site sequence GBDASQ04

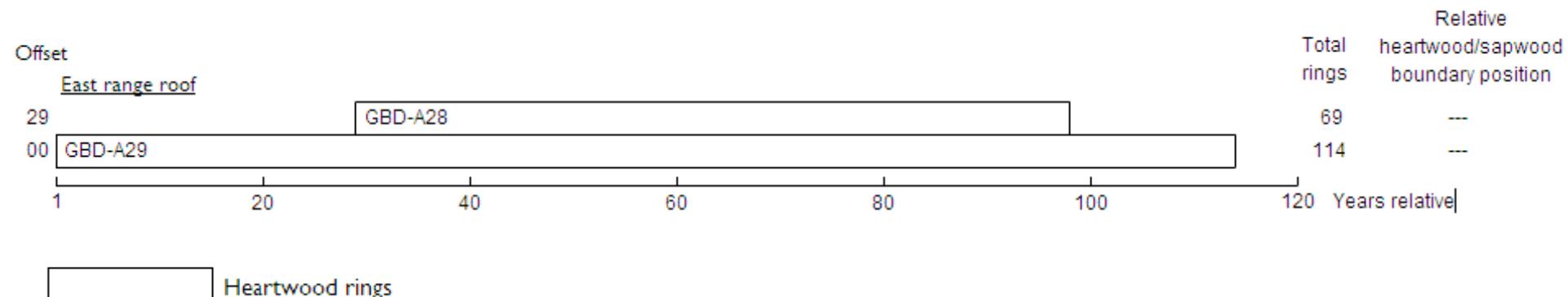


Figure 62: Bar diagram of samples in undated site sequence GBDASQ05

59

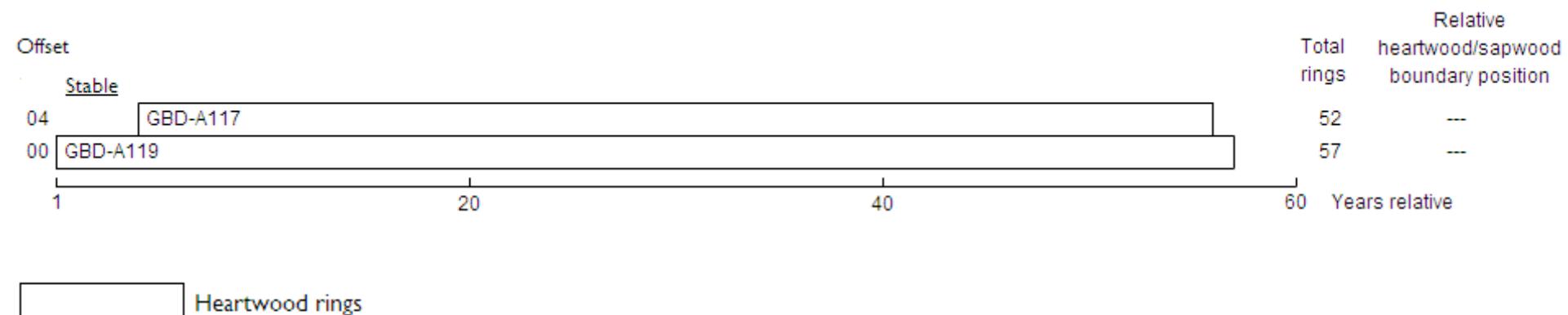


Figure 63: Bar diagram of samples in undated site sequence GBDASQ06

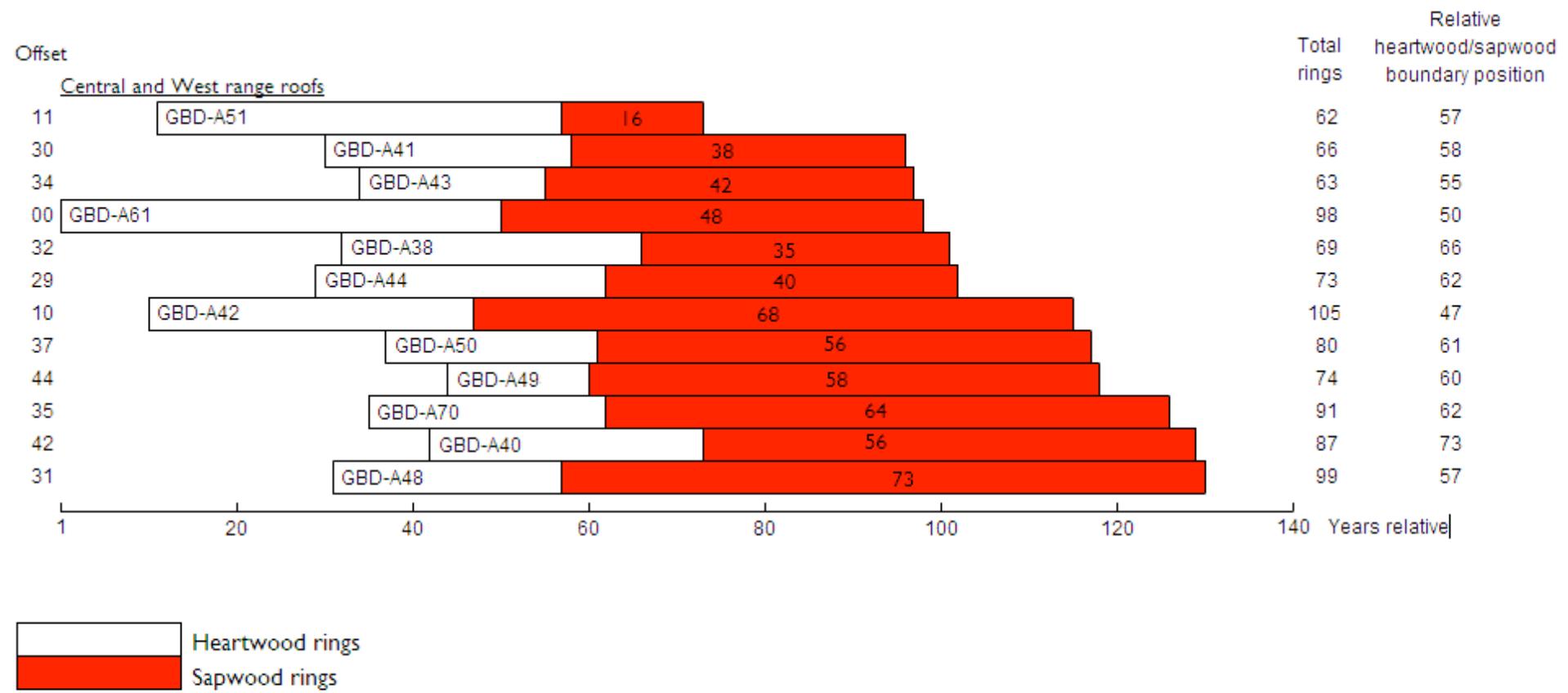


Figure 64: Bar diagram of samples in site sequence GBDASQ07

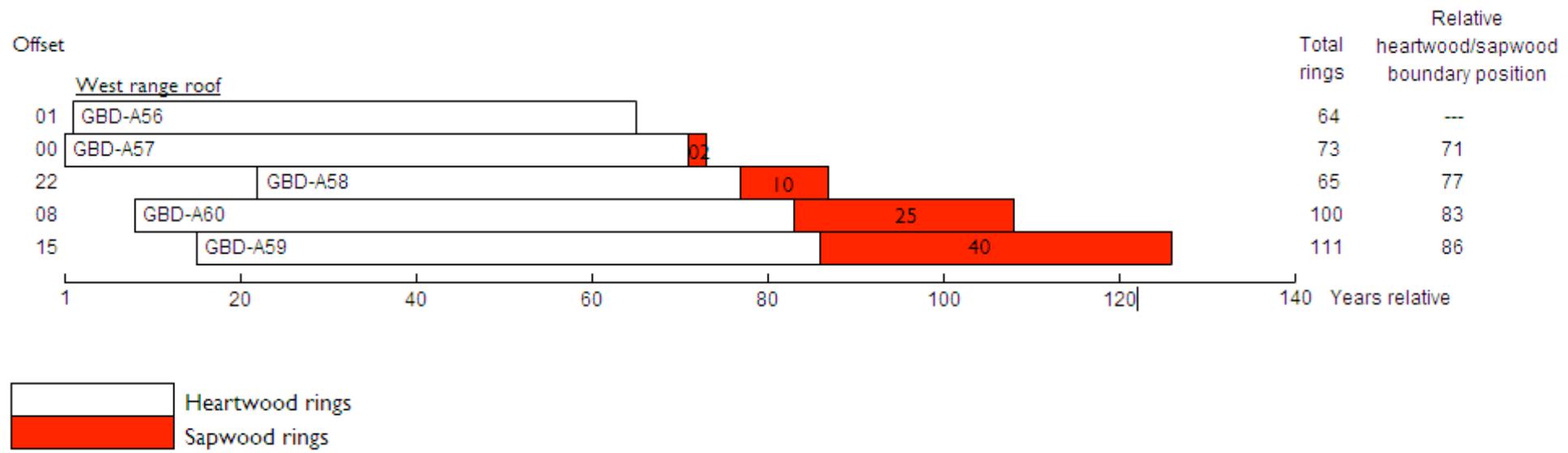


Figure 65: Bar diagram of samples in site sequence GBDASQ08

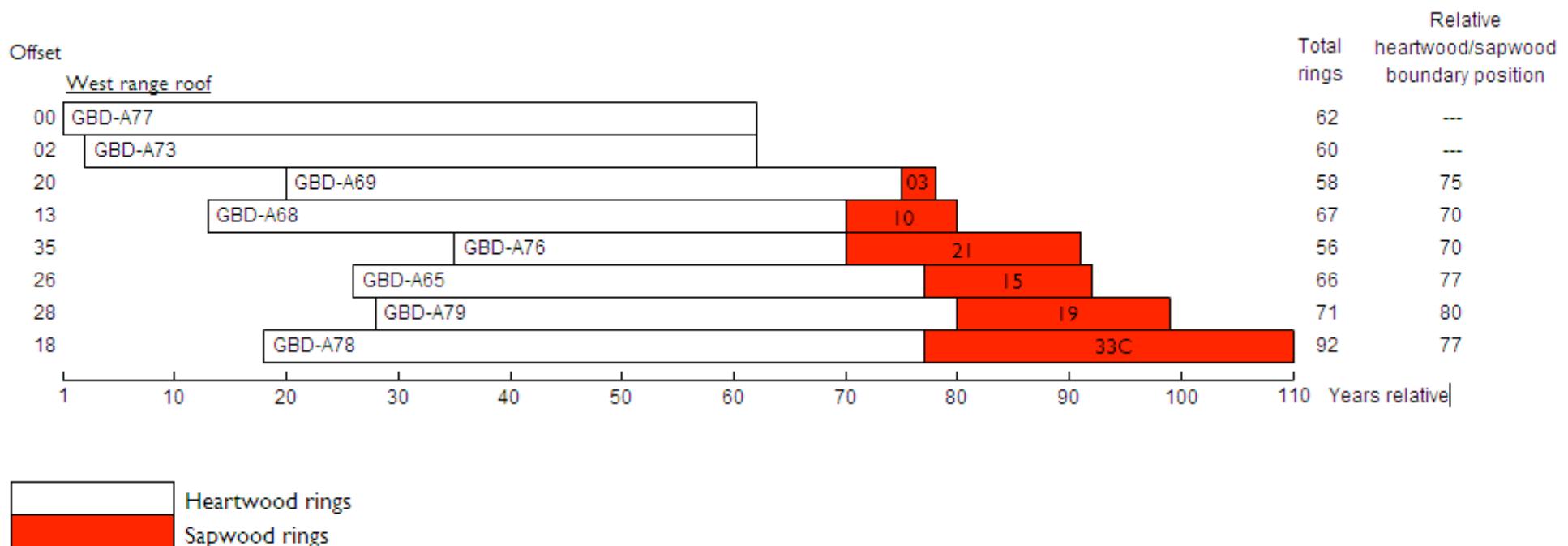


Figure 66: Bar diagram of samples in undated site sequence GBDASQ09

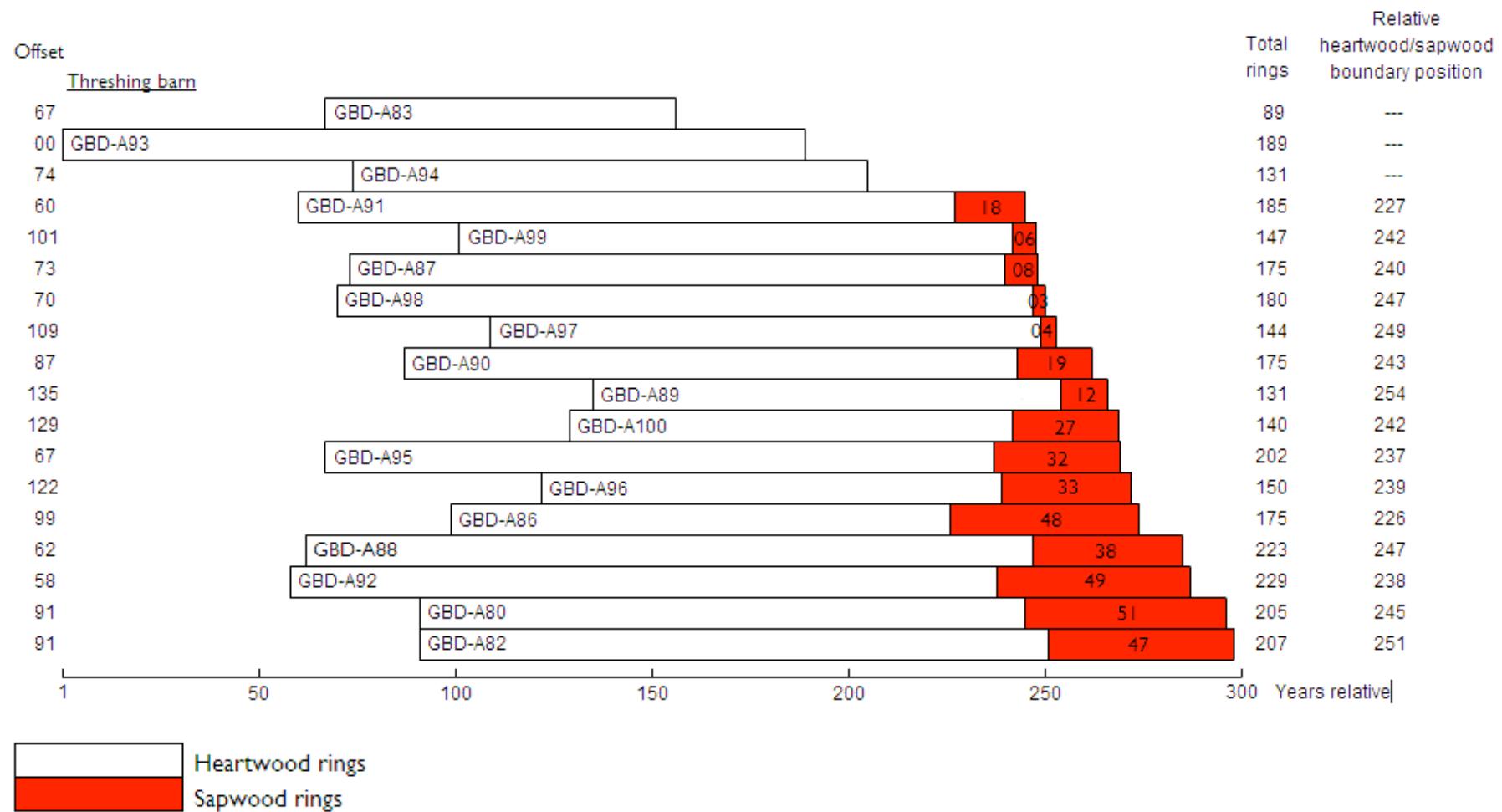


Figure 67: Bar diagram of samples in undated site sequence GBDASQ10

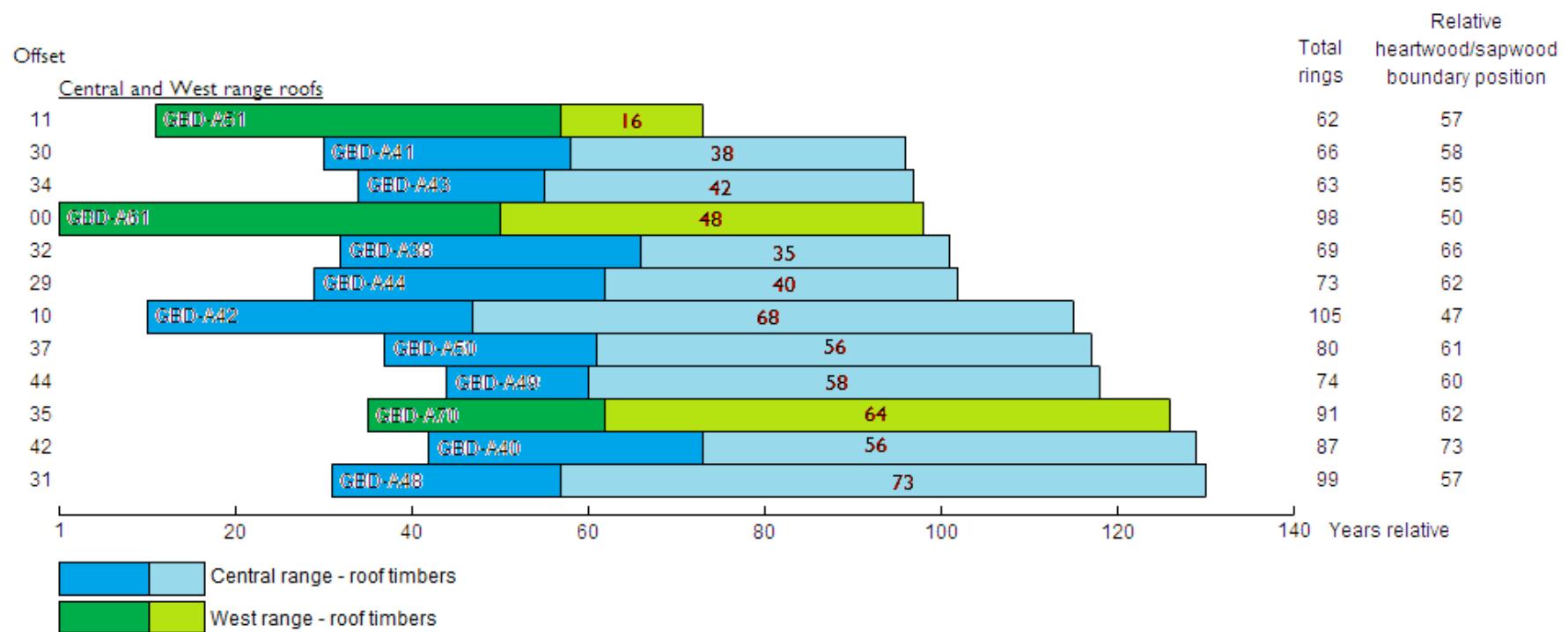


Figure 68: Bar diagram of samples in undated site sequence GBDASQ07, colour coded by area

DATA OF MEASURED SAMPLES

Measurements in 0.01mm units

GBD-A01A 42
148 340 427 193 428 415 454 407 583 508 523 453 429 249 385 310 472 369 399 368 265 364 379 217
336 402 349 353 275 330 293 301 300 186 163 168 175 159 277 186 224 240
GBD-A01B 42
135 340 400 217 420 426 454 371 588 481 525 461 426 250 382 308 467 360 397 363 273 344 378 207
344 385 362 348 285 345 265 304 300 206 176 148 176 160 281 200 203 239
GBD-A03A 54
501 378 445 288 424 495 547 419 345 311 343 336 375 233 192 178 250 176 176 199 167 100 160 126
99 107 109 82 158 159 158 145 174 204 146 140 130 179 167 159 136 116 95 74 92 67 81 73 47
64 50 57 87 68
GBD-A03B 54
406 471 385 356 415 514 534 432 345 279 366 335 383 253 211 160 252 207 185 205 157 108 175 127
96 111 106 82 147 148 160 142 170 192 133 135 114 137 120 129 126 91 90 73 100 68 76 66 48
72 58 62 79 75
GBD-A04A 48
420 548 507 483 375 334 311 390 291 136 141 147 194 151 133 131 113 90 88 103 88 98 68 85 67
47 55 63 81 42 69 61 60 53 52 42 45 46 59 46 40 47 34 43 50 55 44 52
GBD-A04B 48
416 560 501 490 385 333 290 392 281 137 128 157 194 157 148 134 117 92 89 103 104 85 73 75
69 50 50 67 78 43 72 60 58 45 49 49 44 39 61 56 44 47 39 39 46 51 49 53
GBD-A05A 44
475 557 514 464 520 258 368 374 499 410 557 433 443 361 425 248 357 306 434 396 417 342 315 415
418 245 340 362 367 296 210 239 212 246 212 151 177 147 195 219 211 186 171 245
GBD-A05B 44
479 545 520 454 520 268 364 376 506 406 556 444 420 353 430 259 351 308 448 409 408 349 311 428
419 227 350 387 376 300 210 246 226 252 212 146 172 152 172 203 259 176 178 245
GBD-A06A 63
110 227 236 151 179 173 105 123 138 204 243 279 335 293 293 313 227 162 220 256 230 300 282 206
171 272 248 285 391 360 267 458 379 323 438 286 213 232 204 263 260 311 322 273 321 437 422 353
234 171 180 200 143 167 211 226 222 196 261 284 221 281 318
GBD-A06B 63
158 196 225 174 171 170 105 126 138 200 237 251 327 298 270 327 231 176 211 250 233 309 278 214
185 267 253 286 390 353 255 461 396 316 431 261 221 267 178 265 258 311 316 269 337 445 459 341
239 174 162 226 135 186 191 211 215 221 242 286 225 278 319
GBD-A07A 53
228 320 293 266 300 239 309 431 408 238 378 307 233 467 234 308 273 214 267 149 231 315 236 230
270 262 194 256 195 152 159 158 196 317 374 321 323 296 346 375 292 250 283 237 305 294 321 357
347 266 194 157 152
GBD-A07B 53
245 300 283 276 314 230 325 416 405 243 408 314 223 480 255 306 289 203 282 157 227 313 253 228
269 272 232 245 205 149 161 150 202 330 379 324 314 318 345 380 288 261 280 246 306 297 329 359
345 264 196 158 156
GBD-A08A 71
363 287 247 170 125 157 230 166 334 325 397 240 187 301 245 253 237 311 250 131 228 226 297 283
226 178 183 192 289 159 193 289 232 197 263 173 256 185 189 165 282 219 309 223 201 329 236 277
347 217 222 197 170 206 201 154 173 236 180 220 184 130 107 107 97 150 157 145 153 150 144
GBD-A08B 71
362 285 246 167 131 177 219 173 331 328 414 237 200 270 238 257 224 319 254 108 252 236 278 285
238 166 202 185 281 185 187 281 237 227 262 171 289 170 186 180 282 220 316 207 195 316 244 268
371 205 223 193 155 236 204 164 166 243 173 224 172 138 102 95 103 141 136 138 161 176 139
GBD-A09A 55

42 34 58 136 163 228 289 171 150 102 71 74 73 83 107 96 95 108 112 119 158 105 113 198 204
154 118 136 196 231 283 260 242 176 135 105 40 81 90 53 56 76 133 125 148 122 114 128 147 163
130 162 173 196 156
GBD-A09B 55
34 32 58 140 163 231 293 166 151 104 74 70 79 79 110 90 101 119 93 125 171 113 115 200 215
156 102 125 185 246 272 282 240 177 139 108 43 68 96 51 55 81 129 128 148 120 114 131 149
154 128 163 184 179 153
GBD-A11A 61
128 112 129 66 128 246 256 235 284 176 225 345 326 139 80 141 309 351 289 289 466 264 409 307
228 285 219 254 199 123 173 219 300 309 295 187 201 274 215 274 262 93 115 143 241 192 151 206
294 150 127 134 90 128 170 155 232 358 350 477 210
GBD-A11B 61
134 103 125 77 122 254 258 237 277 196 232 310 308 103 90 143 295 350 310 339 496 252 416 306
226 302 228 249 196 120 214 226 296 314 285 194 197 281 221 261 269 94 89 150 244 186 160 193
310 157 118 130 83 140 180 148 220 268 361 482 216
GBD-A13A 56
222 195 249 309 252 154 149 107 184 143 193 204 205 192 131 152 145 110 86 83 123 96 94 110
81 82 152 226 216 201 193 156 151 250 262 281 228 164 261 197 273 217 78 174 147 188 174 131
119 135 95 124 176 105 92 174
GBD-A13B 56
214 184 239 339 241 141 150 124 188 162 172 200 205 180 143 152 140 104 81 81 108 104 86 109
81 72 156 239 232 228 172 173 142 242 264 284 215 156 265 208 271 212 73 173 137 179 169 127
117 137 101 117 163 97 103 117
GBD-A14A 51
157 274 176 125 118 147 185 284 285 192 166 121 121 107 125 148 120 133 145 117 150 152 202 181
135 133 134 219 161 161 163 202 197 157 177 157 141 82 103 154 125 118 174 121 122 169 220 242
222 157 174
GBD-A14B 51
158 287 177 119 123 145 162 286 281 188 193 130 111 101 131 140 113 132 165 120 141 146 204 179
