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Upper Quay Street Gloucester Gloucestershire

Tree-Ring Analysis of Oak Timbers

Nigel Nayling

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Front Cover: Excavations at Upper Quay Street, Gloucester. Photo courtesy of Gloucester City Council.

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SUMMARY
This report covers the dendrochronological analysis of samples taken from timbers held in store at the Gloucester Museum derived from excavations undertaken at Upper Quay Street, Gloucester in 1989 and 1990. The majority of the timbers relate to a succession of Roman waterfront timber structures.

A 471-year, 35-timber mean ring-width series, QST35, was produced and cross-matched providing absolute dating from 377 BC to AD 94 inclusive. The report considers the dating of individual timbers in relation to the structures and stratigraphic phases with which they have been associated.

Two samples, from timbers post-dating the Roman phases, were derived from a single parent tree and were combined to produce a 112-year ring-width series. This was cross-matched providing absolute dating from AD 880 to AD 991 inclusive, implying felling of the parent tree after AD 1001.

CONTRIBUTORS
Nigel Nayling

ACKNOWLEDGEMENTS
I am most grateful to Andy Mudd and Jon Hart of Cotswold Archaeology for collaboration during post-excavation analysis of stratigraphic information from the site. Sean Cook of the Gloucester Archaeology Unit assisted during rapid recording, assessment, and sampling of the wood held in store in Gloucester Museum in 2002. Shahina Farid (Historic England Scientific Dating team) commissioned this analysis and reporting, whilst Cathy Tyers (Historic England Scientific Dating team) kindly reviewed the tree-ring data during compilation of this report, as well as commenting on the draft report. I am also grateful to Ian Tyers (Dendrochronological Consultancy Ltd) and Anne Crone (AOC Archaeology) for access to unpublished data.

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INTRODUCTION

This report covers the dendrochronological analysis of samples taken from timbers held in store at the Gloucester Museum derived from excavations undertaken at Upper Quay Street, Gloucester (Site Code 8/89) in 1989 and 1990 (Figs 1–3). These excavations were undertaken in advance of local development (Atkin 1990; Atkin *et al* 1991), and included investigation of Roman waterfront timber structures. The stored timbers were assessed by the author at the request of the Gloucester Archaeology Unit (GAU) in 2002 (Nayling 2002 unpubl). Following rapid recording, samples were taken from timbers considered suitable for dendrochronological analysis. These samples were measured by the author in 2002 and the initial results were the subject of discussion with staff from the GAU until funding came to an end. Following submission of a project proposal and subsequent project design to Historic England by Cotswold Archaeology in 2017, the author was asked to revisit this analysis and prepare this research report and publication text as part of a wider project leading to the publication of a number of excavations in the Blackfriars quarter of the City of Gloucester (Mudd 2017). The dendrochronological input for this project was funded directly through the Historic England Scientific Dating team.

METHODOLOGY

The methods employed at the Lampeter laboratory follow practice as defined in current guidance on the application of dendrochronology to historic buildings and archaeological assemblages (English Heritage 1998; Historic England forthcoming).

The samples selected for analysis had their cross-sectional surfaces cleaned with a razor blade to expose the tree-ring sequences. The complete sequences of growth rings in the samples that were selected for dating purposes were measured to an accuracy of 0.01mm using a micro-computer based travelling stage (Tyers 2004a). Cross-correlation algorithms (Baillie and Pilcher 1973; Munro 1984) were employed to search for positions where the ring sequences were highly correlated. The ring sequences were examined using digital graphical software to enable visual comparisons to be made between sequences at the positions indicated as an aid to identification of any measurement errors. New mean sequences were then constructed from the synchronised sequences. The *t*-values reported below are derived from the original CROS algorithm (Baillie and Pilcher 1973). A *t*-value of 3.5 or over is usually indicative of a good match, although this is with the proviso that high *t*-values at the same relative or absolute position must be obtained from a range of independent sequences, and that satisfactory visual matching supports these positions.

During this analysis, all the measured sequences were compared with each other and any found to cross-match were combined to form a site master curve. These,

and any remaining unmatched ring sequences, were tested against a range of reference chronologies using the same matching criteria: high *t*-values, replicated values against a range of chronologies at the same position, and satisfactory visual matching. Where such positions are found, these provide calendar dates for the site master curve and the individual ring-sequences from which it was composed.

The tree-ring dates produced by this process initially only date the rings present in the timbers. The interpretation of these dates relies upon the nature of the final rings in the sequence. If the sample ends in the heartwood of the original tree, a *terminus post quem* (*tpq*) for the felling of the tree is indicated by the date of the last ring, plus the addition of the minimum expected number of sapwood rings which are missing. This *tpq* (or felled after date) may be many decades prior to the actual felling date. Where some of the outer sapwood or the heartwood/sapwood boundary survives on the sample, a felling date range can be calculated using the maximum and minimum number of sapwood rings likely to have been present. The sapwood estimates applied throughout this report are a minimum of 10 and maximum of 46 annual rings, where these figures indicate the 95% confidence limits of the range. These figures are applicable to oaks from the British Isles (Bayliss and Tyers 2004). Alternatively, if bark-edge survives, then a felling date can be directly utilised from the date of the last surviving ring. If the outermost ring has both earlywood and latewood present and therefore appears to be complete, the timber was felled whilst dormant during late summer - early spring. This is referred to as winter felled. If only the earlywood is present, then the timber was probably felled during 'late spring - early summer', which is referred to as 'summer felled'.

The dates obtained by the technique do not by themselves necessarily indicate the date of the structures or contexts from which they are derived. It is necessary to incorporate other specialist evidence concerning the reuse or redeposition of timbers and the repairs of structures before the dendrochronological dates given here can be reliably interpreted as reflecting the construction date of structures.

RESULTS

A total of 51 timbers were sampled for dendrochronological analysis from the Upper Quay Street timber assemblage held in store at the Gloucester Museum (Table 1). All samples were oak (*Quercus* spp), and had sufficient rings to merit measurement. Unsurprisingly, some timbers were in relatively poor condition after more than a decade in storage or had suffered compression / distortion in the burial environment making reliable measurement impossible (QS5566, QS5611, and QS5612). In one case (QS5518), the inner and outer ring-width sequences could be measured but the middle section was too poorly preserved to be reliably measured. Thus, a 49 ring-width measurement series were obtained from 48 samples, these being given in the Appendix. Comparison of these ring-width series resulted in the dating of 38 ring-width series (37 samples), the other 11 measured samples could not be dated.

Five ring-width series (QS5515, QS5518A, QS5518B, QS5519, and QS5596), from four samples correlated against each other with sufficiently high *t*-values and medium term growth trends to indicate that they probably derived from the same parent tree (Fig 4; Table 2). A raw 408-year ring-width series, QSTree01, was calculated for this parent tree. Similarly, a raw 79-year ring-width series, QSTree02 was calculated from highly correlated series QS5501 and QS5537 (Fig 5; Table 3); a raw 111-year ring-width series, QSTree03 was calculated from highly correlated series QSTemp9 and QSTemp10 (Fig 6; Table 4); and a raw 117-year ring-width series, QSTree04 was calculated from highly correlated series QS5589 and QS5607 (Fig 7; Table 5).

Twenty-five individual ring-width series and the single tree series (QSTree01-QSTree04) were successfully cross-matched against each other with significant *t*-value correlations (Table 6) and good visual matching with the intra-site cross-matching confirmed by comparison of the individual ring series with the British and Irish regional chronologies and site chronologies where appropriate. A 471-year, 35 timber mean ring-width series (Fig 8), QST35, was calculated and cross-matched against a range of British and Irish regional chronologies and site chronologies (Table 7) providing absolute dating from 377BC to AD94 inclusive.

Three sampled timbers (QS5033, QS5041, and QS5044), were derived from medieval or undated contexts post-dating the excavated Roman phases. The ring-width series of two of these (QS5033 and QS5044), cross-matched with a high *t*-value and very good visual matching suggesting they derived from the same parent tree (Fig 9; Table 8). A raw 112-year ring-width series, QSTree05, was calculated for this parent tree. This was cross-matched against a large number of regional chronologies and site masters to AD880 to AD991 inclusive, implying felling of the parent tree after AD1001 (Table 9).