139 142 145 208 165 166 159 194 195 159 166 168 151 103 110 153 127 113 183 113 134 185 253 240
205 137 160
GBD-A16A 53
314 344 295 288 306 460 269 242 335 230 189 199 190 166 125 172 104 102 220 340 274 203 222 229
236 360 403 399 272 191 329 280 335 268 152 118 125 139 203 122 108 124 113 154 204 116 143 135
156 140 121 130 127
GBD-A16B 53
309 336 298 291 307 451 278 235 335 217 209 197 200 150 132 168 113 105 222 342 268 203 226 223
248 375 432 389 288 193 330 294 322 277 154 121 121 143 204 115 110 121 131 138 214 119 133 134
157 139 119 157 99
GBD-A17A 54
231 349 290 198 250 216 265 240 115 127 189 276 217 210 332 235 186 276 267 274 346 156 94 195
319 210 144 151 192 220 280 285 210 210 193 168 175 189 142 147 234 246 110 101 112 190 170 239
305 198 212 128 131 130
GBD-A17B 54
277 347 288 200 248 214 270 232 121 123 196 267 211 223 343 247 189 288 262 275 344 150 96 190
324 209 146 146 199 245 259 281 200 206 199 160 178 187 147 146 233 248 110 99 118 182 184 231
309 197 211 125 131 144
GBD-A19A 69
70 79 191 223 184 106 159 89 484 574 519 490 288 341 395 277 376 336 371 393 423 325 435 403
328 359 321 271 465 458 422 335 249 335 254 320 52 34 33 74 85 109 139 168 139 139 207 187
129 190 137 190 252 229 185 158 194 141 173 146 128 170 143 190 139 135 144 195 235
GBD-A19B 69
92 80 192 223 208 131 153 86 466 570 523 503 294 327 335 285 402 326 369 373 410 319 441 412
322 355 320 274 450 457 430 343 269 331 250 319 53 36 35 76 90 97 143 162 147 136 211 168
118 193 135 185 261 240 175 160 185 144 162 150 138 169 143 187 134 146 131 194 231
GBD-A20A 78
238 381 265 199 226 237 246 244 234 204 195 175 304 236 235 280 97 257 326 362 381 407 274 217
167 184 131 137 111 170 141 142 123 115 126 183 109 134 184 161 191 142 157 127 107 87 129 150

90 89 111 152 98 161 165 154 95 129 99 144 155 104 110 115 138 136 120 125 81 174 125 184
151 124 141 130 65 83
GBD-A20B 78
215 377 267 198 226 236 245 243 234 214 188 189 302 232 228 274 102 258 323 365 379 394 271 219
164 179 133 141 117 163 148 145 121 117 127 176 106 144 192 156 186 146 161 126 111 89 121 150
89 95 103 155 96 167 154 155 95 126 109 141 144 100 101 110 120 129 132 127 105 164 128 175
151 131 135 133 73 81
GBD-A22A 89
94 79 139 200 147 132 259 263 250 248 398 280 231 275 320 313 369 401 257 244 325 262 256 246
288 152 237 202 223 235 156 171 212 198 219 168 176 200 270 195 227 153 200 260 301 213 245 277
259 207 180 173 147 141 171 99 86 78 100 82 111 78 101 87 85 63 76 57 67 63 68 43 61 89
85 70 47 43 83 65 83 103 67 59 67 71 57 76 67
GBD-A22B 89
83 79 134 201 147 139 261 273 262 252 412 271 233 277 317 314 371 395 263 245 318 238 241 245
282 148 237 210 222 244 157 161 204 174 216 182 189 207 259 186 229 163 199 240 309 205 250 284
274 202 169 163 158 153 178 87 89 87 98 96 107 89 94 85 74 60 82 47 69 73 68 51 53 85
83 71 44 47 77 79 78 111 62 62 75 65 59 70 78
GBD-A23A 97
215 326 227 193 262 288 220 215 248 200 275 224 217 159 172 171 216 167 204 219 197 145 281 154
163 137 112 160 180 147 169 144 203 131 176 167 221 135 192 132 101 106 140 111 129 115 143 138
123 104 83 104 109 75 94 111 94 100 76 109 72 70 73 52 44 56 76 62 59 55 51 69 55 49
63 49 71 98 144 211 292 313 279 183 218 220 218 125 273 212 179 169 175 138 119 139 184
GBD-A23B 97
210 318 218 198 261 287 258 205 262 199 269 225 229 151 166 169 203 167 219 236 204 148 279 143
170 147 115 148 197 154 158 138 215 115 194 163 208 138 194 115 105 102 139 115 139 111 168 96
126 115 86 97 115 63 103 120 94 103 74 106 67 76 72 49 50 54 76 70 56 53 52 64 54 59
57 53 65 94 148 214 287 318 270 184 211 241 198 121 300 207 175 175 162 158 123 150 185
GBD-A24A 111
191 239 295 264 355 437 243 279 290 249 323 258 281 373 163 352 280 291 327 267 288 211 337 190
210 225 146 101 144 181 166 167 233 204 121 124 176 149 150 140 80 89 109 94 94 84 135 99
110 119 142 118 141 116 119 77 99 78 75 64 59 63 69 64 56 45 47 39 64 66 70 49 70 63
69 60 48 59 62 50 48 66 80 74 73 64 62 56 38 41 62 60 68 99 76 84 63 52 58 50 63 66
105 89 67 86 57 65 37 42 43
GBD-A24B 111
180 247 291 270 358 446 271 283 302 257 320 249 274 371 161 351 274 293 338 264 297 208 345 190
199 241 142 120 149 180 154 158 215 204 121 125 175 138 146 145 83 84 114 87 100 81 146 104
104 129 144 116 138 132 112 78 98 78 82 67 61 55 62 55 60 43 45 44 68 64 59 64 60 73
61 55 52 57 64 55 45 66 81 71 73 67 58 59 54 37 68 62 65 105 70 87 63 51 56 52 68
66 90 101 73 67 71 64 43 51 36
GBD-A25A 61
351 472 432 342 253 123 159 223 141 94 88 109 96 121 179 195 168 157 293 181 260 280 205 269
414 339 348 233 280 281 206 259 207 204 220 291 269 181 213 151 202 178 179 119 149 212 197 182
218 165 239 179 247 291 213 235 208 212 179 150 136
GBD-A25B 61
366 457 430 348 246 134 161 217 141 92 88 114 92 126 171 200 180 149 288 182 255 270 161 268
432 359 247 256 280 302 203 277 204 200 216 305 267 192 214 145 201 178 171 113 141 220 206 180
208 167 240 177 253 287 218 236 206 200 181 139 138
GBD-A26A 110
157 295 220 231 222 229 204 294 272 318 299 253 272 291 305 157 130 223 154 102 250 422 238 147
140 238 119 63 44 51 34 70 72 78 72 95 109 119 111 96 54 39 37 68 82 53 50 44 59 61 52
60 81 61 87 83 91 87 128 97 113 98 135 120 117 137 202 167 133 202 180 124 137 160 193 223
286 225 150 149 112 104 124 153 150 108 113 116 149 142 218 149 121 136 161 115 125 112 137 169
137 125 137 100 92 103 95 131 85 99
GBD-A26B 110
196 279 224 220 213 218 196 296 277 305 308 235 273 294 310 162 127 221 150 103 243 410 282 137
153 259 110 59 71 40 42 67 87 81 76 114 123 115 108 77 53 41 42 60 91 56 38 42 43 60
59 61 70 66 86 76 91 94 115 109 105 99 142 119 122 152 207 182 134 204 173 126 156 155 191

225 288 221 149 147 116 104 130 146 138 115 104 115 154 140 212 146 130 149 159 120 136 120 119
158 135 125 136 102 98 132 113 128 91 86
GBD-A27A 76
226 162 162 260 371 231 172 216 280 111 80 61 44 44 45 95 83 97 154 114 139 137 98 66 61
58 89 98 54 26 48 39 44 56 41 53 46 62 49 59 77 72 80 68 62 80 61 76 73 84 94 55
84 66 76 83 110 113 92 89 87 55 70 44 51 62 66 64 60 80 56 86 65 80 63 70
GBD-A27B 76
196 162 164 271 368 227 171 218 280 119 73 54 49 43 44 102 78 103 154 106 142 139 94 66 59
71 81 101 42 34 41 43 45 55 40 56 42 62 54 51 62 75 82 74 67 75 65 67 85 79 94 55
80 67 67 92 97 124 87 95 80 65 66 53 51 59 66 67 56 82 57 84 61 86 60 64
GBD-A28A 69
33 70 86 60 80 82 72 50 49 66 51 45 54 36 29 57 78 69 62 71 98 90 103 117 105 83 110
58 92 95 135 116 69 98 77 110 100 91 87 108 122 85 78 79 61 52 49 62 82 41 41 71 49
50 82 44 58 73 55 53 63 41 38 35 75 46 48 68 48
GBD-A28B 69
38 63 88 66 73 85 63 60 53 58 52 51 47 38 33 58 73 78 60 66 101 96 98 119 104 88 113
58 80 106 136 107 77 91 85 98 109 94 87 112 111 94 67 90 54 55 56 58 75 47 45 64 60
40 84 56 57 68 61 56 55 43 37 40 73 47 48 66 48
GBD-A29A 114
32 23 32 28 25 33 26 49 45 28 26 31 28 36 42 20 43 34 28 37 46 44 37 35 43 45 38
29 45 56 71 89 62 64 106 108 80 114 146 115 109 84 95 60 89 103 113 58 69 72 89 85 105
93 78 76 58 49 57 78 68 47 78 57 75 71 70 52 68 62 76 56 48 53 40 38 58 64 50 46 45
53 62 110 56 71 66 55 54 70 99 48 60 81 55 84 120 85 74 87 84 68 51 68 38 40 27 61
48 66 71 71 79 88
GBD-A29B 114
23 20 37 30 23 29 29 50 46 38 27 27 29 36 42 19 37 30 34 39 49 41 42 36 36 48 42
23 46 56 72 103 57 64 112 108 78 110 140 117 119 83 92 60 91 95 122 63 62 83 89 81 106
90 81 80 54 49 53 70 70 49 83 54 75 68 62 63 69 61 78 52 47 41 45 44 52 68 48 44 50
47 64 107 54 63 69 53 58 74 97 53 57 74 62 87 116 87 70 85 92 66 53 65 38 44 32 55
45 65 74 71 79 83
GBD-A30A 112
80 109 137 143 142 132 117 131 143 130 159 87 96 127 155 125 167 182 149 138 151 116 122 76
68 61 81 61 83 82 101 107 92 74 89 74 82 63 51 54 74 66 61 72 85 51 69 48 40 33 41
21 27 33 33 31 33 21 27 38 34 35 29 30 45 33 30 39 34 38 44 35 38 60 73 49 46 40
38 40 43 45 35 27 34 28 19 43 22 55 59 35 54 49 40 56 71 78 68 61 89 101 111 81 67
66 85 98 77 128 139 93
GBD-A30B 112
83 104 134 138 141 130 120 129 131 131 158 84 94 126 151 131 155 186 127 155 142 129 119 79
66 74 90 61 68 77 100 104 90 72 86 81 79 58 57 50 68 68 59 66 82 54 70 46 45 34 39
25 29 29 35 25 35 18 29 32 34 41 28 30 37 34 37 40 42 33 40 36 37 53 74 50 43 35
48 37 42 40 36 33 34 23 19 40 25 58 49 37 57 48 35 61 67 79 69 64 90 91 120 77 69
60 91 95 72 135 106 129
GBD-A31A 106
185 190 179 213 190 136 148 130 96 119 112 98 93 92 68 80 80 115 100 90 100 111 104 88 80
67 86 99 114 72 93 87 60 54 52 77 39 38 49 59 42 54 45 89 89 54 74 79 90 105 125 105
131 130 115 135 148 100 86 93 126 95 134 91 115 70 76 62 98 116 93 62 77 75 42 52 35 40
53 42 68 83 89 94 125 153 104 85 65 71 87 80 83 85 70 95 71 86 87 96 61 63 103 79 93
100
GBD-A31B 106
177 190 174 223 190 130 140 136 102 114 108 108 82 94 75 83 79 101 107 81 99 109 105 78 70
68 76 110 108 78 78 93 58 63 53 70 47 43 43 51 52 48 52 92 78 58 73 71 94 106 121 109
135 129 116 133 151 90 101 90 128 98 120 91 106 95 72 65 81 122 91 70 77 78 37 62 30 37
60 49 86 74 90 91 125 152 102 93 79 66 89 79 85 70 71 86 80 73 109 92 73 56 102 69 85
100
GBD-A32A 101
106 191 250 120 140 174 201 168 282 255 228 169 194 129 124 146 64 85 74 74 59 65 105 107
99 146 220 127 55 67 58 87 50 74 70 86 98 146 139 184 144 102 140 170 178 195 129 51 76
153 128 285 162 303 477 342 328 258 244 262 266 277 181 143 141 136 130 220 134 127 103 124 82

117 105 88 68 98 199 164 159 98 153 125 76 167 134 101 111 118 187 190 154 173 228 362 189
180 121 156 106
GBD-A32B 101
127 193 246 124 143 177 197 168 271 255 206 168 203 163 163 136 71 83 79 88 56 65 110 99 103
142 222 129 58 70 57 84 52 69 72 87 99 145 133 181 138 111 133 182 167 204 124 57 58 164
132 279 166 309 477 348 334 250 241 273 265 272 170 149 140 133 132 201 136 126 110 116 90 115
99 89 74 95 201 157 165 98 147 130 69 176 126 99 111 120 186 194 152 182 233 359 184 175 127
160 104
GBD-A33A 93
114 233 302 291 167 203 187 210 191 107 156 147 136 108 103 136 157 148 186 153 129 76 86 95
108 93 122 107 95 87 94 115 126 109 73 72 59 81 83 90 52 82 129 80 114 119 153 180 189
161 88 126 114 106 119 72 91 73 81 57 66 74 68 65 59 55 60 50 34 33 50 101 68 106 64
57 78 58 83 87 64 82 92 134 158 155 187 199 249 174 178 118 133
GBD-A33B 93
118 218 305 206 138 215 207 216 194 100 124 142 144 103 104 138 160 149 181 152 126 83 78 96
102 101 123 103 106 75 81 100 128 101 72 70 76 61 86 85 63 90 121 83 114 106 155 189 195
163 97 126 99 113 128 60 91 64 82 59 69 76 76 66 57 54 63 59 35 38 43 83 74 110 58
66 77 50 100 80 72 81 103 149 170 150 182 203 257 179 179 118 145
GBD-A35A 49
188 174 85 80 77 124 160 112 149 197 227 135 130 147 144 197 192 255 327 292 295 321 230 248
257 176 209 248 216 183 116 148 145 395 617 412 303 350 335 321 278 263 178 276 204 163 171 201
137
GBD-A35B 49
187 169 90 65 88 120 150 127 159 192 212 148 129 147 144 189 201 260 338 303 283 323 244 234
264 170 219 256 203 182 125 132 158 392 632 415 313 340 333 337 273 253 200 263 204 151 192 192
189
GBD-A36A 174
202 183 164 111 171 115 108 93 85 113 64 83 63 102 63 93 163 92 118 147 89 93 53 91 131 95
52 64 63 106 81 100 71 67 118 70 62 53 53 45 55 42 46 48 61 52 55 51 40 62 47 39 35
52 46 42 39 46 42 38 31 26 49 24 24 50 70 53 62 66 49 44 36 39 33 34 49 61 61 41 41
49 123 82 83 112 93 79 44 38 32 36 63 66 82 110 100 75 43 43 48 45 47 40 55 75 60 60
64 49 40 80 39 67 76 60 46 48 48 40 59 51 46 50 32 52 32 30 46 37 32 35 30 27 34
35 22 26 27 38 43 34 35 38 32 50 50 42 44 51 59 58 48 52 67 74 56 78 102 120 222 146
147 133 123 127 93 95 64 44 80 112 136 133
GBD-A36B 174
202 158 156 118 165 114 116 89 82 97 62 84 64 104 69 82 169 90 100 155 99 92 55 89 131
91 54 61 66 109 77 99 77 66 128 77 52 54 39 43 54 46 50 39 74 48 39 70 40 52 56 38
44 44 53 37 39 32 36 47 33 32 47 23 42 39 62 53 66 61 51 44 41 29 35 40 38 61 64
45 41 42 127 103 90 120 97 75 42 37 27 46 58 75 72 112 98 91 45 31 44 47 38 40 52 67
57 61 65 47 45 76 46 54 82 61 57 43 41 51 68 47 47 48 35 44 34 33 50 30 40 26 28
29 38 32 22 20 32 40 41 34 36 32 33 53 53 41 42 44 60 60 48 50 64 75 52 85 97 122
219 153 140 131 119 124 96 94 60 52 73 111 135 134
GBD-A37A 50
51 47 52 62 82 111 107 96 91 136 134 106 122 182 129 154 104 69 96 120 75 125 189 184 188
214 345 265 259 246 170 195 151 153 137 191 215 92 106 137 132 125 101 109 133 183 333 277 176
173
GBD-A37B 43
93 125 132 100 132 141 127 143 91 77 89 131 90 120 172 197 194 152 282 225 214 202 200 160
126 112 117 161 162 77 60 113 79 79 59 71 70 56 82 115 115 121 138
GBD-A38A 69
146 149 134 123 157 126 125 127 114 127 111 118 130 141 127 125 137 177 179 141 160 143 136 137
147 127 167 151 133 134 163 113 97 133 104 77 99 170 178 254 171 142 150 98 76 94 78 85 117
126 113 141 142 119 120 123 90 111 96 65 83 84 85 88 75 117 111 96 93
GBD-A38B 69
144 149 134 125 152 127 125 129 114 125 104 117 126 140 131 124 136 172 183 136 159 147 132 138
141 136 164 152 133 129 157 112 101 126 104 87 94 168 180 249 178 139 148 100 73 91 82 82
117 120 105 141 143 124 122 97 105 102 61 89 77 91 82 75 121 93 108 94
GBD-A39A 66