The implications for internal dating of structures and phases encountered during the excavations at Upper Quay Street are considered in the discussion below, whilst some of the wider implications of the dating of both Roman and medieval timbers are briefly considered in the conclusion.

DISCUSSION

The results of the dendrochronological analysis are considered with reference to the context from which the dated timbers were derived, and the proposed phasing of these contexts (Hart and Mudd forthcoming). The following should be read in conjunction with Figures 8 and 9.

During the first-century AD, a number of structures were built on the north side of an inlet of the river Severn (Period 1.1). Timbers encountered during 1990 excavations in Trench 5 included a box timber drain (context 518) hewn from a single oak (timber QS5581) felled after AD 73, and a timber (QS5591) found within

the drain's fill (context 519) dated as being felled during the period AD 69–105. An associated, and possibly contemporary, timber walkway (context 532) comprised four oak planks set out at regular intervals. Three of these have produced dendrochronological felling dates of winter AD 73/74 (QS5543), summer AD 74 (QS5545) and a felling date range of AD 69-103 for QS5537. The whole complex could therefore be contemporary with construction dating to summer AD 74 or soon thereafter.

Improvements to the waterfront, through the construction of revetments, occurred during the late first century and into the second century AD (Period 1.2). One timber (QS5032) from a line of posts and stakes (context 40), which may have formed a jetty, was dated. The outermost measured ring was possibly the heartwood/sapwood boundary, which produces a possible felling date range of AD 55–91. One of two vertical posts (QS5607) lap-jointed to tiebeam 5548 to form revetment 531 dated as felled after 172 BC. A layer of silt (context 522), which had accumulated behind this tiebeam contained timber fragments including two which produced a felling date after AD 18 (QS5613); and a felling date range of AD 66–102 (QS5592). A further timber within this context (QS5589), with a felling date of after 179 BC, was derived from the same parent tree as the vertical QS5607 from revetment 531. A possible pit, or natural depression (context 505) contained an upper fill of silt (context 506) with wood fragments including QS5513, which has been dated, with a possible heartwood sapwood boundary, producing a possible felling date in the range AD 53–89.

Context 507, an inundation layer contained wood fragments from which 16 were sampled for dendrochronology. Ten of these produced absolute dates including possible felling date ranges of AD 40–76 (QS5539), AD 49–85 (QS5567), and AD 58–94 (QS5569) and a felling date range of AD 61–97 (QS5546). It should be stressed that none of these timbers were found *in situ*, and may well have been washed into their found location from earlier structures. This suggestion is strengthened by the observation that the tree-ring series of timber QS5596 is highly correlated against those of QS5515, QS5518, and QS5519 (see Fig 4; Table 2) which are probably derived from the same parent tree. The latter timbers were all from context 278 and again appear to have been redeposited from earlier structures probably dating to Period 1.2. An organic layer (context 503), located between two drains (contexts 293 and 294), which post-date the silting represented by context 507, contained waterlogged wood including three dated pieces felled after AD 6 (QS5294), after AD 65 (QS5501), and possibly during the range AD 76–112 (QS5504). Timber QS5501 is derived from the same parent tree as timber QS5537 (see Fig 5; Table 3) found in context 507, again suggesting the redeposition of timbers. QS122, a single timber from context 167, a dark organic layer which accumulated to the north of revetment 164 also assigned to Period 1.2, was dated as felled after AD 29.

Period 1.3 is characterised by silting and abandonment during the early second century AD. Timber and wood fragments found within estuarine silt (context 278) overlying earlier timber structures are again probably redeposited. This encourages careful interpretation of the precise felling date of the winter of AD 94/95 for timber QS5530. Similar caution is required with reference to the unlabelled timber QStemp10 (possible felling date range of AD 50–86), which is assigned to context 268, which overlay context 278.

Some samples dated to the Roman period could not be assigned to a particular context with any confidence. These included QStemp7 (from an unlabelled pile) and QStemp9 (from a radial plank fragment), which produced, respectively, a precise felling date of AD 77 (season of felling indeterminate), and a possible felling date range of AD 42–78. The dated radial plank fragment QStemp10 (context 268) appears, on the basis of high correlation and growth trends, to be from the same parent tree as QStemp9.

Two samples, QS5033 and QS5044, were taken from charred radial plank fragments, one of which (QS5033), came from a medieval pit fill context 18. The other has no context information. The two samples cross-matched with high correlations suggesting they derived from the same parent tree (QStree05, Figure 9 and Table 8). Dating indicated felling of this parent tree after AD 1001.

CONCLUSION

The analysis of the substantial timber assemblage retained in store from the excavations of Upper Quay Street, Gloucester, has allowed the construction of a well-replicated ring-width site chronology for the late prehistoric and early Roman periods. Due to the presence of at least two very long-lived oak trees, this site chronology extends back into the fourth century BC. This site chronology provides a significant addition to the spatial extent of British late prehistoric / early Roman tree-ring data complementing existing datasets that are dominated by London and the north-west (most notably Carlisle). During the early 1980s, ring-width sequences from a limited number of excavated Roman timbers from Gloucester (Hillam 1982a; Morgan 1982) could only be compared with data from Roman London. The initial absolute dating of timber 305 from Gloucester Eastgate (site 46/74) with a last ring at AD 43 (Hillam 1982a, 6), which depended on correlation with the developing London sequences can now be confirmed with reference to the Upper Quay Street, Gloucester, site mean (Table 7).

The medieval data from two cross-matched timbers from the same parent tree (QSTree05, Table 8) provides a dated ring-width series spanning the late-ninth to late-tenth centuries AD (AD 880–AD 991). It is notable that this series dates well against site chronologies from the south east of England but also the early Dublin chronology and, intriguingly, the Skuldelev 2 wreck which, although scuttled in

Roskilde Fjord, Denmark, has on the basis of its tree-rings been assigned an Irish origin (Bonde and Crumlin-Pederson 1990).

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FIGURES

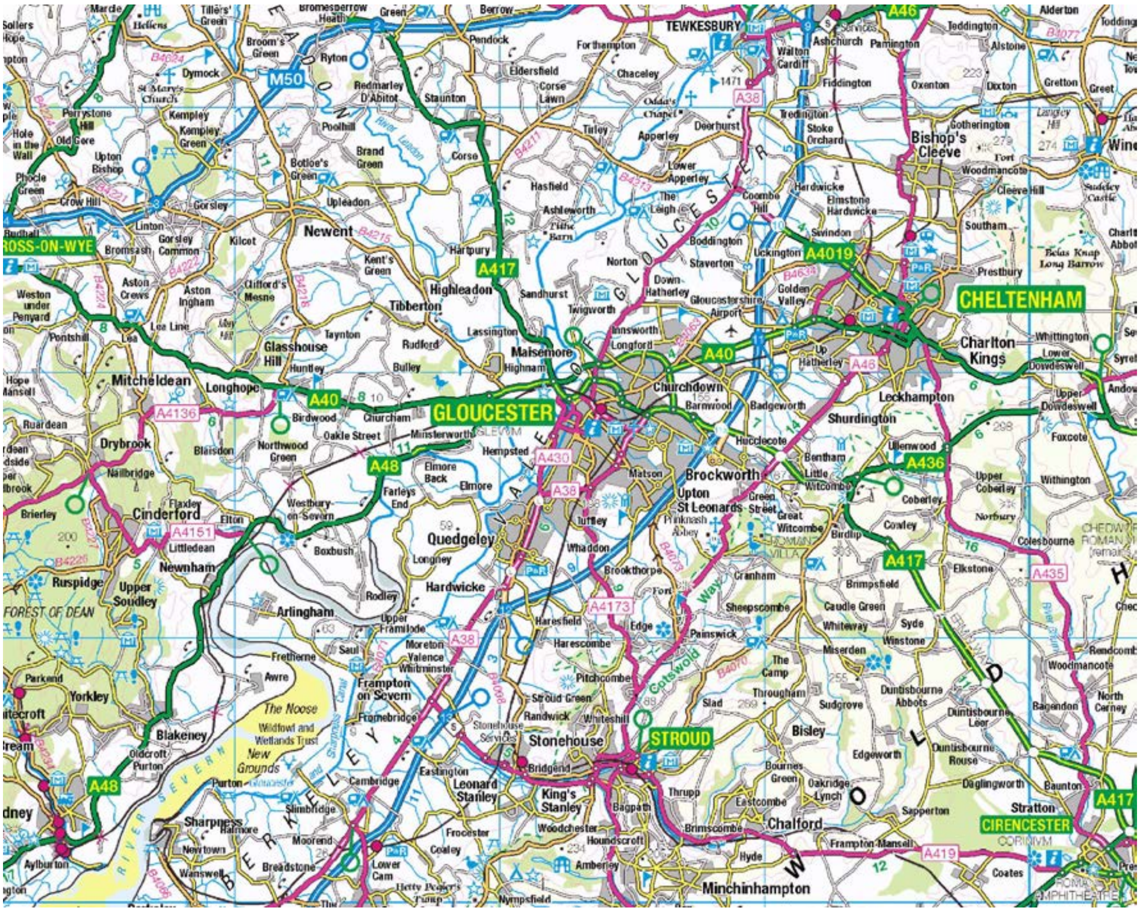

Figure 1: Map to show the general location of Gloucester © Crown copyright and database right 2019. All rights reserved. Ordnance Survey licence number 100024900