368 578 555 436 465 466 470 285 283 308 363 342 356 195 221 231 255 249 181 162 220 139 162 164
166 135 139 199 161 119 105 111 76 87 116 120 153 140 137 124 114 135 147 132 122 102 80 106
85 83 84 80 85 90 70 75 79 101 112 105 67 82 124 122 95 88
GBD-A39B 66
313 582 556 431 460 488 453 326 297 315 358 345 313 227 198 242 236 254 201 168 196 164 182 147
170 130 120 213 156 109 113 118 68 88 118 123 163 132 137 120 110 109 139 133 135 92 85 106
86 80 87 74 92 88 66 73 76 103 114 101 73 74 125 124 87 84
GBD-A40A 87
174 250 202 185 180 157 185 230 175 167 188 151 187 189 186 172 190 179 199 197 141 141 134 150
108 94 131 216 193 174 145 143 133 109 81 94 135 120 190 182 149 158 190 149 120 113 109 131
109 78 74 84 89 85 55 95 114 113 136 187 178 168 147 111 93 98 140 166 116 173 111 112 87
85 66 72 81 106 183 136 80 97 51 35 59 58 46
GBD-A40B 87
170 254 190 184 180 157 182 220 171 170 183 147 186 184 188 176 188 168 191 204 135 142 133 156
118 97 147 187 170 196 135 125 130 112 80 93 127 130 177 177 151 158 185 150 123 118 104 126
113 71 75 81 93 84 56 97 115 108 138 192 183 166 146 110 95 95 136 171 118 160 118 112 83
84 64 71 85 114 184 131 74 92 58 37 58 55 45
GBD-A41A 66
170 160 107 114 156 143 136 136 105 109 95 130 136 154 103 121 128 122 118 168 115 117 144 122
146 108 121 110 101 132 149 125 127 125 116 118 84 69 111 132 104 130 131 135 135 107 71 98
82 75 105 110 91 125 137 114 112 123 92 116 108 69 94 90 97 66
GBD-A41B 66
181 186 112 118 154 151 137 139 112 120 109 123 131 163 116 135 121 97 145 171 131 123 139 123
142 108 119 109 103 121 153 148 128 123 117 121 79 75 103 136 104 126 132 141 131 103 77 94
87 75 111 94 95 119 136 120 114 119 99 121 106 72 88 88 88 85
GBD-A42A 105
216 212 196 152 153 158 118 193 187 192 175 194 125 202 160 123 93 107 107 115 126 103 97 93
117 116 134 132 103 71 63 76 73 100 60 99 88 70 80 97 83 108 109 90 94 147 136 118 74 86
85 90 79 79 86 79 66 60 95 94 92 70 72 78 84 64 55 58 64 53 67 72 71 90 86 77 85
94 76 103 70 58 66 58 53 55 49 55 59 42 43 47 42 54 46 38 31 39 59 59 53 67 65 64
61
GBD-A42B 105
216 217 195 151 155 151 109 193 188 196 180 200 121 197 153 126 92 106 100 108 130 110 96 95
115 116 146 120 93 79 58 75 75 99 60 97 100 64 89 93 92 100 114 83 98 141 141 106 92 78
90 82 88 76 87 71 71 58 94 97 91 70 73 80 70 61 53 57 75 51 65 81 68 92 79 81 83
95 74 97 66 52 65 57 54 55 48 49 58 45 40 41 43 64 42 36 36 40 55 56 56 65 68 64 59
GBD-A43A 63
225 258 307 273 217 171 146 176 196 232 173 168 131 145 129 135 134 113 141 129 134 141 171 132
118 122 164 148 133 135 135 162 122 95 128 157 118 109 103 118 148 112 62 91 82 70 109 104
75 111 95 90 79 87 69 97 84 58 70 67 88 76 68
GBD-A43B 63
206 256 298 278 226 166 147 177 204 225 180 163 132 117 126 171 142 116 138 139 127 144 169 136
119 114 168 148 137 132 131 164 124 96 126 155 115 112 109 121 143 110 61 91 80 63 99 100
78 106 110 99 88 91 75 99 89 50 74 71 81 85 66
GBD-A44A 73
337 338 303 254 244 252 275 216 156 126 144 170 186 178 142 178 148 136 149 129 115 132 144
128 164 162 166 130 112 99 140 128 151 131 144 142 107 85 143 152 127 145 120 130 147 132 100
123 103 88 121 121 94 118 105 75 75 101 96 146 136 85 95 83 75 86 67 99 101 90 83 97
GBD-A44B 73
321 342 306 255 245 250 267 280 215 159 125 144 178 184 151 155 187 160 141 150 133 120 132 147
118 161 162 166 134 110 105 140 127 152 130 146 144 117 83 139 148 121 146 113 144 150 123 95
118 107 89 125 123 96 107 117 74 82 80 86 119 133 84 102 82 76 87 69 96 99 91 82 99
GBD-A48A 99
267 208 191 179 254 258 297 193 146 152 134 175 126 152 150 149 128 138 156 139 129 164 100 132
128 143 119 107 83 106 124 116 109 108 107 88 81 118 163 158 169 127 156 171 115 72 90 69
66 88 100 80 101 104 102 80 85 74 111 86 71 88 80 91 80 57 81 81 61 70 73 59 64 58 72
60 83 86 73 77 77 62 84 74 80 55 63 60 63 64 44 40 43 39 30 45 38 34 43
GBD-A48B 99

263 205 180 161 240 262 286 213 151 151 135 172 127 150 154 144 129 132 160 137 128 156 104 136
127 139 122 107 83 104 117 119 110 102 111 88 80 119 162 157 180 127 162 173 113 80 84 68 63
93 98 79 110 103 101 78 90 70 115 87 74 89 82 93 78 56 75 85 60 70 73 69 62 65 66 62
79 90 86 73 80 70 86 80 76 59 59 67 60 50 36 43 37 27 44 42 36 45
GBD-A49A 74
216 227 248 191 181 150 145 150 206 242 235 210 213 183 147 159 281 237 178 145 134 155 130 103
126 168 166 208 162 176 188 136 106 121 111 100 150 139 137 139 158 163 149 127 86 122 108 65
68 61 67 60 50 75 66 58 66 70 64 58 55 71 64 70 109 100 105 117 97 98 79 82 44 42
GBD-A49B 74
189 253 246 272 174 149 129 157 209 247 188 208 235 168 132 150 288 234 174 148 134 154 122 104
122 171 159 208 166 177 183 126 115 124 111 87 147 141 137 140 154 161 150 127 88 119 113 69
63 62 72 59 49 72 71 61 67 63 62 54 59 80 64 74 101 106 104 118 100 108 85 75 48 47
GBD-A50A 80
173 222 204 219 282 278 308 171 210 203 176 194 196 126 145 174 198 195 240 206 145 125 179 255
180 154 132 122 147 125 67 98 127 106 114 107 107 119 86 86 87 90 78 125 131 105 128 114 128
150 138 118 145 102 72 77 87 84 54 46 46 61 54 72 84 64 69 90 76 70 77 122 92 82 103
86 99 86 81 72
GBD-A50B 80
214 212 208 227 278 298 287 157 211 216 186 195 212 154 134 181 211 201 240 214 162 128 179 225
180 157 128 120 146 128 63 97 123 111 113 101 111 122 85 89 90 84 75 127 127 111 127 112 123
145 147 120 138 116 65 80 76 84 49 42 53 60 57 74 81 67 73 86 80 66 84 123 97 82 105
89 94 87 82 69
GBD-A51A 62
326 327 520 488 430 457 445 374 375 409 442 371 365 305 295 269 291 298 294 325 286 326 307 304
267 301 204 169 154 138 184 213 221 173 181 181 195 167 206 141 145 167 146 194 167 205 185 130
159 180 181 166 110 103 122 95 76 78 96 78 75 54
GBD-A51B 62
318 343 490 486 433 459 456 372 377 411 444 369 361 307 295 266 295 296 295 328 305 316 312 302
276 301 205 159 153 139 176 224 221 187 163 188 191 159 199 141 143 170 147 195 170 210 187 123
156 179 183 161 116 105 125 93 77 84 91 74 75 59
GBD-A54A 86
130 135 169 160 234 148 186 154 145 139 181 138 137 200 155 99 118 119 100 127 186 111 112 171
116 169 132 86 176 147 136 120 140 139 99 81 118 114 126 108 93 145 69 82 67 101 107 143 111
170 88 131 158 137 148 111 139 84 96 132 103 77 106 54 67 81 57 50 73 87 76 60 78 82 99
83 99 85 115 136 69 76 66 62 99 85
GBD-A54B 86
155 141 162 159 236 144 179 152 159 149 176 136 134 203 154 105 120 117 103 121 186 100 113 174
111 175 126 90 175 152 143 124 137 136 94 84 127 108 129 107 91 145 63 87 60 104 110 148 114
164 89 135 157 138 145 110 140 82 105 122 107 91 109 51 68 87 60 50 84 81 86 61 89 85
101 80 101 78 107 128 66 73 67 60 99 84
GBD-A55A 63
172 253 247 159 185 202 121 226 288 230 295 209 206 208 255 318 289 289 173 159 189 149 129 179
202 198 146 215 224 184 163 183 174 202 129 139 149 186 177 183 233 152 132 117 134 145 180 124
114 104 107 129 131 101 119 137 104 96 85 113 92 112 157
GBD-A55B 63
168 263 242 154 190 199 122 228 290 223 291 208 201 208 261 325 283 291 175 151 188 155 123 191
194 206 147 223 219 179 168 184 168 194 133 141 157 184 168 186 225 149 140 111 131 147 185 128
109 107 112 125 130 106 109 146 104 95 84 111 93 108 156
GBD-A56A 64
360 661 401 533 678 493 367 549 404 452 534 349 377 459 446 382 301 305 404 299 393 399 288 178
239 198 183 190 246 308 223 209 184 178 156 180 188 256 147 193 117 163 132 140 146 155 138 108
86 94 89 86 78 85 113 135 176 195 143 144 166 202 151 151
GBD-A56B 64
357 651 406 533 683 473 368 557 387 464 549 365 375 448 452 383 304 305 406 301 386 394 288 175
235 202 191 182 246 273 221 210 177 183 153 183 206 253 151 199 113 153 135 141 133 152 141 111
84 96 87 89 75 83 112 137 173 194 146 146 166 199 156 143
GBD-A57A 73

797 355 598 393 465 620 478 328 467 396 406 535 391 317 342 386 264 237 220 328 239 324 399 279
148 225 193 187 128 188 211 181 167 135 135 107 151 133 149 91 158 123 157 130 157 161 133 96
114 89 98 86 99 93 87 143 182 218 178 142 137 141 153 125 110 109 118 93 75 101 109 156 172
GBD-A57B 73
804 346 585 406 424 608 479 346 452 383 411 517 373 301 324 374 262 236 217 317 240 316 394 278
151 218 178 171 129 203 197 180 160 135 139 111 146 130 138 91 161 124 165 126 151 147 129 97
101 79 90 83 95 90 87 136 178 214 173 133 129 139 156 132 123 109 110 96 72 98 111 163 167
GBD-A58A 65
287 136 153 220 207 191 142 177 165 167 147 139 125 113 138 116 116 80 124 124 142 119 105 101
81 84 79 53 97 73 69 75 100 126 125 150 177 117 116 110 125 98 113 96 71 86 73 60 65 72
82 81 46 64 88 77 70 60 61 89 67 64 58 57 45
GBD-A58B 65
287 136 157 227 201 194 134 190 169 165 147 140 130 110 143 120 110 77 130 125 162 131 117 96
93 67 83 57 95 68 72 77 93 133 125 141 179 133 128 108 117 97 114 96 61 87 73 61 72 79
79 81 47 64 89 74 75 61 57 94 71 60 58 51 36
GBD-A59A 111
351 322 241 210 226 211 334 495 348 171 284 222 169 127 208 238 191 158 140 158 107 129 132 143
79 121 110 181 171 138 162 128 70 66 50 80 84 71 62 95 121 125 183 188 112 90 93 78 90
108 121 65 79 75 109 69 90 78 121 126 154 106 79 74 100 96 92 74 60 78 50 47 76 35 63
90 87 83 44 50 72 82 85 77 105 52 35 38 52 60 52 57 42 55 56 41 37 41 48 49 62 45
50 41 55 50 66 55 48 48 41
GBD-A59B 111
341 317 234 189 235 204 337 493 353 161 278 229 172 120 211 243 184 161 141 150 109 132 132 132
80 110 104 179 176 144 160 131 71 60 56 76 98 67 59 94 114 120 199 187 118 88 87 91 78
104 115 77 80 87 97 72 78 81 103 120 166 116 100 94 85 109 83 76 55 70 58 50 65 47 57
96 75 79 54 59 72 89 74 92 83 56 35 39 50 67 48 54 42 53 55 47 43 33 49 49 61 49 45
53 53 51 67 60 41 53 39
GBD-A60A 100
213 365 303 380 291 290 265 282 226 238 179 200 173 260 342 215 164 255 220 171 125 169 247 188
195 152 169 137 146 136 147 91 146 113 129 157 152 172 151 91 86 134 90 105 118 126 134 139
133 119 153 158 136 119 115 97 102 126 123 110 98 74 92 121 122 93 60 72 72 75 78 58 85
91 73 59 46 39 44 51 30 46 73 74 83 67 81 84 103 77 97 78 54 42 40 50 67 55 67 62
GBD-A60B 100
182 370 310 370 298 288 268 284 215 224 180 206 166 258 335 217 161 255 212 189 125 169 232 178
192 139 146 122 142 135 154 95 143 105 116 161 160 173 147 105 92 123 88 90 135 124 140 137
130 129 154 160 136 125 115 94 105 125 123 110 92 72 99 123 128 89 67 73 67 70 78 61 89
89 78 56 47 48 38 54 34 46 68 77 81 68 75 83 102 81 94 79 54 40 39 53 68 57 65 65
GBD-A61A 98
332 296 343 371 315 314 232 252 195 192 163 177 148 142 131 189 157 152 129 132 159 148 128 171
122 92 80 159 107 105 138 85 92 93 104 130 126 109 96 76 108 87 95 88 74 89 81 58 78 72
78 79 81 65 87 84 109 117 102 87 90 111 103 78 98 84 60 58 78 100 71 53 46 48 67 51 41
60 62 44 65 72 52 78 88 86 105 102 66 73 59 40 51 46 55 56 55 70
GBD-A61B 98
333 299 345 367 323 299 234 244 194 162 155 169 153 156 132 188 158 154 125 124 160 141 139 196
121 88 93 149 112 104 135 91 80 77 108 123 133 112 94 83 102 94 88 92 77 92 77 60 76 65
79 88 91 55 87 77 120 108 102 85 96 116 89 78 81 78 59 59 96 98 70 51 39 52 66 51 43
67 59 44 66 71 55 84 86 91 99 99 72 77 55 45 48 41 60 59 45 62
GBD-A65A 66
161 207 257 197 187 185 172 170 151 168 257 192 175 258 208 273 268 286 241 213 282 235 186 175
167 224 229 290 214 267 285 201 186 241 215 266 241 260 253 263 291 195 252 233 221 270 304 187
292 241 297 293 258 276 287 236 234 222 251 297 259 229 253 262 240 238
GBD-A65B 66
191 219 262 197 195 191 160 166 158 169 261 185 173 260 225 273 256 277 247 206 296 231 183 174
165 221 241 281 216 260 315 202 184 235 223 262 245 257 252 261 299 194 249 240 218 269 309 190
295 239 299 290 258 279 277 246 236 213 257 290 259 216 257 261 239 225
GBD-A68A 67

235 173 178 247 293 294 327 340 278 299 340 345 377 335 301 385 334 304 331 277 225 289 310 375
288 322 374 325 410 416 420 371 286 375 350 256 227 209 262 243 264 212 225 267 182 172 228 204
220 226 236 250 258 312 211 267 250 241 266 319 188 290 230 237 224 207 247
GBD-A68B 67
239 170 174 249 291 295 328 340 276 297 342 343 376 341 307 386 328 312 322 279 223 293 313 370
291 319 380 324 410 410 423 374 286 379 337 263 228 216 265 246 255 218 222 265 184 176 231 200
230 221 235 255 254 314 204 270 252 240 265 315 200 284 227 233 229 214 240
GBD-A69A 58
236 221 191 297 269 326 238 269 335 292 235 244 210 199 232 257 331 263 252 290 270 312 331 329
287 230 360 299 217 192 210 255 285 291 235 249 273 245 193 286 211 246 225 233 250 248 264 193
247 203 198 212 250 162 255 179 202 224
GBD-A69B 58
217 220 237 277 252 296 249 269 330 283 249 240 208 189 236 253 330 244 257 282 262 319 311 328
276 233 367 296 222 189 217 262 284 289 242 255 276 238 193 284 233 237 228 228 248 247 262 197
241 209 193 205 251 159 248 182 211 218
GBD-A70A 91
124 123 137 131 103 141 148 154 180 141 127 141 110 139 150 120 100 113 109 125 128 151 151 130
140 162 159 123 125 107 132 108 76 111 160 148 166 157 150 164 114 77 81 85 79 126 120 95
136 156 136 126 120 90 127 114 76 82 80 82 80 56 101 94 82 83 124 101 88 109 91 84 100
113 93 78 110 96 109 92 103 62 73 64 86 75 75 80 102 83 48
GBD-A70B 91
121 127 131 130 106 142 146 156 189 142 129 147 118 137 143 118 97 107 117 118 132 162 154 138
123 162 165 121 122 111 134 104 83 108 168 152 165 163 168 141 120 71 86 89 74 130 120 95
138 163 127 123 126 93 124 121 73 91 72 87 73 64 100 91 80 87 127 99 84 104 92 89 106
107 103 77 110 98 101 97 99 63 79 60 87 76 73 84 87 80 58
GBD-A73A 60
154 396 224 175 139 210 195 176 144 78 104 103 58 72 125 129 110 115 108 93 108 134 137 173
129 134 140 148 133 123 102 123 118 120 165 149 143 194 182 200 208 211 215 187 220 205 197 174
187 236 243 244 187 218 250 170 164 209 173 173
GBD-A73B 60
178 436 226 173 144 221 190 164 132 82 104 111 49 76 124 130 122 107 105 95 112 138 150 176
125 125 151 150 131 119 102 123 119 127 161 146 146 199 173 203 210 209 216 196 222 200 195 166
171 242 253 231 200 211 248 187 151 208 184 194
GBD-A74A 54
320 416 374 497 444 351 266 303 336 323 256 185 183 185 142 275 328 238 215 216 156 160 172 156
155 155 143 148 120 116 79 113 143 179 172 144 161 150 154 137 141 111 103 102 74 99 118 100
89 82 52 57 59 68
GBD-A74B 54
328 418 361 494 440 350 261 312 333 324 279 195 192 185 141 268 333 237 218 210 154 164 172 160
148 154 144 150 107 116 82 111 144 178 173 141 164 152 157 133 141 114 95 97 71 96 117 99
85 79 57 57 60 61
GBD-A76A 56
291 382 299 307 360 327 376 360 376 324 248 334 277 246 215 220 254 260 295 249 281 320 253 203
294 219 242 243 224 221 281 297 190 226 210 210 245 290 186 260 217 220 230 164 221 241 213 236
186 234 258 229 212 213 240 165
GBD-A76B 56
284 380 305 307 353 329 372 374 370 329 245 328 285 239 209 229 265 269 293 255 279 319 256 207
279 229 246 240 233 222 262 295 197 239 212 202 255 299 179 266 217 223 219 160 215 235 211 228
188 233 253 228 208 215 241 176
GBD-A77A 62
352 394 344 317 235 220 148 185 204 224 188 202 248 250 204 237 266 269 206 202 199 162 181 178
192 201 140 180 224 189 181 192 184 182 171 159 216 179 153 222 206 209 231 226 209 202 212 225
199 168 199 208 210 223 202 191 228 167 183 201 197 188
GBD-A77B 62
332 408 343 310 284 289 146 179 200 223 193 211 239 240 212 237 268 270 203 197 200 158 181 177
196 200 134 186 230 187 189 188 182 178 170 155 214 178 150 218 207 210 223 230 210 205 214 221
196 167 199 211 214 217 194 201 236 165 181 201 197 192
GBD-A78A 92

195 187 215 149 147 176 188 186 155 257 214 197 165 154 133 141 122 115 185 140 116 166 168 170
181 212 187 182 197 188 173 125 171 161 184 201 176 189 172 174 151 167 159 142 164 137 153 155
204 129 124 96 106 164 148 125 144 117 121 113 113 143 144 116 109 72 81 74 58 78 81 79 93
92 89 110 86 100 84 100 75 71 79 79 74 75 85 73 101 119 143 75
GBD-A78B 92
151 184 212 138 151 176 188 185 154 260 211 198 163 157 136 138 137 117 184 145 109 169 173 164
185 226 180 182 200 182 183 132 169 168 179 188 168 200 172 179 149 173 150 136 163 146 151 170
198 137 120 95 112 165 143 117 148 117 115 104 118 128 148 119 115 69 68 84 60 80 72 88 88
94 85 103 94 104 82 101 68 89 73 75 77 76 83 73 112 118 140 75
GBD-A79A 71
175 199 181 183 159 155 163 153 209 198 171 195 184 212 210 258 240 209 205 180 196 148 173 182
206 195 162 175 161 165 155 174 190 178 174 163 171 202 216 166 147 121 99 203 223 195 196 135
154 151 111 146 198 159 177 159 137 178 132 146 138 157 237 242 201 244 156 140 112 155 86
GBD-A79B 71
138 202 178 187 155 156 163 162 198 204 170 197 201 209 213 256 241 213 196 188 193 136 182 192
217 188 160 174 162 152 156 172 191 174 171 163 175 208 219 167 146 112 107 204 221 194 196 135
158 146 118 147 190 164 179 156 139 177 134 159 126 158 238 237 211 236 156 141 107 152 90
GBD-A80A 205
211 237 188 187 191 212 181 207 227 253 276 324 232 217 105 159 207 197 167 137 163 170 147 144
124 103 94 110 91 97 151 114 86 40 61 77 122 116 127 161 161 167 134 134 131 129 131 144
165 103 122 154 236 239 132 121 113 130 91 96 68 63 89 78 67 68 61 67 51 63 74 73 90 86
81 75 103 76 91 81 78 72 117 78 80 66 69 80 70 92 51 61 54 56 55 58 49 60 54 60 56
54 48 63 61 43 43 48 67 57 52 46 41 44 45 57 39 47 38 45 42 32 38 50 36 32 30 38
47 43 28 43 30 28 27 31 29 44 35 32 28 34 35 37 43 30 38 40 45 37 39 38 41 40 40
40 39 32 26 27 20 36 35 29 42 38 41 45 39 44 46 45 41 34 34 25 25 25 29 30 29 34 33
31 36 25 40 37 40 43 46 47 40 33 30 43 41 40 40 50 60 55 61 85 76
GBD-A80B 205
204 240 187 188 193 222 186 209 239 266 268 346 242 217 104 155 228 189 161 138 163 155 162 144
133 116 101 112 84 101 154 107 85 39 57 84 117 123 126 156 148 150 132 127 146 132 120 140
168 108 117 156 201 237 133 123 113 131 89 100 65 64 91 75 71 58 66 69 52 65 73 73 95 74
85 79 104 77 87 80 75 73 122 75 81 63 71 82 70 81 58 63 54 54 59 58 50 57 56 58 56
59 46 63 58 43 41 55 64 58 47 45 42 54 52 60 40 50 44 34 40 39 43 49 33 26 36 44
44 37 36 46 28 28 26 26 29 44 38 27 29 36 40 33 41 31 38 52 38 35 37 46 41 37 41
39 41 30 24 24 27 32 43 26 37 38 42 47 33 41 48 49 35 34 36 24 31 26 25 27 29 37 31
33 33 34 39 33 41 45 50 45 39 30 37 44 45 32 41 53 55 53 65 79 83
GBD-A81A 132
190 219 163 174 194 170 84 109 144 71 75 95 156 154 137 160 239 226 176 171 169 256 271 169
236 262 262 282 244 226 244 233 220 204 227 175 113 138 181 260 251 221 155 148 111 103 132 231
186 233 232 219 223 209 207 210 256 224 260 287 184 183 283 217 233 178 197 199 149 194 215
213 206 139 187 203 174 164 107 167 150 118 123 159 146 145 110 93 95 101 136 141 91 97 121
132 190 163 123 113 107 187 136 142 154 132 76 75 131 185 141 107 85 110 82 78 77 79 57 87
74 65 59 58 38 32 39 59 61 54
GBD-A81B 132
185 214 162 171 198 176 82 101 135 53 69 97 159 153 135 158 241 220 174 172 161 257 268 175
236 260 257 284 244 226 242 230 226 203 226 173 118 142 182 259 258 222 153 152 102 108 132 227
189 230 235 224 216 223 199 211 247 227 228 256 294 182 182 286 216 226 181 195 204 143 198 217
209 202 146 186 192 180 162 114 168 139 115 131 156 157 142 101 106 80 101 131 139 88 86 122
135 187 169 121 122 122 185 150 129 154 121 97 66 142 192 146 99 87 108 79 78 85 73 63 79
74 68 56 58 55 41 30 44 55 63 64
GBD-A82A 207
122 105 96 101 100 73 85 102 103 114 134 159 156 139 140 135 139 120 126 180 144 155 147
187 133 112 132 138 113 110 106 71 41 61 70 114 90 101 106 120 127 97 86 108 134 140 132
122 88 108 143 181 182 152 196 201 184 153 145 115 94 120 109 93 98 94 112 95 94 99 73 84
78 104 91 84 80 105 87 56 50 63 71 72 78 70 81 56 68 68 62 57 67 65 70 84 68 83 76
113 63 77 83 66 79 74 54 49 42 47 59 62 51 67 86 71 94 72 82 54 43 64 77 55 45 46
55 51 45 50 57 40 53 20 25 37 57 47 47 52 44 61 50 57 51 79 57 53 64 61 74 62 71
68 74 52 37 31 32 30 30 28 34 33 30 31 33 31 33 38 43 44 34 25 34 23 33 29 26 28
20 34 31 24 27 16 34 29 36 30 25 23 21 30 22 23 22 32 27 30 43 56 61 91 72

GBD-A82B 207
106 102 101 95 106 67 88 101 107 109 129 160 166 148 144 136 139 135 129 117 180 149 153 148
187 142 110 126 138 122 102 108 77 40 63 73 107 97 99 112 121 124 104 82 111 126 136 134
140 72 119 150 180 185 149 199 196 190 151 148 108 101 130 105 94 95 92 118 92 95 95 83 75
90 92 95 84 84 99 71 54 68 73 65 77 74 77 78 49 77 62 57 61 62 70 73 78 77 76 83 94
68 70 82 67 68 78 53 53 39 51 53 65 54 61 95 67 99 69 74 61 34 57 80 55 53 50 45
55 52 51 51 49 54 19 27 36 59 51 45 51 50 55 49 65 54 73 54 55 55 66 67 55 77 73
75 53 34 31 37 30 27 32 23 37 29 34 32 30 32 37 42 38 46 33 31 33 23 32 25 27 36 23
24 32 22 30 22 29 28 30 35 24 27 21 24 21 23 22 29 32 34 34 59 69 87 78
GBD-A83A 89
296 324 331 355 266 330 343 282 285 350 275 308 220 300 270 232 186 229 272 224 240 192 184 187
171 173 121 120 113 130 187 153 125 147 128 166 145 110 97 116 130 121 150 99 152 124 123 93
158 80 98 109 116 119 139 137 97 92 110 110 103 83 81 99 112 134 119 110 148 124 110 120
113 107 109 187 207 166 95 123 156 163 163 143 123 110 98 122 104
GBD-A83B 89
301 325 332 357 273 331 337 281 287 344 283 298 216 296 272 225 184 231 267 233 232 194 181 195
174 174 118 121 106 133 169 148 137 143 128 159 138 112 95 121 133 120 145 114 147 123 124 88
158 87 93 112 119 116 139 142 95 94 114 100 110 79 86 93 120 126 120 114 146 120 107 122
117 111 113 183 207 163 97 112 166 166 157 142 125 107 108 130 92
GBD-A84A 209
147 180 183 165 146 184 145 151 117 138 195 166 163 210 158 163 122 74 106 105 85 138 157 134
102 107 97 104 69 80 109 115 80 125 98 94 103 109 109 92 86 98 102 84 81 91 87 66 69 77
47 80 75 64 69 90 86 69 64 64 60 66 59 70 65 63 65 79 62 64 93 53 38 56 38 41 45
54 51 29 45 53 48 34 32 52 59 59 63 62 62 47 37 32 37 38 45 44 49 54 54 60 60 49 47
50 53 50 51 53 44 39 47 59 71 43 44 51 51 52 44 47 46 32 41 42 24 36 44 41 37 31
33 36 45 37 41 43 50 39 34 44 51 50 45 52 45 43 44 53 40 38 33 44 49 46 51 55 41
35 28 34 36 43 46 36 38 26 27 34 44 46 46 34 34 44 53 45 64 53 44 33 23 45 50 43 45
39 39 49 43 33 44 34 42 36 43 45 48 40 35 42 46 41 55 45 44 30 28
GBD-A84B 209
145 179 179 170 144 188 142 147 122 137 195 168 161 210 158 157 104 86 117 95 113 149 148 134
101 105 100 95 71 79 114 116 77 123 100 86 99 107 117 90 93 92 106 80 84 85 86 68 77 66
44 80 77 64 67 94 86 66 65 58 65 70 57 72 61 58 75 76 62 64 89 52 37 55 38 42 44
51 55 32 35 57 48 37 37 51 60 60 54 68 62 49 37 33 36 33 50 46 48 56 55 56 60 48 50
47 48 52 48 56 45 41 47 59 68 46 44 55 41 48 41 54 51 34 40 44 18 34 36 39 43 30
37 43 35 38 42 42 39 44 40 45 49 52 46 50 42 48 42 51 41 39 35 42 48 49 49 56 44
34 27 32 33 51 45 40 35 26 34 32 40 42 47 38 35 40 54 48 62 51 46 36 22 40 54 44 42
40 35 54 42 31 45 38 43 35 38 50 45 41 34 39 45 43 55 50 42 30 25
GBD-A85A 100
341 271 383 361 372 302 296 344 398 370 367 399 327 361 321 316 355 366 244 280 303 225 280 306
317 373 234 226 191 234 189 225 260 196 202 202 248 195 252 201 245 230 234 189 176 241 200 222
216 177 146 128 203 196 146 216 204 177 177 160 140 172 135 153 169 149 179 183 174 173 196 175
200 187 170 203 181 134 142 109 150 146 154 122 112 116 119 112 120 96 117 131 149 174 187 174
156 187 160 184
GBD-A85B 100
258 262 372 366 376 296 312 341 397 369 371 390 337 357 324 323 357 373 234 288 297 226 280 302
319 362 238 229 189 229 183 225 265 196 200 209 251 192 253 208 241 234 234 195 175 232 204 226
216 181 135 127 205 200 159 217 188 179 183 157 141 171 131 151 171 136 188 179 181 171 197 178
197 196 170 209 186 137 143 110 154 142 156 118 117 115 119 108 121 97 84 138 149 161 191 171
163 180 162 163
GBD-A86A 175
201 196 211 172 153 129 139 137 122 169 120 120 156 144 152 136 167 132 139 133 129 129 150 113
122 103 111 148 170 156 157 172 194 158 151 115 127 127 104 91 107 105 101 140 140 153 109 110
126 163 138 140 90 82 107 93 87 94 114 108 114 113 113 120 124 151 128 103 84 86 89 93 104
90 111 84 132 86 84 78 73 72 61 62 50 49 47 40 42 38 57 44 53 78 33 50 67 54 81 57
53 69 56 35 34 66 54 46 46 48 45 44 51 46 39 43 40 35 33 41 58 46 44 60 39 39 48
38 40 38 40 37 32 47 53 39 42 35 60 45 45 44 44 42 34 42 49 43 39 37 31 28 17 22
23 29 34 32 32 32 30 34 34 33 31 30 34 34 34 26 33 25 30 28
GBD-A86B 175