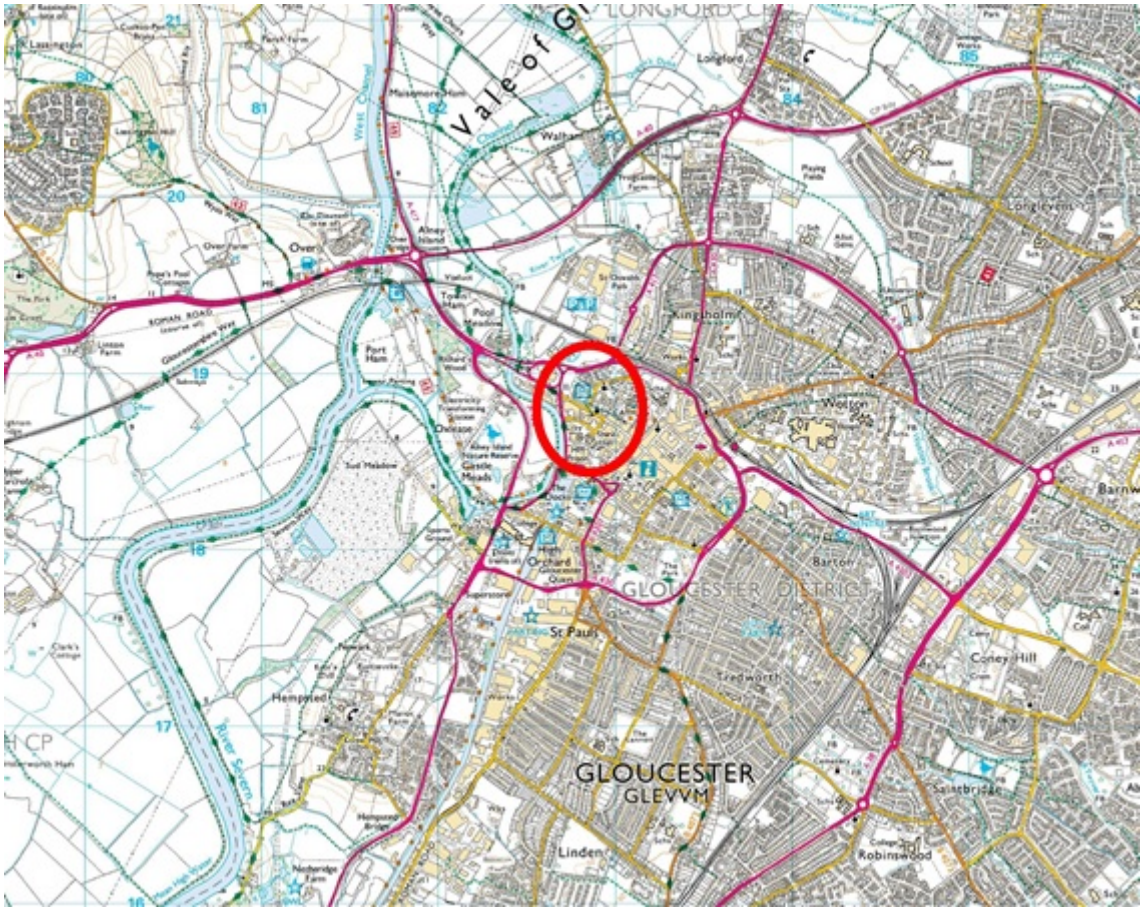

Figure 2: Map to show the general location of Upper Quay Street, Gloucester (red ellipse) © Crown copyright and database right 2019. All rights reserved. Ordnance Survey licence number 100024900

Figure 3: Map to show the detailed location of Upper Quay Street, Gloucester (red ellipse) © Crown copyright and database right 2019. All rights reserved. Ordnance Survey licence number 100024900

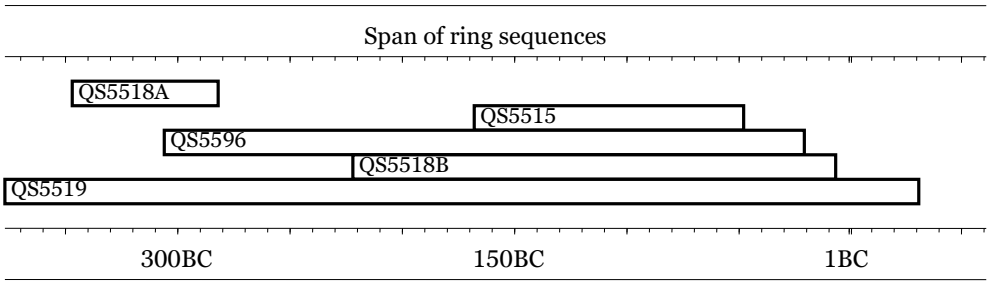

Figure 4: Bar diagram of cross-matched ring-width series from the same tree, Tree 1. White bars - heartwood

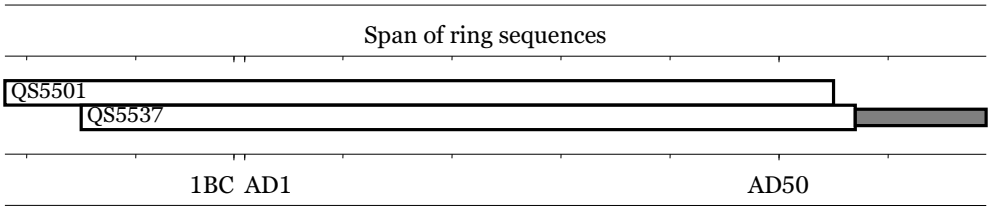

Figure 5: Bar diagram of cross-matched ring-width series from the same tree, Tree 2. White bars – heartwood; shaded narrow bar – unmeasured sapwood

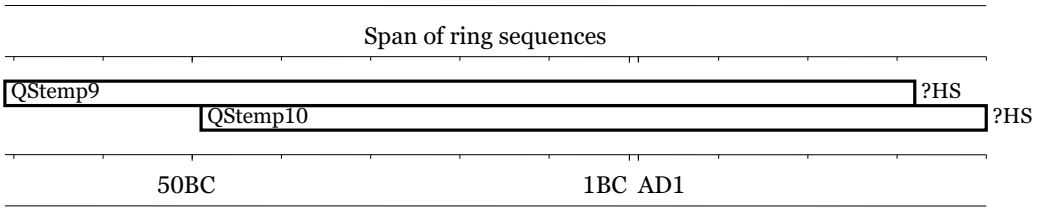

Figure 6: Bar diagram of cross-matched ring-width series from the same tree, Tree 3. White bars – heartwood; ?HS – possible heartwood/sapwood boundary