199 201 209 166 150 134 129 138 131 153 117 126 155 141 154 141 165 136 137 126 134 131 149 117
120 102 100 153 168 157 163 169 193 158 158 108 128 126 93 100 103 110 112 134 133 159 116 112
128 161 134 139 81 82 100 88 80 98 115 103 109 112 124 124 115 148 132 118 73 93 88 97 105
86 102 92 120 92 91 77 72 74 58 65 48 44 47 44 37 41 54 48 53 60 51 51 63 62 73 57
62 63 52 37 37 62 50 51 48 43 46 42 57 45 40 38 42 38 32 48 47 47 46 57 36 39 51
39 39 36 39 40 31 42 53 42 48 29 58 49 43 40 45 47 34 40 45 42 42 32 28 24 29 25
21 32 26 33 31 32 33 32 34 30 34 37 25 29 34 37 33 28 26 26 28
GBD-A87A 175
325 319 259 218 210 239 163 238 253 224 175 162 180 167 175 128 137 138 136 183 154 169 152 143
133 110 127 115 121 133 112 67 65 107 129 127 119 77 96 68 69 75 112 114 121 81 94 104 127
117 146 102 115 115 94 45 24 52 52 72 74 69 99 85 92 91 83 93 105 121 143 159 124 145
133 122 99 102 89 99 123 105 106 99 72 85 66 71 64 59 72 78 65 72 66 59 67 63 60 55
56 53 70 68 68 59 63 78 73 78 66 86 65 73 60 65 62 62 62 65 59 62 42 37 67 64 52
53 69 56 58 65 55 74 75 75 58 61 58 67 55 53 47 46 44 49 56 51 76 75 60 51 55 55
40 48 38 45 44 46 27 33 37 36 38 37 45 45 27 41 35 38 39 36 43
GBD-A87B 175
345 339 257 216 218 240 165 229 263 222 173 168 181 171 170 139 123 138 142 174 151 173 155 134
127 114 128 106 127 134 108 75 55 117 127 124 132 89 86 95 72 70 117 106 121 91 89 110 129
105 156 108 104 124 96 48 20 47 53 76 73 75 80 89 86 94 84 97 103 120 144 161 127 139
131 128 103 100 99 93 125 111 106 105 70 85 67 70 70 58 67 84 61 76 62 62 65 59 62 51
58 53 68 63 74 61 65 83 71 88 61 78 65 74 62 65 57 63 52 65 59 59 33 43 69 47 64
58 63 59 55 64 59 65 70 74 57 67 59 62 62 56 52 51 46 45 52 58 66 69 59 51 57 57
39 39 43 48 41 45 26 35 37 34 37 37 46 44 31 35 33 40 36 42 42
GBD-A88A 223
173 198 248 131 224 203 172 201 237 219 264 266 198 201 225 223 220 219 262 312 288 205 244 303
265 276 222 236 230 180 196 172 158 184 151 153 126 124 147 134 200 208 137 156 165 114 151 125
103 136 124 125 96 127 107 115 123 111 100 110 132 166 127 120 97 100 85 74 96 100 99 71 91
133 103 93 97 81 80 70 80 113 122 102 98 127 114 95 87 70 79 104 81 54 62 69 56 58 63
62 75 71 58 55 60 60 71 64 66 77 47 56 51 75 73 94 67 50 49 47 57 45 49 42 64 57 58
46 35 36 37 41 56 41 31 51 40 52 49 45 50 40 41 38 58 45 46 39 38 33 44 39 35 39
39 33 41 45 44 47 42 30 32 29 28 22 23 31 29 36 23 22 28 29 31 28 30 31 39 24 30 29
38 28 30 27 36 33 35 27 37 43 25 36 38 32 28 26 31 37 37 34 33 29 35 43 42 48 35
34 34 36 23 36 34 56 30 37 34 35 15 21 14
GBD-A88B 223
165 198 246 138 219 206 173 207 230 200 259 264 199 193 222 234 230 203 293 340 282 205 239 312
268 267 221 237 229 175 197 172 161 182 156 161 129 130 144 129 200 211 132 152 174 110 149 126
105 136 133 119 95 129 105 109 121 118 98 110 139 178 123 111 95 108 83 74 92 100 106 70 94
114 103 100 94 85 83 68 84 119 130 107 94 115 116 91 80 66 84 100 81 55 56 71 62 56 68
66 80 68 54 63 60 63 76 66 85 61 53 57 49 71 77 93 65 52 59 48 54 49 52 41 52 59 66
38 35 40 39 39 57 41 36 54 44 51 49 43 54 41 38 35 60 51 47 35 34 36 40 34 46 40
43 30 41 45 48 53 37 29 30 36 28 23 22 30 33 33 24 26 25 27 32 30 27 32 38 23 31 35
34 26 32 28 37 33 33 29 40 43 28 35 36 24 38 26 33 29 35 35 34 38 28 39 40 43 34
33 36 41 21 31 35 43 37 32 34 23 19 20 20
GBD-A89A 131
297 284 252 239 316 276 278 354 337 313 152 131 157 173 141 118 138 115 195 171 119 100 114 113
121 104 117 122 110 103 107 123 118 121 138 160 141 117 131 117 145 114 157 147 126 132 143 147
137 161 177 159 139 133 116 73 68 38 35 51 37 32 46 47 66 60 69 65 56 87 67 84 83 74
65 64 65 69 69 105 67 77 82 83 85 65 73 68 68 57 58 56 34 38 43 54 40 45 49 41 43
36 54 56 51 46 47 52 38 53 72 63 73 56 76 64 48 62 66 51 64 68 49 53 45 49 47 53
58 53 53
GBD-A89B 131
343 298 238 233 325 285 254 359 349 314 155 129 164 169 129 135 131 115 195 175 123 102 117 115
118 106 114 126 115 99 96 134 109 134 132 163 145 115 130 121 144 111 156 143 130 127 140 149
144 145 186 156 146 139 119 72 69 39 33 53 38 28 48 48 64 68 69 61 55 90 71 96 75 73
68 58 64 70 73 102 72 82 76 80 83 73 69 75 55 61 58 58 28 40 44 51 37 50 49 42 40
41 54 54 50 57 39 53 40 56 68 62 68 64 81 60 48 67 62 43 74 65 49 52 43 47 48 55
51 58 64
GBD-A90A 175

150 194 156 172 158 192 116 149 157 130 141 124 130 94 153 144 153 70 104 101 118 125 130 113
123 121 86 81 141 136 111 137 118 108 138 106 127 129 148 117 105 46 22 33 50 46 64 78 73
95 109 104 109 94 115 111 123 132 91 90 116 94 117 107 118 100 102 91 74 94 92 95 74 73
60 70 84 81 73 65 75 80 89 74 74 66 69 53 78 68 82 76 81 94 75 66 61 81 79 79 73 89
62 73 78 79 80 84 72 55 79 59 66 71 61 66 66 56 55 62 69 78 56 60 68 69 66 61 44
53 49 48 64 53 67 65 66 63 60 54 48 44 51 53 40 41 37 35 40 33 36 36 40 37 44 44
44 36 37 31 34 32 31 34 30 35 35 34 32 36 38 27 25 26
GBD-A90B 175
167 191 160 171 155 187 117 150 151 127 133 137 120 96 146 154 146 71 102 104 116 124 125 115
130 106 88 69 142 139 109 135 117 102 125 116 131 123 148 126 97 52 24 28 48 50 60 78 77
88 110 113 99 97 114 111 133 132 88 95 113 100 114 115 108 106 104 71 86 83 100 87 79 69
78 61 88 73 67 78 67 91 73 83 65 61 71 56 81 76 80 76 76 104 75 65 60 78 82 73 76
87 72 71 74 79 78 86 65 63 76 54 74 64 66 60 63 63 52 56 71 74 57 67 62 68 73 53
46 53 40 55 77 49 67 66 64 65 61 49 50 48 48 54 41 39 37 33 37 37 33 33 44 35 46
43 46 35 36 36 33 29 32 35 27 33 34 39 32 31 36 38 30 21 26
GBD-A91A 185
320 314 347 300 240 144 149 168 134 86 93 72 86 113 106 139 106 103 97 76 84 89 89 106 107
81 124 139 109 75 44 45 49 62 75 118 113 105 154 155 168 163 140 152 138 168 151 136 167 122
108 116 103 95 86 96 111 106 93 105 69 115 110 72 61 58 84 86 102 79 91 106 88 82 77 74
69 69 57 72 70 72 74 72 104 93 63 82 82 69 103 71 61 47 61 96 62 93 104 99 65 88 94
61 61 77 55 86 59 49 69 74 71 87 58 67 67 73 61 71 61 49 48 47 66 62 41 44 51 63
46 49 56 35 49 53 24 39 23 25 31 39 29 40 39 46 39 40 42 27 30 39 26 28 28 27 26
22 22 24 18 28 36 38 22 36 24 23 32 34 34 32 37 51 49 59 68 54 47 48 43 41 50 45 63
GBD-A91B 185
315 310 328 307 225 148 156 162 131 107 76 83 80 122 103 124 115 98 94 92 70 75 94 121 95
94 139 139 107 74 50 41 50 59 83 119 100 111 140 160 157 167 131 144 140 171 160 130 138 118
109 114 103 93 87 94 113 111 81 113 62 125 112 72 64 63 79 92 89 83 89 116 79 81 78 73
64 72 68 69 79 63 69 75 94 93 62 87 74 76 90 77 56 43 62 92 60 92 102 97 72 81 88
66 62 78 52 83 67 40 66 71 73 89 59 75 64 71 54 66 64 53 47 45 60 61 45 46 45 66
44 51 46 41 49 51 25 32 23 20 36 36 26 39 43 43 44 41 38 29 33 41 34 29 29 31 27
19 23 28 16 28 35 31 25 35 24 26 32 36 31 31 40 53 45 57 72 54 46 50 47 42 44 48 56
GBD-A92A 229
103 82 109 102 105 116 98 79 116 82 107 99 100 93 123 125 112 94 109 97 117 74 66 62 71
80 90 97 98 88 98 111 106 103 102 92 103 97 82 79 62 72 79 91 99 101 94 107 89 80 78
86 44 57 72 71 82 74 73 69 67 71 72 75 65 57 61 60 47 68 65 79 89 76 73 42 32 36
24 33 35 41 46 50 51 67 83 52 68 82 62 85 81 77 53 57 47 42 61 64 71 67 81 67 57
61 65 69 61 54 50 66 65 63 52 55 53 62 60 61 68 56 69 56 65 70 75 74 71 59 75 75
63 52 57 67 80 64 68 76 71 80 80 85 64 69 54 42 52 33 38 40 46 54 46 50 65 45 45
44 54 68 49 60 59 50 54 59 65 59 52 56 53 40 50 40 43 45 44 45 55 46 51 45 50 43
44 51 40 40 43 53 37 31 32 33 38 35 48 29 38 28 30 36 30 22 27 23 25 27 29 32 25
21 26 20 19 24 24 36 38 44 37 41 42 36 27 34 39
GBD-A92B 229
113 76 104 89 116 105 95 76 103 82 102 102 93 95 115 117 115 87 100 98 114 76 59 62 70
82 82 94 91 91 90 109 107 90 100 89 89 93 83 79 61 64 88 84 95 95 98 89 93 72 82 72
44 58 72 72 81 78 72 63 75 62 71 85 58 68 55 49 59 62 62 74 83 78 64 41 28 31 30
33 38 48 54 44 53 66 72 55 71 78 71 74 87 71 51 53 48 41 69 64 61 72 63 72 63 50
66 70 65 54 54 62 64 62 49 59 52 54 56 59 66 61 64 54 65 66 69 76 68 59 76 62 60
57 63 61 79 66 64 79 69 72 87 84 55 63 57 52 45 35 34 39 53 45 46 48 65 47 42 41
57 65 50 59 59 58 55 63 55 53 56 55 54 47 44 45 40 47 41 45 51 48 51 48 51 43 44
47 35 41 41 47 31 32 24 31 33 33 35 27 35 25 31 33 29 24 25 23 20 29 38 32 25 19
25 20 21 23 25 32 36 48 36 39 38 38 32 34 31
GBD-A93A 189
198 183 192 196 190 171 148 141 166 197 184 171 198 175 154 146 125 152 161 156 164 122 120 101
141 107 181 145 140 138 159 157 132 134 138 144 99 120 109 133 156 125 63 101 122 100 104 112
107 123 117 79 121 128 119 113 81 110 107 99 143 110 135 88 74 71 88 73 88 100 95 87 120
116 96 86 100 90 94 84 75 68 76 83 78 112 123 107 88 97 106 88 110 90 85 97 86 85 88
57 81 69 74 75 79 115 92 99 76 60 43 49 69 79 82 76 73 63 76 67 71 92 69 76 67 71
88 114 94 95 94 93 74 70 53 40 37 36 41 57 71 45 50 57 76 48 61 84 58 68 65 71 60

57 51 43 75 79 90 77 78 63 59 55 54 62 61 46 53 70 59 66 60 78 70 77 77 73 98 76
85 69 68 80 74 78 74 80 72
GBD-A93B 189
200 183 191 206 186 183 151 142 175 194 187 171 205 174 159 142 121 150 162 162 163 123 123 96
140 110 193 147 139 135 165 156 133 130 135 144 100 120 111 120 153 128 65 86 119 92 106 112
116 127 112 90 114 129 118 116 82 116 118 80 136 109 126 106 67 76 89 70 88 101 96 90 119
122 96 90 96 91 88 75 80 70 75 78 88 110 116 112 90 103 107 89 102 85 89 105 82 88 83
62 74 70 76 75 85 110 95 86 84 65 41 52 65 77 85 76 70 61 79 65 71 92 71 78 67 75
79 116 95 98 90 100 76 64 50 40 33 42 50 48 72 39 64 52 67 54 69 70 66 75 68 68 57
57 54 52 68 82 79 75 79 66 61 50 58 64 58 51 55 62 64 66 62 78 70 77 80 74 103 70
86 68 81 66 76 78 76 89 80
GBD-A94A 131
218 183 199 203 255 154 185 210 248 237 236 228 249 226 215 174 154 152 147 115 75 165 160 156
123 156 146 115 150 169 80 126 163 193 165 169 171 170 138 107 96 137 145 112 96 108 127 142
130 157 145 178 163 143 43 22 45 64 74 103 104 113 112 108 105 116 119 151 153 190 171 136
147 109 131 129 116 117 115 116 114 123 115 117 127 97 99 84 80 85 95 111 104 115 98 115
113 91 98 102 78 89 92 99 81 66 88 84 108 83 122 108 108 114 103 73 87 91 92 84 102 74
60 92 59 70 60 77 63 41 67
GBD-A94B 131
229 173 204 204 251 181 212 205 249 231 236 221 245 220 214 174 157 152 146 118 93 174 148 158
127 150 140 120 147 194 78 119 161 187 164 169 165 178 140 100 91 142 145 109 106 96 122 153
130 159 143 179 169 140 41 25 44 61 81 99 116 111 107 107 100 115 115 143 167 173 174 126
148 121 118 127 124 109 115 121 106 123 116 118 134 99 96 98 80 94 92 112 111 99 99 111 118
93 95 99 76 96 86 96 86 72 85 83 104 86 118 115 108 104 108 75 92 83 94 84 102 75 66
85 62 67 60 77 60 48 68
GBD-A95A 202
142 106 98 104 84 93 94 73 100 117 125 148 130 121 95 118 119 126 97 163 149 122 108 86 84
92 90 84 87 80 62 87 78 103 95 74 52 53 68 60 63 69 63 61 61 56 61 42 45 50 57 51
39 32 47 35 41 46 43 45 64 63 74 71 66 38 48 51 49 47 61 52 53 71 63 65 63 87 67
58 81 69 72 87 65 40 38 54 68 64 75 75 70 55 79 79 63 71 56 40 40 33 31 39 55 49
54 55 61 38 51 33 57 36 28 30 25 44 42 47 42 54 45 31 45 42 24 31 30 19 25 21 28
29 24 20 26 33 43 38 28 33 28 21 32 36 34 29 21 25 20 21 23 19 24 34 29 27 25 24
32 27 37 33 28 37 44 47 49 47 42 40 56 43 49 62 37 44 47 48 45 37 36 18 19 18 23
22 24 18 25 20 24 20 23 23 27 17 17 23 25 28
GBD-A95B 202
147 105 94 105 89 90 94 76 99 118 127 148 131 117 92 123 116 127 96 160 153 129 93 89 92
94 89 87 92 72 69 85 79 93 91 72 51 52 66 60 58 67 64 58 64 56 56 46 44 58 55 49
48 34 55 31 42 36 40 41 66 68 72 79 63 41 51 44 49 54 47 58 60 69 60 64 65 87 65
61 80 82 70 89 63 46 41 59 62 68 77 72 74 55 83 72 61 73 58 42 50 29 30 42 55 45
54 58 56 41 50 43 49 32 28 39 26 43 39 47 45 46 51 32 44 38 25 32 35 20 30 22 23
27 25 19 27 32 44 37 32 31 29 21 30 42 27 29 25 22 20 18 28 17 21 42 26 27 20 30
31 32 39 31 29 42 46 42 46 46 38 52 45 53 56 41 44 50 45 44 40 34 19 16 21 19
20 23 20 23 19 21 20 19 22 28 23 18 20 25 27
GBD-A96A 150
254 224 118 145 137 152 145 129 128 182 186 238 188 219 193 190 193 206 181 143 152 170 181 152
153 197 179 167 165 101 94 83 114 102 122 147 162 168 152 189 188 147 159 168 173 90 78 97
100 102 99 153 97 108 84 100 109 100 108 81 90 66 96 95 84 81 92 104 98 106 108 78 100
90 57 75 64 52 57 37 39 52 45 54 54 53 43 38 27 29 30 32 33 34 19 24 27 20 18 35
26 25 27 37 31 40 44 51 45 31 31 36 33 44 47 45 42 59 53 64 72 59 61 58 58 57 60
34 34 44 45 39 32 40 43 44 39 51 47 43 39 28 15 16 21 23 17 14 13
GBD-A96B 150
259 226 128 137 132 153 147 129 128 177 182 231 193 217 198 190 190 208 180 141 148 174 178 153
151 201 181 166 167 101 97 90 111 122 131 131 155 185 151 180 201 153 161 161 176 88 82 91
96 105 99 142 106 90 97 92 103 100 115 90 84 67 102 97 88 82 94 103 85 106 108 79 106 94
57 74 57 48 58 36 36 51 52 56 55 46 44 37 28 31 33 34 37 33 20 27 25 24 15 25 30
21 29 39 36 39 48 52 39 35 33 35 32 46 39 42 41 56 52 72 71 60 61 58 66 61 56 35
37 37 39 39 43 39 41 40 55 34 48 45 40 44 28 20 19 18 17 22 15 16
GBD-A97A 144

101 49 83 92 119 103 72 70 76 89 90 89 112 78 67 68 66 69 75 87 81 92 101 86 67 64
60 51 55 78 94 85 73 80 98 108 85 95 114 106 110 124 87 86 61 61 58 69 86 96 82 89
105 78 73 106 106 87 88 74 98 92 86 95 116 79 92 99 102 106 84 103 73 92 84 113 99 107
91 97 97 62 71 72 70 88 66 55 86 66 76 89 99 84 79 95 73 81 64 50 51 56 66 57 50
72 63 53 65 67 75 50 60 72 62 58 66 76 63 71 90 65 51 60 73 54 69 70 67 70 70 85
72 96 75 79 78 69 80 67 67 63 56 49
GBD-A97B 144
94 57 80 87 116 105 65 72 82 78 102 82 66 64 66 58 76 90 96 89 104 78 73 62
53 56 60 64 100 77 78 84 94 106 92 93 115 107 93 118 76 84 61 63 55 78 88 90 72 81
91 81 73 112 103 99 89 74 91 93 80 91 106 93 106 93 100 111 84 98 74 100 90 109 105 99
100 97 98 55 76 80 75 86 69 58 86 66 69 86 94 83 77 90 80 75 58 55 50 52 63 54 51
75 52 56 67 58 73 57 56 63 61 55 69 72 62 77 83 75 49 61 73 58 64 72 71 69 74 78
77 82 83 72 68 74 87 60 62 61 49 57
GBD-A98A 180
102 107 137 120 117 100 126 101 131 92 94 81 84 94 97 105 123 98 98 113 106 94 124 102 109
118 96 105 80 79 101 90 95 91 96 112 100 91 95 91 61 84 104 99 86 82 81 67 84 84 90
87 75 61 48 67 72 97 73 87 83 103 57 54 58 55 57 62 71 78 93 72 91 95 99 81 86 106
94 87 100 96 78 76 66 56 69 78 93 78 96 83 69 61 76 85 80 60 64 80 79 75 96 77 77
102 103 97 106 96 125 95 101 107 123 98 99 93 96 90 81 81 84 67 95 94 65 78 93 81 95
101 90 73 80 68 68 60 56 60 54 74 55 46 57 43 41 42 50 64 50 38 40 44 48 54 63 54
56 63 53 36 44 48 40 52 42 44 49 52 54 54 52 47 45 51 45 44 43 52
GBD-A98B 180
106 116 129 120 121 91 128 112 123 96 90 82 82 94 103 98 128 97 97 116 101 96 125 100 114
107 98 104 81 84 96 97 85 99 88 113 98 95 92 95 55 90 99 99 85 85 71 79 75 90 82 95
66 71 51 60 80 87 80 87 88 93 70 56 59 59 56 60 74 81 84 79 90 96 95 81 88 96 96
80 103 96 89 74 72 60 65 84 91 85 83 89 68 62 71 83 76 59 64 66 77 81 98 91 72 105
104 100 110 100 126 101 100 125 111 103 102 89 105 80 83 72 96 62 92 83 71 90 91 90 91
100 92 75 90 66 76 59 56 69 46 69 49 45 62 38 35 38 59 61 36 45 46 53 50 55 57 61
56 65 47 45 44 42 47 42 41 45 48 55 54 55 58 52 54 52 45 46 43 47
GBD-A99A 147
135 141 130 78 105 129 211 237 207 170 154 141 102 79 157 137 126 141 123 128 140 135 171 158
158 141 122 51 27 44 61 73 95 94 119 124 116 116 118 132 146 150 156 172 133 159 172 161
118 116 105 116 120 98 87 96 100 119 106 105 72 98 82 105 85 103 102 99 112 110 91 94 105
90 112 100 99 91 82 93 88 98 87 115 112 95 88 100 85 92 114 94 85 111 87 64 92 85 75
80 72 82 88 87 81 93 92 92 73 88 81 76 82 83 69 86 66 79 69 85 75 80 73 74 76 78
48 60 52 71 51 64 47 48 40 56 54 52 62 65 35 54 57 40 50 48 49
GBD-A99B 147
137 147 138 74 107 125 214 216 203 148 156 141 88 96 162 128 129 136 143 98 135 143 177 130
169 144 118 50 31 41 67 81 79 97 111 127 120 110 124 132 136 146 166 166 129 154 166 159
124 111 108 116 118 95 91 98 93 99 106 99 83 91 81 100 99 93 103 106 117 111 90 96 97
97 107 97 96 88 80 91 88 101 87 114 105 88 93 105 76 96 103 99 85 108 80 65 96 87 73
82 78 73 77 84 88 79 93 87 78 87 82 71 87 76 69 82 66 77 71 81 74 76 77 71 79 70
47 61 54 61 53 68 50 46 43 45 55 52 58 55 36 54 53 44 49 51 43
GBD-100A 140
135 120 113 100 80 74 68 70 56 78 97 86 70 82 86 89 84 97 111 74 63 69 91 71 66 74
67 75 75 109 86 97 103 102 72 98 88 76 78 70 73 78 67 81 101 87 95 99 109 121 103 104
106 96 111 124 104 105 103 101 115 88 95 102 97 102 94 83 102 96 104 126 126 96 88 94 80
66 59 56 52 61 71 56 63 73 65 67 74 78 69 76 84 78 71 88 72 75 76 86 72 59 55
69 64 84 74 87 84 73 70 92 72 65 64 71 63 62 66 61 59 45 42 53 60 54 55 58 50
58 54 49 45 53 40 45 51 54
GBD-100B 140
140 112 120 101 71 81 66 64 69 75 97 80 76 81 100 108 81 99 107 77 67 74 87 73 62 71
69 71 79 106 85 97 105 106 73 96 90 80 77 74 73 69 67 78 94 90 96 100 100 124 101 107
96 100 115 124 106 108 98 108 117 81 103 98 97 102 91 78 108 96 107 127 127 91 91 100 76
65 56 60 51 59 74 56 59 78 61 67 67 72 82 67 78 86 76 80 84 74 71 85 87 69 52 58
82 54 86 67 85 76 74 76 72 86 74 62 64 69 64 65 71 57 57 44 44 55 56 57 57 54 49
62 51 51 46 53 40 42 53 50
GBD-101A 87

219 368 163 250 265 238 223 206 177 176 188 141 168 87 66 151 126 74 66 86 71 78 110 57 55
54 61 77 93 77 64 89 76 89 100 113 84 104 76 114 87 103 121 261 252 231 143 141 124 157
131 185 181 108 145 111 83 148 174 115 92 84 103 134 111 174 154 137 124 67 99 114 90 113
136 118 91 106 141 101 78 69 129 109 72 83 106
GBD-101B 87
201 361 155 252 255 256 224 202 177 174 187 150 154 81 73 157 106 95 64 91 70 72 99 68 64
50 64 73 88 86 61 95 77 91 97 112 81 113 85 99 98 92 143 258 251 209 155 130 139 152 134
186 172 93 153 114 81 149 169 107 100 84 92 143 96 171 146 138 114 69 97 112 98 94 151 123
84 112 139 98 87 59 143 99 81 81 126
GBD-102A 85
158 208 204 214 150 182 75 70 154 119 104 85 121 112 118 139 122 75 120 138 147 139 125 117
186 120 144 112 158 134 144 167 148 151 185 193 307 273 251 185 235 231 229 179 237 189 154 143
116 104 174 139 119 95 73 83 219 106 154 141 110 107 76 127 101 100 105 151 159 138 143 170
106 90 72 153 172 113 133 125 160 143 122 78 54
GBD-102B 85
187 231 194 211 147 182 87 77 169 122 110 90 115 107 131 143 115 86 126 129 151 141 137 111
184 118 143 127 163 131 134 174 149 151 184 188 306 264 253 188 231 237 236 181 228 190 153 142
115 98 171 147 110 89 85 135 167 119 141 140 97 105 85 132 110 88 116 152 157 132 138 173
114 83 79 155 137 146 152 124 150 163 111 81 51
GBD-103A 77
268 268 157 94 78 61 199 188 171 59 205 114 164 139 136 148 189 194 145 192 157 184 138 193
216 189 170 134 160 146 87 121 80 80 97 97 134 115 100 89 117 133 194 215 192 186 121 171
184 140 156 114 116 106 82 138 75 102 90 152 115 80 91 67 83 49 55 110 94 101 108 112 159
127 62 65 57
GBD-103B 77
272 262 154 103 67 68 200 185 171 62 215 113 149 143 131 152 200 197 143 193 142 192 147 193
212 185 174 130 155 152 99 124 88 72 99 102 116 122 99 83 117 124 191 218 192 189 116 170
188 136 152 118 112 104 83 133 84 94 94 146 119 78 94 67 78 52 54 113 87 103 101 121 156
98 90 63 58
GBD-104A 54
322 223 182 183 221 358 217 251 235 292 247 123 138 131 210 248 164 218 190 179 287 235 228 327
363 257 274 329 412 348 329 448 326 261 257 220 295 252 284 234 268 303 268 241 156 159 150 116
213 281 230 218 187 202
GBD-104B 54
322 169 222 168 209 348 206 254 225 281 262 135 135 141 214 252 167 209 183 195 296 229 236 327
360 238 282 328 406 360 351 431 304 267 261 211 294 257 275 236 267 305 266 242 160 150 145 122
222 265 225 209 221 177
GBD-105A 53
144 182 259 118 239 171 186 180 219 264 191 143 221 178 108 205 180 233 293 326 245 211 230 410
273 293 376 260 259 244 206 279 193 223 207 255 238 173 174 128 133 125 111 226 201 171 142 164
260 194 176 154 57
GBD-105B 53
127 173 261 125 241 174 192 181 227 263 178 157 211 162 142 185 182 229 292 312 263 215 221 407
255 289 358 284 264 246 206 287 196 217 210 227 272 146 202 125 167 123 110 218 183 195 129 160
262 221 171 131 52
GBD-106A 83
83 125 146 46 71 41 185 210 115 100 130 114 215 200 183 111 236 189 180 178 150 152 199 191
142 193 145 145 110 123 177 155 168 143 246 154 119 117 110 104 99 96 133 131 91 96 90 78
123 146 115 109 99 148 127 93 124 106 82 54 50 110 82 137 103 181 175 123 99 78 68 56 46
92 103 109 88 102 119 118 67 54 52
GBD-106B 83
71 127 147 49 65 36 186 214 115 99 132 116 217 200 184 114 230 192 182 175 154 149 206 190
141 196 141 145 107 125 174 150 174 147 241 157 123 114 108 104 96 94 129 137 85 93 92 74
135 140 114 107 100 145 139 83 125 112 74 58 61 112 80 113 102 175 177 116 108 78 68 51 47
92 101 114 90 96 120 118 69 52 59
GBD-107A 52