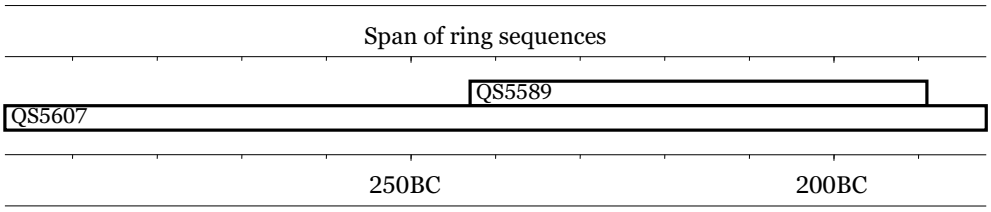

Figure 7: Bar diagram of cross-matched ring-width series from the same tree, Tree 4. White bars – heartwood

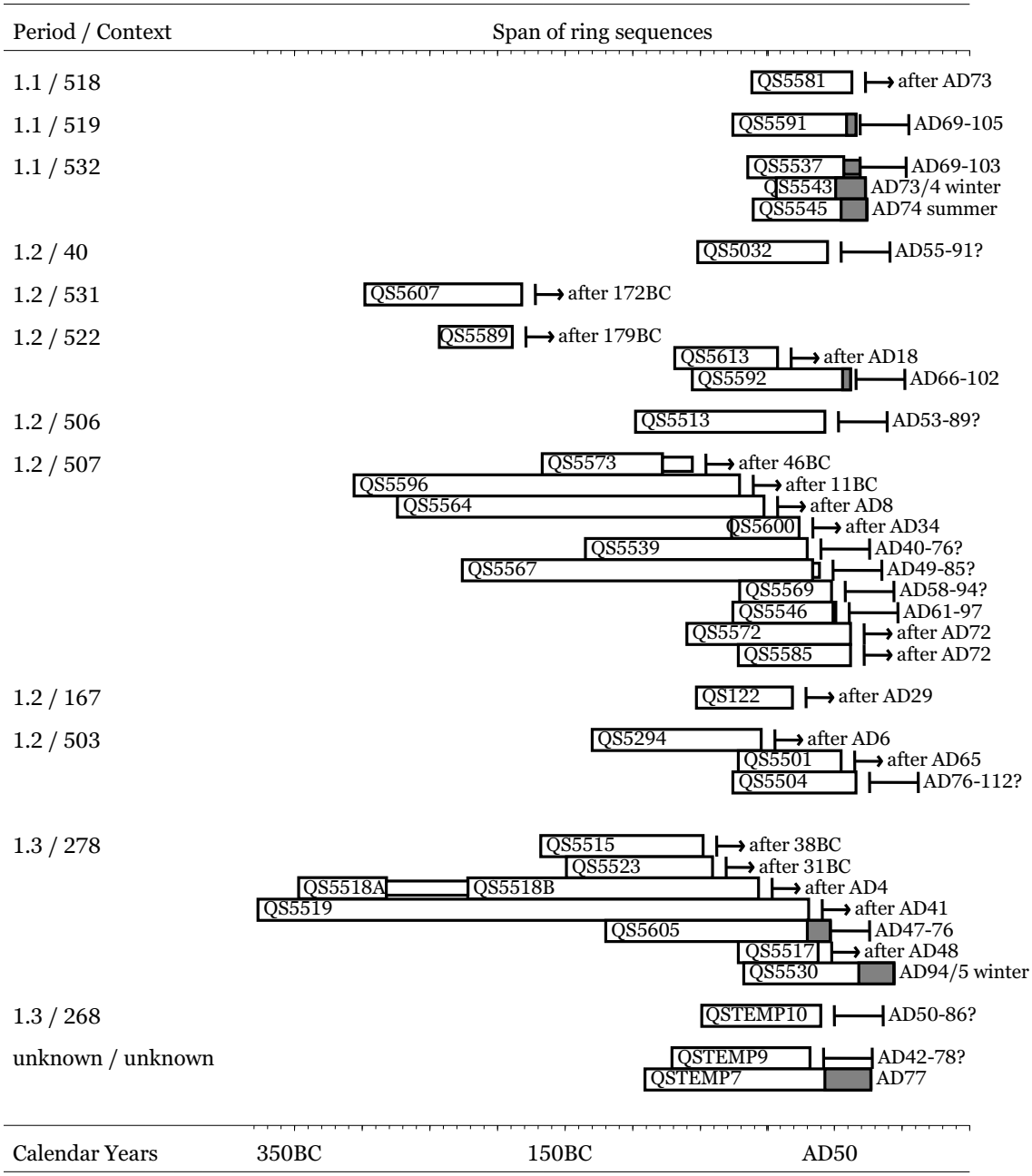

Figure 8: Bar diagram of all dated samples from Roman contexts. Bars are ordered by period, grouped by context, and then ordered by felling date. White bars – heartwood; narrow white bar – unmeasured heartwood; shaded bar – sapwood; narrow shaded bar – unmeasured sapwood

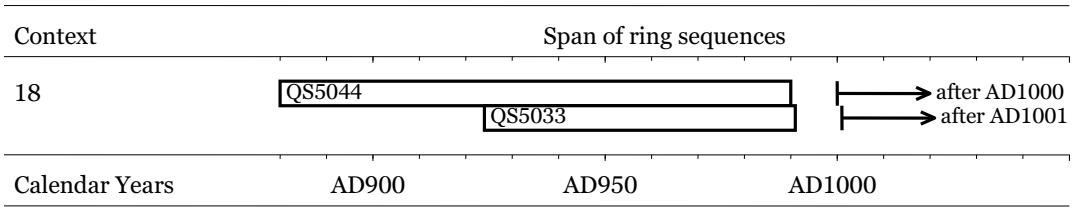

Figure 9: Bar diagram of cross-matched ring-width series from the early medieval same tree, Tree 5. White bars - heartwood

TABLES

Table 1: Details of the tree-ring samples from the Upper Quay Street excavation (site code 8/89), Gloucester

Sample code	Context	Comments	Conversion	Dimensions (mm)	Total rings	Sapwood	Average ring width (mm)	Dated sequence	Felling date
QS122	167	-	radial	205 x 111	72	-	2.70	53BC-AD19	after AD29
QS5032	40	-	radial	126 x 8	97	?HS	1.28	52BC-AD45	AD55-91?
QS5033	18	medieval pit fill	radial	95 x 25	68	-	1.42	AD924-AD991	after AD1001
QS5041	22	-	radial	170 x 25	161	-	1.07	undated	-
QS5044	None	-	radial	175 x 18	111	-	1.46	AD880-AD990	after AD1000
QS5190	282	-	radial	72 x 50	68	-	1.08	undated	-
QS5294	503	-	radial	193 x 5	126	-	1.47	130BC-5BC	after AD6
QS5501	503	same parent tree as 5537	radial	130 x 15	77	-	1.61	22BC-AD55	after AD65
QS5504	503	-	radial	170 x 7	92	?HS	1.80	26BC-AD66	AD76-112?
QS5505	503	-	radial	56 x 8	59	-	0.82	undated	-
QS5508	503	-	radial	90 x 28	78+5h	*(+?HS)*	1.06	undated	-
QS5513	506	-	radial	120 x 8	141	?HS	0.83	98BC-AD43	AD53-89?
QS5515	278	same parent tree as 5518, 5519 and 5596	radial	240 x 33	121	-	0.76	168BC-48BC	after 38BC
QS5517	278	-	tangential	205 x 26	60	-	0.65	22BC-AD38	after AD48
QS5518A	278	SF5518 inner. Same parent tree as 5515, 5519 and 5596	radial	255 x 28	66	-	0.88	347BC-282BC	after 272BC
QS5518B	278	SF5518 outer. Same parent tree as 5515, 5519 and 5596	radial	355 x 28	216	-	0.78	222BC-7BC	after AD4
QS5519	278	same parent tree as 5515, 5518 and 5596	radial	345 x 48	408	-	0.86	377BC-AD31	after AD41
QS5522	507	-	radial	131 x 5	50	-	2.26	undated	-