271 441 237 416 309 158 84 157 186 147 212 395 254 242 308 298 234 300 373 339 309 265 473 476
321 462 226 313 229 150 187 130 117 119 226 180 131 109 133 114 75 99 201 101 92 108 102 101
118 87 102 41
GBD-107B 52
236 446 226 419 298 153 94 160 190 160 198 405 257 241 304 290 238 295 373 344 303 262 481 472
328 453 210 325 213 147 195 133 131 121 233 181 119 112 134 108 88 92 196 122 100 85 111 131
92 104 97 48
GBD-108A 55
126 124 94 47 99 55 109 119 262 436 377 413 358 375 376 388 349 160 319 296 120 99 209 271
182 291 263 222 267 335 359 214 384 423 337 357 354 517 461 333 537 259 358 195 136 190 132 131
71 168 136 79 55 74 77
GBD-108B 55
109 130 91 53 109 60 104 120 264 434 376 416 355 381 381 389 348 163 324 278 108 90 182 268
183 292 263 227 236 330 363 219 372 451 325 363 363 514 448 330 519 266 358 193 149 176 129 127
84 158 128 98 63 71 82
GBD-110A 50
212 265 230 289 336 309 250 226 272 252 190 161 199 208 212 262 281 256 165 225 225 169 221 258
235 274 240 263 258 240 271 256 243 206 181 280 180 184 171 211 182 181 171 161 136 111 123 183
184 118
GBD-110B 50
225 269 230 278 343 310 249 211 275 254 195 166 190 214 216 258 289 250 188 229 213 173 228 255
242 276 250 258 256 241 266 254 250 208 180 276 182 181 205 167 215 165 184 143 107 107 172
144 147
GBD-111A 45
259 212 271 314 309 256 159 255 238 255 276 259 137 79 134 303 112 108 199 235 208 248 279 395
232 188 197 241 197 277 303 226 191 281 339 356 178 223 203 239 210 130 122 87 107
GBD-111B 45
256 218 276 315 325 279 159 241 244 245 292 245 142 90 115 326 95 107 190 240 215 250 274 381
233 147 220 227 218 262 294 234 198 279 336 359 178 228 207 233 219 145 121 79 110
GBD-114A 60
126 161 95 90 23 40 68 69 43 50 43 53 43 67 144 277 341 320 192 147 167 195 164 231 217
105 67 117 101 204 201 252 137 190 149 189 92 127 148 161 186 211 189 157 172 188 204 92 92
83 104 60 47 60 48 111 102 162 246 237
GBD-114B 60
139 139 106 74 25 48 71 67 51 44 45 49 54 59 144 279 336 303 168 155 169 182 169 209 222
78 87 100 102 210 211 234 164 199 127 213 103 119 149 161 182 211 184 168 179 218 208 92 86
101 81 71 58 56 52 118 90 160 154 247
GBD-116A 121
105 105 68 113 100 106 129 116 139 150 110 100 105 112 109 71 114 97 105 76 59 83 106 158 83
92 74 72 105 100 91 93 91 99 103 57 89 80 70 104 74 101 59 83 51 97 98 101 126 75 141
65 77 51 96 109 100 82 97 138 123 104 73 98 98 125 107 92 117 96 102 103 144 84 96 122 110
125 72 71 82 70 68 70 63 83 76 53 66 52 60 65 74 85 84 102 96 78 68 75 55 45 67 73
71 53 96 117 79 53 69 113 77 73 76 63 60 53 60 57 89
GBD-116B 121
108 109 70 108 99 108 135 111 120 142 107 102 104 92 118 67 121 98 108 75 60 83 111 141 90
93 74 57 106 97 93 93 95 87 110 58 93 80 74 88 86 90 64 80 60 91 102 97 136 74 145 49
75 59 96 105 114 67 113 130 127 100 65 109 88 136 116 77 115 88 112 112 147 60 95 123 113
131 80 65 80 75 66 57 65 78 74 62 72 55 64 56 74 85 80 103 81 89 72 75 55 47 76 81
66 52 95 114 67 58 71 108 79 74 70 68 49 56 61 81 75
GBD-117A 52
152 340 333 361 277 322 277 144 176 290 252 180 87 84 169 185 166 131 95 98 206 337 343 245
343 383 411 412 254 292 307 211 159 170 245 161 132 131 184 160 214 232 329 283 362 407 284 229
219 285 282 379
GBD-117B 52
143 340 337 366 272 322 287 109 194 298 257 203 83 85 169 190 170 129 98 127 184 347 340 249
331 390 416 413 246 293 314 207 166 171 251 170 136 129 180 164 217 224 320 267 375 417 282 243
228 297 323 352
GBD-119A 57

152 177 208 342 455 421 361 279 458 504 459 208 375 474 339 337 129 68 138 205 220 141 80 118
239 310 360 227 332 320 339 364 240 301 356 252 226 255 355 359 191 223 290 319 348 377 464 386
400 386 373 241 276 304 369 328 274

GBD-119B 57

150 175 204 349 454 451 352 297 502 498 460 210 373 472 342 326 134 80 189 213 222 134 90 125
300 306 342 241 352 353 369 380 233 307 363 241 233 256 323 378 221 220 270 313 369 378 498 387
390 388 346 246 280 298 365 312 274

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 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

I. 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

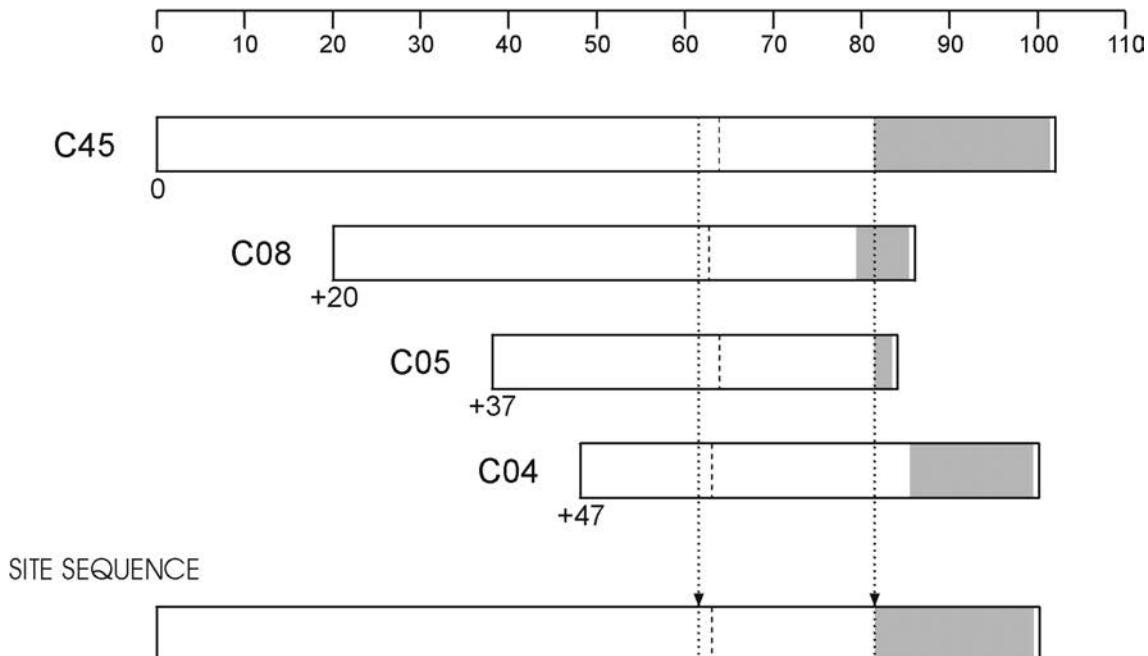


Figure A5: Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them

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

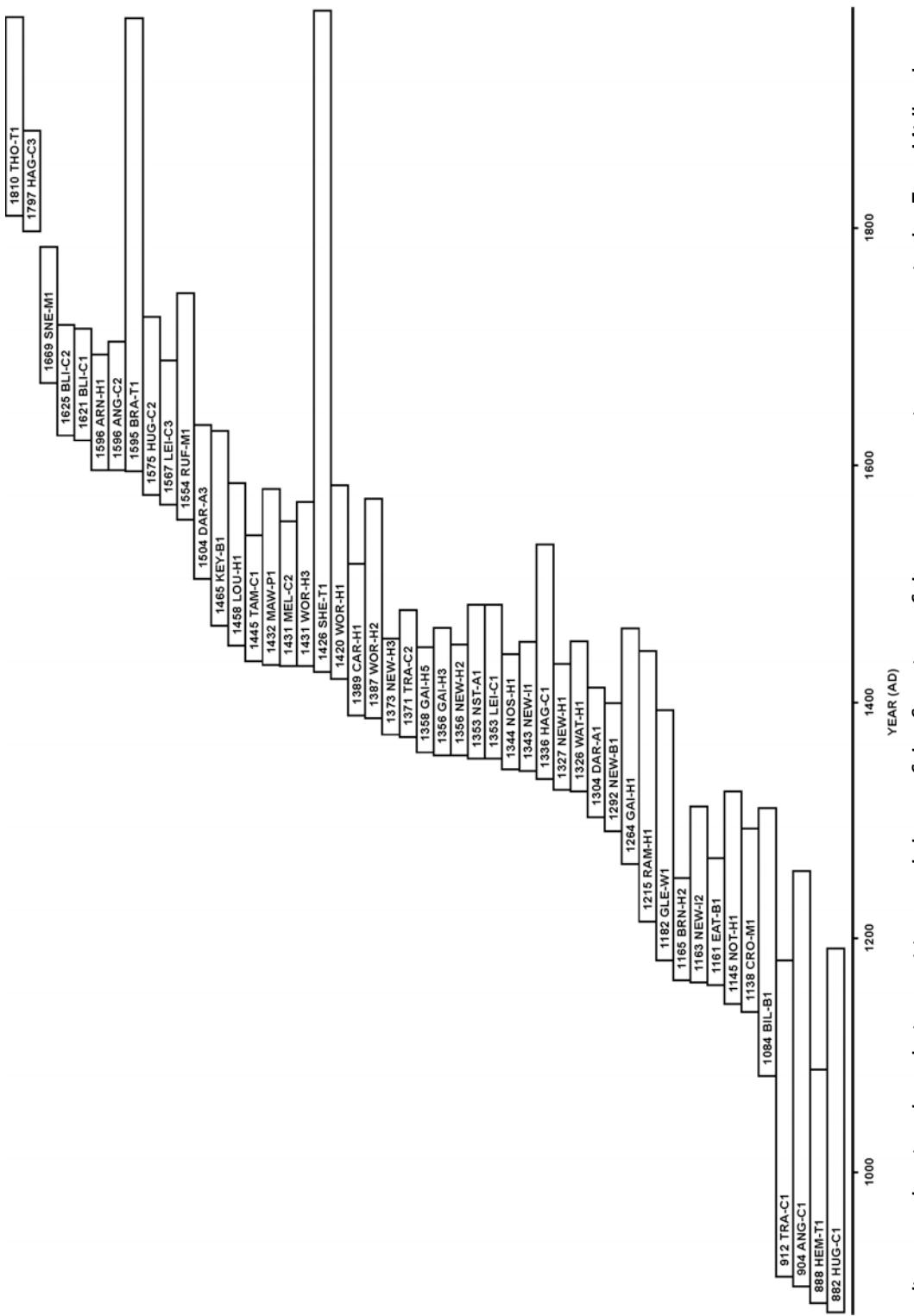
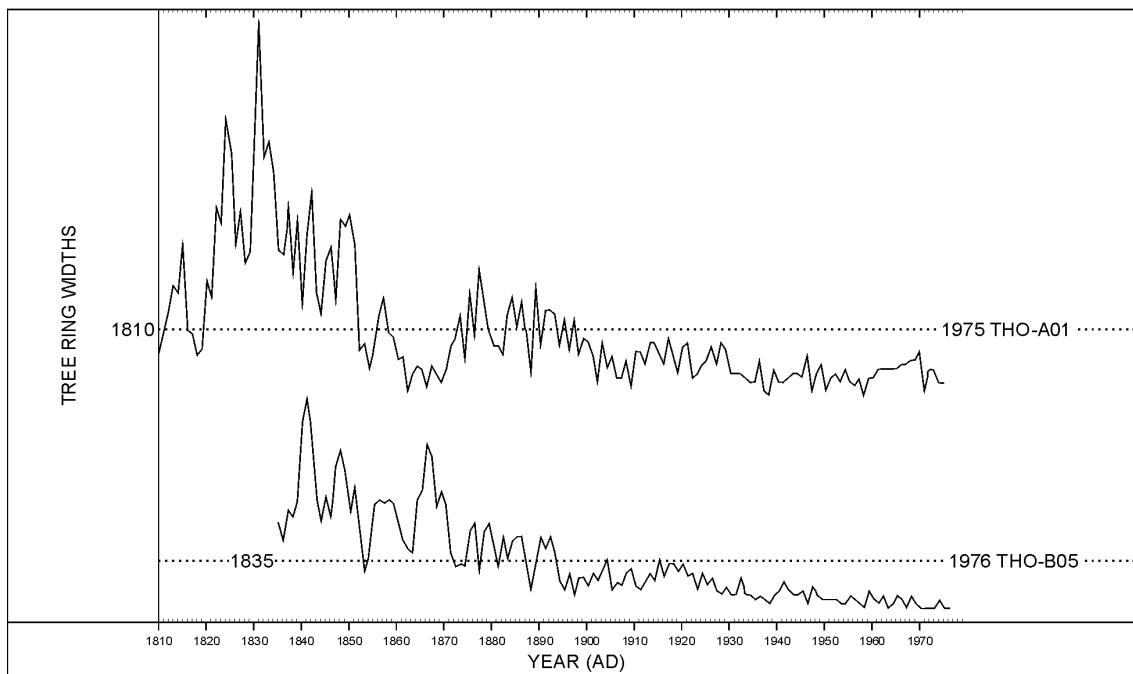


Figure A6: Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08/87

(a)



(b)

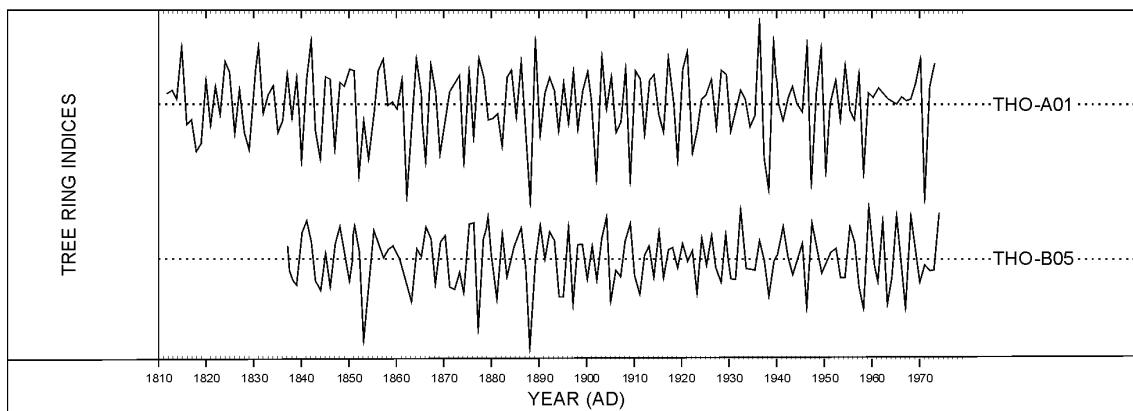


Figure A7 (a): The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known

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**
- 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
- Laxon, 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
- Laxon, 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
- Laxon, 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 DEPARTMENT

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 sustainable management, and to promote the widest access, appreciation and enjoyment of our heritage.

The Research Department provides English Heritage with this capacity in the fields of buildings history, archaeology, and landscape history. It brings together seven teams with complementary investigative and analytical skills to provide integrated research expertise across the range of the historic environment. These are:

- * Aerial Survey and Investigation
- * Archaeological Projects (excavation)
- * Archaeological Science
- * Archaeological Survey and Investigation (landscape analysis)
- * Architectural Investigation
- * Imaging, Graphics and Survey (including measured and metric survey, and photography)
- * Survey of London

The Research 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 outreach and education activities and build these in to our projects and programmes wherever possible.

We make the results of our work available through the Research Department Report Series, and through journal publications and monographs. Our publication Research News, which appears three times 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 Department 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