QS5523	278	-	radial	191 x 65	109	-	1.68	149BC-41BC	after 31BC
QS5530	278	-	radial	152 x 98	112	26 Bw	1.29	18BC-AD94	AD94/95 winter
QS5537	532	same parent tree as 5501	radial	113 x 33	72	HS+12s	1.36	15BC-AD57	AD69-103
QS5539	507	-	radial	235 x 25	165	?HS	1.34	135BC-AD30	AD40-76?
QS5543	532	-	radial	110 x 90	67	22 Bw	1.28	AD7-AD73	AD73/74 winter
QS5545	532	-	radial	160 x 82	85	19 Bs	1.68	11BC-AD74	AD74 summer
QS5546	507	-	quartered	102 x 75	77	HS	1.07	26BC-AD51	AD61-97
QS5564	507	-	radial	206 x 18	272	-	0.75	274BC-3BC	after AD8
QS5566	507	compressed and distorted ring sequence	radial	76 x 18	*c* 175	-	<0.70	not measured	-
QS5567	507	-	radial	172 x 14	260+5h	*(+?HS)*	0.64	226BC-AD34	AD49-85?
QS5569	507	-	radial	120 x 21	69	?HS	1.68	21BC-AD48	AD58-94?
QS5570	507	-	radial	140 x 14	55	2	2.32	undated	-
QS5571	507	-	radial	145 x 14	56	?HS	2.12	undated	-
QS5572	507	-	radial	199 x 22	122	-	1.59	60BC-AD62	after AD72
QS5573	507	outer rings desiccated	radial	120 x 30	90+22h	-	0.93	167BC-78BC	after 46BC
QS5575	507	-	radial	133 x 7	60	-	2.18	undated	-
QS5577	522	-	radial	135 x 55	69	-	1.93	undated	-
QS5581	518	-	whole	300 x 200	75	-	2.28	12BC-AD63	after AD73
QS5585	507	-	radial	170 x 28	84	-	1.99	22BC-AD62	after AD72
QS5589	522	same parent tree as 5607	radial	73 x 31	55	-	1.32	243BC-189BC	after 179BC
QS5590	522	-	radial	102 x 7	52	-	1.88	undated	-
QS5591	519	-	quartered	125 x 70	92	7	1.00	26BC-AD66	AD69-105
QS5592	522	-	radial	115 x 11	118	6	0.94	56BC-AD62	AD66-102
QS5596	507	same parent tree as 5515, 5518 and 5519	radial	237 x 37	286	-	0.83	306BC-21BC	after 11BC
QS5600	507	-	radial	95 x 10	51	-	1.85	27BC-AD24	after AD34
QS5603	507	-	quartered	200 x 160	122	HS	1.18	undated	-
QS5605		context uncertain and possibly reused	halved	173 x 122	167	17	0.82	120BC-AD47	AD47-76

QS5607	531	same parent tree as 5589	radial	155 x 105	117	-	1.32	298BC-182BC	after 172BC
QS5611	278	compressed and distorted ring sequence	whole	190 x 175	*c* 150	11	<0.60	not measured	-
QS5612	278	compressed and distorted ring sequence	quartered	125 x 105	*c* 150	-	<0.80	not measured	-
QS5613	522	-	radial	140 x 135	77	-	1.94	69BC-AD8	after AD18
QStemp7	---	unlabelled	whole	260 x 240	168	34 B	0.73	91BC-AD77	AD77
QStemp9	---	unlabelled. Same parent tree as temp10	radial	160 x 45	103	?HS	1.35	71BC-AD32	AD42-78?
QStemp10	268	unlabelled. Same parent tree as temp9	radial	123 x 25	89	?HS	1.25	49BC-AD40	AD50-86?

Key: H/S = heartwood/sapwood boundary; Bw = bark edge, winter felled; Bs – bark edge, summer felled; B – bark edge, season of felling indeterminate; +*nn*h – number of unmeasured heartwood rings; +*nn*s – number of unmeasured sapwood rings

Table 2: t-*values between overlapping ring-width series from separate samples derived from the same parent tree, Tree 1. \ = overlap < 30 years, * = empty triangle*

Sample	QS5518A	QS5518B	QS5519	QS5596
QS5515	\	9.90	7.91	11.25
QS5518A	*	\	10.57	\
QS5518B	*	*	12.03	15.86
QS5519	*	*	*	13.45

Table 3: t-*values between overlapping ring-width series from separate samples derived from the same parent tree, Tree 2.*

Sample	QS5537
QS5501	15.67

Table 4: t-*values between overlapping ring-width series from separate samples derived from the same parent tree, Tree 3.*

Sample	QStemp10
QStemp9	19.85

Table 5: t-*values between overlapping ring-width series from separate samples derived from the same parent tree, Tree 4.*

Sample	QS5607
QS5589	10.11

Table 6: t*-values between ring-width series from individual samples or common parent trees which form the site mean QST35. \ = overlap < 30 years, - =* t*-values less than 3.00, * = empty triangle, the QS prefix has been omitted from sample names*

Sample	5032	5294	5504	5513	5517	5523	5530	5539	5543	5545	5546	5564	5567	5569	5572	5573	5581	5585	5591	5592	5600	5605	5613	TEMP7	Tree1	Tree2	Tree3	Tree4
122	3.63	-	-	-	-	\	4.08	3.62	\	-	-	5.94	-	6.73	3.07	\	3.19	-	-	3.10	-	4.21	4.05	-	-	5.09	-	\
5032	*	-	5.04	3.79	4.80	\	7.59	3.67	-	-	4.74	4.35	4.16	7.26	3.27	\	5.85	4.82	-	4.81	-	4.62	3.68	5.16	4.41	6.07	4.79	\
5294	*	*	\	5.08	\	-	\	4.40	\	\	\	4.34	-	\	-	-	\	\	\	-	\	3.92	-	-	6.17	\	3.55	\
5504	*	*	*	3.09	5.03	\	6.63	3.14	4.85	5.33	5.30	\	-	4.89	4.52	\	6.92	6.87	3.45	4.90	3.02	3.17	-	4.73	4.30	6.13	4.93	\
5513	*	*	*	*	-	-	3.32	-	-	-	-	3.83	-	-	4.27	\	-	3.12	-	5.08	-	4.54	4.55	4.60	8.65	3.70	-	\
5517	*	*	*	*	*	\	3.90	-	-	3.73	3.93	\	6.40	3.02	-	\	-	3.51	-	-	3.35	4.15	-	3.75	3.83	3.63	-	\
5523	*	*	*	*	*	*	\	3.38	\	\	\	5.25	4.21	\	\	3.83	\	\	\	\	\	-	\	-	5.86	\	-	\
5530	*	*	*	*	*	*	*	4.16	3.58	5.16	5.46	\	-	6.29	4.17	\	5.31	5.32	4.52	4.01	-	3.22	\	3.06	4.54	5.91	3.07	\
5539	*	*	*	*	*	*	*	*	\	-	3.15	5.15	-	5.19	3.13	-	3.44	3.44	-	3.36	-	-	-	-	4.61	3.97	3.23	\
5543	*	*	*	*	*	*	*	*	*	7.48	3.43	\	\	3.72	5.09	\	5.95	4.87	-	4.75	\	-	\	-	\	5.21	3.75	\
5545	*	*	*	*	*	*	*	*	*	*	4.98	\	4.43	3.99	5.13	\	6.92	7.33	4.44	4.12	3.55	-	\	-	4.20	6.60	4.66	\
5546	*	*	*	*	*	*	*	*	*	*	*	\	3.13	6.12	3.08	\	5.51	7.92	-	3.47	-	4.64	3.58	-	5.28	5.57	5.24	\
5564	*	*	*	*	*	*	*	*	*	*	*	*	5.46	\	4.34	7.39	\	\	\	5.36	\	4.52	4.79	-	11.36	\	3.25	7.53
5567	*	*	*	*	*	*	*	*	*	*	*	*	*	-	-	4.39	-	3.55	-	-	-	-	-	3.22	7.36	3.50	3.37	4.11
5569	*	*	*	*	*	*	*	*	*	*	*	*	*	*	4.46	\	7.87	5.85	-	4.02	-	-	\	-	4.00	5.73	-	\
5572	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	\	6.53	6.67	3.25	6.26	3.51	-	3.31	3.81	6.02	6.82	3.46	\
5573	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	\	\	\	\	\	-	\	\	6.39	\	\	\
5581	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	9.03	4.29	5.51	3.03	-	\	4.16	4.13	8.08	4.29	\
5585	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	4.06	4.24	-	3.10	-	3.45	4.90	8.09	4.41	\
5591	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	-	-	-	3.48	5.26	3.25	-	-	\
5592	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	3.47	-	5.03	5.59	7.91	5.07	4.78	\
5600	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	-	-	3.03	4.58	4.03	-	\
5605	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	3.81	3.80	6.73	3.71	5.58	\
5613	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	5.41	5.61	3.25	5.50	\
TEMP7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	4.74	3.09	3.90	\
Tree1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	4.33	5.66	7.11
Tree2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	3.59	\
Tree3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	\

Table 7: t-*value correlations between the 471- year, 37-timber Roman site master QST35 dated to 377 BC – AD 94 inclusive and a selection of regional chronologies and site master ring-width series*

Chronology / Site Master	Start Date	End Date	*t*-value
Regional Chronologies			
London England (Tyers pers comm)	368BC	AD294	11.54
Northern England (Tyers pers comm)	434BC	AD193	9.03
East Anglia and South East England (Tyers pers comm)	263BC	AD315	6.96
England London			
1 Poultry City (Tyers 2000)	307BC	AD290	10.23
Bucklersbury City (Nayling 1990)	211BC	AD79	9.74
Regis House City (Boswijk and Tyers 1996)	186BC	AD107	8.06
Cannon St Station City (Hillam 1989 unpubl)	136BC	AD64	8.61
England West Midlands			
Droitwich Friar Street Worcestershire (Hillam 1982b)	125BC	AD44	9.99
Droitwich Old Bowling Green, Worcestershire (Crone pers comm)	215BC	AD25	13.27
Droitwich Upwich, Worcestershire (Groves and Hillam 1997)	256BC	AD61	11.54
England North-East			
Vindolanda, Northumberland (Hillam 1993)	367BC	AD103	6.93
England North-West			
Carlisle The Lanes northern, Cumbria (Groves 1996 unpubl)	434BC	AD118	6.16
Nantwich Kingsley Fields, Cheshire (Tyers 2004b)	198BC	AD130	8.58
Walton-le-Dale Lancashire (Groves 1987)	282BC	AD119	7.28
England Yorkshire			
Castleford, West Yorkshire (Hillam 1987)	161BC	AD56	7.13
Rossington Bridge, Humberside (Nayling 1999)	222BC	42BC	4.87
England South-East			
Dover Town Wall, Kent (Nayling 2001)	263BC	AD32	5.94
England South-West			
Gloucester Eastgate, Timber 305, Gloucestershire (Hillam 1982a)	32BC	AD43	7.36
Ireland			
Belfast Long Chronology (Pilcher *et al* 1984)	5289BC	AD1983	7.47

Table 8: t-*values between overlapping ring-width series from separate samples derived from the same parent tree, Tree 5*

Samples	QS5044
QS5033	10.72

Table 9: t-*value correlations between the 112-year raw ring-width series QSTree05 dated to AD880 - AD991 inclusive and a selection of regional chronologies and site master ring-width series*

Chronology / Site Master	Start Date	End Date	*t*-value
Regional Chronologies			
England London (Tyers pers comm)	AD413	AD1782	6.41
England South East (Tyers pers comm)	AD435	AD1811	6.96
England South West (Tyers pers comm)	AD770	AD1833	7.59
Dublin (Baillie 1977)	AD855	AD1306	8.43
London			
London City Billingsgate (Tyers pers comm)	AD611	AD1243	6.19
London City Bull Wharf (Boswijk and Tyers 1996)	AD620	AD1181	6.29
London Fennings Wharf (Tyers 2001a)	AD802	AD1435	5.95
London Guildhall (Tyers 2001b)	AD498	AD1212	6.07
England South-East			
Winchester Cathedral Green (Barefoot and Tyers 2002)	AD792	AD1050	5.00
Winchester The Brooks (Hillam 1992)	AD443	AD1128	7.18
England South-West			
Bristol Dundas Wharf (Nicholson and Hillam 1987)	AD770	AD1202	6.87
Exeter Goldsmith Street, Devon (Mills 1988)	AD775	AD1022	5.66
Launceston Castle, Cornwall (Hillam pers comm)	AD819	AD1025	5.93
Ireland			
Skuldelev 2 shipwreck, Roskilde, Denmark (Bonde and Crumlin-Pedersen 1990)	AD778	AD1023	7.24

APPENDIX

Raw ring measurements in units of 0.01mm

QS122

332	307	323	336	383	315	324	285	308	302
303	274	286	189	161	246	240	274	294	328
294	269	361	332	367	298	340	396	297	254
336	356	271	236	264	288	262	194	216	215
201	273	159	111	191	208	225	258	219	211
215	192	188	186	217	165	193	217	210	206
174	204	255	289	342	318	427	368	411	336
327	279								

QS5032

193	139	113	110	99	127	111	99	100	109
151	117	104	72	59	80	113	111	107	129
136	163	143	154	120	158	126	168	134	149
220	123	116	100	125	107	111	164	147	165
115	85	64	130	118	200	186	138	211	235
226	182	144	175	144	121	187	183	151	132
143	129	95	123	126	147	135	157	153	166
129	146	171	167	135	135	110	102	116	128
118	87	103	106	110	109	131	85	103	112
88	55	49	65	68	62	47			

QS5033

165	175	144	200	194	170	183	187	202	142
173	140	186	203	161	135	187	201	162	146
146	182	149	218	173	165	305	185	209	175
138	148	132	158	158	142	106	147	89	151
98	100	146	150	145	145	136	122	108	95
63	106	82	104	81	70	86	73	75	97
73	68	112	86	74	161	140	120		

QS5041

115	77	98	130	112	123	128	171	127	118
143	145	133	86	77	85	67	98	101	105
111	189	136	157	127	177	162	138	98	129
114	79	63	52	72	76	101	123	74	102
95	127	93	94	89	91	91	123	110	119
66	77	90	68	76	75	74	86	106	87
118	102	97	94	89	62	72	65	63	84
79	77	86	67	96	81	82	83	94	79
78	72	81	63	98	81	93	95	140	95
118	107	61	71	75	83	68	73	51	93
119	81	103	144	95	87	96	90	99	85
91	76	98	87	102	92	100	91	97	100
95	93	139	121	109	148	123	91	86	132
128	117	141	182	181	153	172	153	185	169
242	141	120	116	169	187	99	121	108	112
113	106	108	145	156	141	153	114	127	86
143									

QS5044

162	184	162	183	191	157	158	152	121	136
142	150	126	128	151	199	159	120	147	131
156	136	163	163	132	115	140	149	144	160
157	152	166	180	156	139	133	192	166	124
124	131	117	121	123	132	115	240	276	207
234	224	226	140	167	122	157	182	166	143
215	215	163	122	112	158	143	185	176	159
275	164	203	171	146	166	142	198	205	169
135	160	111	163	114	109	180	155	153	135
136	132	102	121	81	99	113	127	77	98
130	81	114	125	123	107	145	141	107	173
141									

QS5190

206	127	134	176	143	152	91	100	122	128
113	110	119	65	75	66	101	103	120	130
136	126	133	117	91	91	114	83	62	77
85	98	90	105	121	79	99	102	107	70
119	124	102	82	106	101	70	63	77	86
67	96	105	112	67	88	126	121	122	142
151	117	132	116	81	111	145	123		

QS5294

150	150	109	113	206	121	195	125	172	142
169	135	186	167	153	131	113	139	170	209
174	142	207	144	154	146	151	168	150	108
165	147	168	163	110	146	151	155	131	156
158	171	187	114	149	161	165	218	147	165
128	161	153	161	130	142	156	117	165	137
159	130	157	108	110	120	127	120	117	101
115	102	95	75	114	150	112	148	140	154
121	136	101	138	106	127	122	116	139	166
148	111	176	147	191	183	172	173	150	174
195	174	160	212	172	184	143	156	186	132
134	140	161	145	142	162	148	173	152	97
184	112	139	130	111	122				

QS5501

270	134	140	147	210	211	161	184	205	199
189	76	61	160	108	146	190	160	175	203
194	193	150	174	151	130	150	249	154	163
190	161	143	153	174	163	110	141	166	169
122	197	153	197	126	176	147	205	229	173
141	96	136	138	119	131	213	134	176	165
113	62	113	107	115	248	160	194	208	189
183	125	186	158	153	116	205			

QS5504

260	251	250	206	266	217	187	175	261	222
229	228	227	252	200	156	88	104	88	120
110	118	151	116	135	138	165	185	167	156
130	194	139	136	241	170	177	204	147	121

200 205 179 183 139 175 122 159 95 164
126 199 205 197 160 91 165 144 175 185
237 158 197 235 175 97 123 199 175 243
212 241 271 303 140 175 185 256 216 234
250 151 189 136 147 163 193 203 194 235
152 161

QS5505
116 117 139 101 131 101 101 88 62 78
100 91 96 73 64 80 76 65 67 66
64 75 55 39 83 64 57 60 75 67
78 80 69 86 69 83 82 96 96 87
68 56 59 44 71 112 77 86 81 89
80 52 45 90 95 104 125 79 124

QS5508
77 77 113 87 89 125 135 122 108 147
116 120 87 105 127 129 136 161 155 146
110 85 134 141 130 104 126 155 108 71
88 101 109 131 120 134 165 84 132 114
96 64 63 93 91 90 105 90 121 99
83 76 91 98 124 100 92 96 102 98
91 103 117 100 135 121 85 114 86 95
73 72 92 96 88 87 80 89

QS5513
73 88 57 84 69 74 82 88 95 96
90 74 79 103 80 92 92 126 91 97
88 97 96 82 79 66 88 88 81 99
100 84 121 110 105 82 109 105 119 98
111 95 106 85 76 104 117 107 96 107
117 116 117 118 101 106 130 126 93 84
91 75 76 87 88 92 95 90 117 110
86 100 86 69 69 94 119 79 83 95
84 97 72 81 88 106 94 57 93 85
58 70 67 68 82 69 88 67 83 60
61 59 59 80 66 46 52 52 42 50
34 46 53 63 63 69 65 79 79 87
65 65 60 58 67 77 75 54 63 69
67 69 75 57 85 72 69 67 62 70
79

QS5515
86 71 80 61 61 80 59 93 68 69
82 74 81 72 56 76 70 65 77 64
83 84 70 74 77 81 57 57 71 54
76 68 55 68 55 58 58 58 59 65
57 54 65 63 71 65 71 76 68 75
76 67 78 67 74 82 70 97 86 64
79 70 75 73 87 77 77 70 95 78
72 84 94 111 93 88 80 81 78 67
88 63 91 88 73 92 81 112 83 102
81 82 87 88 96 88 120 88 74 97

77 72 83 79 68 79 91 69 74 88
98 74 88 88 55 94 88 62 45 57
39

QS5517
114 76 98 68 82 70 79 104 82 92
52 58 48 77 67 104 75 87 92 81
88 67 82 86 73 61 57 88 54 56
80 56 61 68 60 58 48 61 52 81
49 59 53 58 33 46 37 30 51 54
39 32 46 53 48 48 53 57 73 57

QS5518A
71 71 113 88 102 98 102 80 70 70
82 83 101 81 75 104 110 81 85 85
91 98 90 62 77 89 67 72 102 95
71 81 104 93 82 75 67 61 63 73
97 100 80 83 88 92 85 99 107 124
84 101 109 79 103 94 103 137 108 98
83 79 105 90 82 50

QS5518B
66 67 63 70 66 88 70 82 98 63
76 67 76 85 70 70 77 85 87 95
83 57 92 80 83 66 85 53 61 72
71 71 68 76 97 83 89 104 89 87
58 91 86 87 75 85 101 84 97 67
57 59 93 86 81 87 83 87 74 85
63 96 91 91 90 102 89 89 66 84
74 68 94 83 99 100 93 87 97 98
58 62 80 69 69 62 60 80 55 49
63 71 60 73 65 71 91 66 80 79
81 84 79 75 90 79 90 75 60 89
83 85 85 77 84 86 70 82 78 73
72 74 92 84 76 100 101 105 90 85
70 81 82 76 86 62 93 83 80 92
77 104 82 90 77 75 81 75 84 68
108 83 74 85 81 78 87 85 79 75
92 72 81 71 89 64 84 80 67 84
89 85 74 83 63 88 70 72 69 70
81 77 70 58 74 60 58 68 67 72
55 76 77 76 70 71 70 76 70 64
72 58 68 67 78 74 60 60 69 71
70 56 73 71 47 58

QS5519
49 57 65 93 79 91 78 83 79 89
102 96 91 87 90 114 90 107 115 96
100 85 100 96 96 97 75 110 89 96
78 64 105 81 89 97 93 109 78 93
87 96 90 80 71 97 96 80 80 71
85 98 100 75 82 88 77 86 97 96
78 79 108 107 104 106 100 91 89 81

104	100	93	94	98	100	87	115	132	115
88	110	118	98	119	96	108	140	104	100
111	110	131	120	100	125	129	127	121	146
137	139	123	159	119	136	164	130	131	131
125	136	98	91	94	109	119	127	121	96
112	89	67	111	118	105	119	99	96	101
102	93	131	117	117	113	98	120	126	103
118	96	99	82	148	108	105	110	122	117
122	120	102	125	102	99	104	92	87	74
139	110	99	135	82	106	99	102	109	94
88	98	102	112	103	90	72	90	75	73
70	89	69	70	81	76	89	68	69	102
91	80	94	92	82	67	81	80	81	86
87	82	94	99	65	71	65	92	69	69
72	86	84	67	77	67	70	87	68	79
93	92	79	60	58	68	62	57	75	81
88	73	75	98	105	52	54	63	67	70
62	45	72	55	59	75	67	72	74	65
60	68	69	70	74	76	78	74	99	105
96	110	99	81	83	89	101	96	80	90
106	73	88	92	82	83	69	85	94	84
117	98	108	95	77	70	72	75	78	80
63	86	78	66	104	62	96	70	105	77
85	81	78	63	70	68	65	70	75	78
57	76	76	68	77	81	60	69	59	64
53	73	64	56	83	86	73	62	64	60
77	66	67	62	73	77	63	77	49	70
64	61	68	69	59	58	62	65	57	50
74	69	61	55	60	76	54	56	63	79
74	60	67	72	64	68	57	62	90	60
74	58	60	69	79	84	69	80	71	63
56	56	82	63	47	66	57	55	59	50
48	48	75	58	62	50	67	57	66	55
60	58	57	58	69	64	40	58		

QS5522

271	118	182	214	214	231	331	228	239	314
185	187	172	183	223	412	407	311	370	470
299	205	206	306	434	473	225	264	200	143
172	120	58	108	121	126	140	140	131	189
167	140	208	292	175	208	205	156	184	242

QS5523

132	234	176	154	212	212	157	108	195	164
162	224	165	158	189	132	123	175	186	188
205	144	139	199	177	163	188	190	265	206
217	205	208	202	166	128	153	140	222	261
146	191	192	227	191	204	255	217	199	235
261	208	278	242	202	128	184	144	210	169
152	152	148	162	159	90	196	126	158	123
143	126	203	193	186	124	164	138	96	125
180	139	100	153	128	181	142	136	126	134
115	118	132	149	136	88	118	156	133	93

123 111 132 100 110 104 125 101 126

QS5530

373 481 324 626 428 375 322 140 105 191
162 288 245 267 288 259 289 218 210 201
157 137 197 255 194 165 213 213 164 197
156 115 143 145 117 127 125 160 125 128
106 113 93 110 109 115 100 73 80 101
119 88 122 102 97 109 75 44 57 82
78 91 76 69 99 59 35 49 48 46
49 49 61 64 47 45 34 49 45 45
53 44 36 32 40 33 32 38 38 34
34 39 33 31 33 27 59 86 92 99
129 124 112 98 135 120 181 125 117 105
106 90

QS5537

131 161 164 171 63 55 125 107 103 164
128 140 138 174 145 151 149 142 127 148
222 156 134 210 123 139 145 125 125 103
117 121 156 116 168 129 177 109 158 140
163 191 137 137 77 132 119 115 122 184
105 161 145 115 68 72 96 78 191 115
158 163 143 145 121 137 132 132 129 160
143 146

QS5539

254 160 140 217 186 204 242 194 183 217
168 207 95 90 127 128 173 174 170 179
192 147 158 152 167 157 141 159 144 187
171 174 194 188 115 195 181 188 170 200
168 142 148 130 126 140 145 139 139 112
152 124 146 145 180 165 136 156 140 144
151 127 115 108 91 138 126 149 110 117
112 149 154 151 140 140 127 122 83 118
115 96 110 93 118 110 125 103 211 93
112 125 122 130 136 147 107 143 124 143
123 146 131 94 152 139 149 119 186 101
120 112 105 129 135 118 132 140 118 111
121 101 110 118 91 73 120 130 111 115
102 124 112 109 125 126 132 119 78 106
118 91 73 85 92 105 114 98 81 91
92 103 112 103 96 124 105 121 134 113
92 95 79 84 71

QS5543

167 124 189 164 162 181 160 136 134 182
157 159 93 129 119 90 109 135 124 149
175 144 117 91 126 103 141 121 139 105
142 114 102 82 102 156 121 191 132 161
136 146 116 119 142 120 131 130 139 149
103 90 108 108 107 120 103 124 90 120
111 103 127 109 93 88 144

QS5545

88	132	163	118	123	125	141	128	151	181
138	154	170	167	127	134	176	160	155	195
166	184	163	181	133	119	145	178	241	172
322	209	182	148	185	188	182	195	194	181
106	163	129	166	179	145	141	165	171	121
79	106	159	115	178	189	192	232	183	142
158	187	198	202	181	237	232	188	140	143
159	148	186	185	216	190	187	188	181	261
210	182	159	228	93					

QS5546

148	162	140	131	137	147	144	196	219	198
144	168	152	136	151	77	62	145	109	191
137	146	142	123	100	72	91	94	62	42
49	73	65	55	63	54	47	42	75	48
59	142	150	120	108	154	138	186	67	125
92	134	129	139	127	76	138	117	124	121
100	83	90	62	36	39	39	84	89	98
112	114	101	92	56	51	47			

QS5564

103	67	52	106	71	86	68	67	63	51
66	84	51	91	91	63	82	81	49	64
57	63	102	65	58	55	56	64	41	61
61	62	49	36	69	105	60	68	58	70
50	69	63	55	50	61	55	70	63	50
62	57	55	72	45	48	41	76	69	60
85	64	79	80	69	86	63	65	51	70
68	55	63	50	57	55	57	50	76	56
54	61	63	75	61	50	79	56	71	74
77	66	46	59	55	66	64	65	69	83
77	66	58	48	74	47	62	80	101	74
119	80	53	67	73	84	103	113	103	72
59	62	72	47	79	71	103	60	71	69
101	57	46	50	67	74	61	60	55	79
66	61	55	66	82	110	79	67	90	78
73	69	71	91	84	98	81	92	90	89
43	83	64	75	74	67	74	75	79	76
116	103	99	78	122	113	106	117	136	111
54	45	45	57	64	66	59	62	92	82
66	103	109	111	90	110	73	65	60	66
75	51	92	57	70	64	67	46	71	81
84	72	99	93	84	91	99	79	92	101
77	102	90	104	96	96	85	108	68	71
86	85	79	76	94	56	102	75	123	106
94	82	63	98	107	94	97	141	166	102
68	97	139	69	77	91	116	70	51	67
66	68	53	46	39	78	71	80	99	75
114	112								

QS5567

124	107	119	100	87	114	66	58	50	66
53	58	81	67	88	79	85	90	74	55
84	89	91	90	73	76	78	74	74	80
105	86	85	101	96	69	36	53	60	70
56	72	81	90	60	77	71	95	78	76
86	90	96	93	42	50	68	63	59	66
54	81	63	74	52	55	54	55	59	90
83	69	59	68	54	82	94	84	96	109
94	74	78	62	46	54	79	98	115	89
89	153	100	98	122	128	124	143	108	68
139	84	66	60	29	46	57	59	49	66
60	59	51	51	44	68	60	43	52	41
46	46	66	63	69	63	83	55	59	66
60	51	37	45	50	49	57	62	58	49
65	58	51	97	87	88	44	61	48	64
55	62	41	57	63	64	60	60	55	68
74	59	54	71	56	49	54	51	82	54
55	57	51	57	44	60	51	52	44	49
44	83	34	61	44	49	54	43	37	49
61	47	47	51	52	51	66	68	47	69
55	61	61	73	60	42	44	37	41	37
46	50	52	44	32	27	33	39	41	43
41	40	43	50	60	43	52	60	59	34
49	54	49	58	72	50	62	59	51	49
34	43	50	58	45	54	67	46	34	41
40	38	46	50	44	45	53	62	52	46

QS5569

217	206	168	245	229	188	176	159	194	250
141	82	237	174	242	204	137	163	206	174
136	185	208	132	110	117	107	128	77	117
145	124	144	123	115	112	192	179	172	134
174	280	204	169	243	144	156	202	212	229
120	140	165	181	166	246	182	177	253	127
81	101	127	144	148	196	149	158	173	

QS5570

356	248	355	314	260	126	101	85	115	150
176	251	215	214	261	175	253	349	357	225
192	175	262	201	125	241	215	314	218	268
319	185	262	300	259	207	155	202	286	199
180	159	158	255	267	252	139	247	273	277
357	387	171	267	213					

QS5571

206	190	170	135	171	200	217	197	245	270
224	207	234	300	203	205	220	205	153	169
226	194	248	188	166	172	199	190	209	213
209	198	170	198	208	223	186	189	144	164
169	175	163	176	284	276	251	216	417	276
252	188	293	224	222	264				

QS5572

157	164	187	145	156	152	119	183	226	212
206	188	185	208	156	119	177	170	209	161
77	117	249	170	135	147	181	130	106	197
166	146	188	218	199	184	114	146	198	205
145	196	240	189	149	162	214	174	89	94
107	221	119	133	143	89	134	137	165	155
159	168	131	127	76	155	126	90	168	137
135	157	139	125	84	174	170	188	122	111
156	102	133	95	87	131	132	127	118	85
93	97	103	108	190	114	145	174	121	85
146	176	138	243	227	173	306	234	197	147
226	205	211	196	281	239	213	189	188	191
211	154								

QS5573

80	74	104	104	111	76	67	100	71	107
84	116	74	63	69	80	44	54	55	45
40	51	47	69	44	42	50	77	81	82
59	53	75	65	71	62	73	65	97	48
59	64	78	76	64	71	99	86	84	93
88	102	105	84	90	75	100	96	83	93
100	112	84	129	96	98	82	152	102	125
114	155	180	140	101	70	88	132	140	120
87	184	159	136	212	152	219	107	193	114

QS5575

194	214	239	264	252	129	171	163	179	224
218	145	164	194	258	214	277	229	250	202
244	222	274	248	190	225	200	265	200	210
274	287	229	295	207	265	247	222	186	203
212	274	202	221	207	185	296	237	247	270
231	192	253	185	174	165	178	171	155	151

QS5577

246	232	138	209	160	170	172	154	191	176
125	104	110	126	176	159	193	244	191	242
203	177	160	110	102	110	157	160	221	184
232	270	208	279	230	211	171	262	208	237
235	234	200	159	226	196	248	225	182	124
148	188	260	178	180	163	202	150	220	155
204	321	162	252	242	207	260	205	190	

QS5581

90	48	44	119	103	125	132	90	129	155
158	139	176	156	169	106	90	123	121	105
158	196	172	182	163	160	169	249	284	212
179	278	232	227	146	275	215	250	213	229
187	117	169	145	201	223	377	190	295	287
309	130	206	332	261	378	321	397	470	470
379	240	338	389	291	391	490	510	361	235
241	231	280	350	358					

QS5585

234 167 235 203 241 263 201 240 241 195
174 107 106 221 209 218 204 206 207 207
241 188 210 166 191 164 168 265 208 215
280 263 245 189 188 141 127 211 202 185
151 165 200 170 139 178 165 232 204 206
203 111 226 164 169 240 218 195 195 215
157 103 104 166 167 254 250 236 281 300
198 164 223 283 249 207 262 225 216 176
180 174 153 150

QS5589

157 143 123 151 137 121 123 113 164 114
152 148 119 117 108 133 135 154 151 140
148 154 159 122 121 114 135 137 136 166
122 137 153 123 153 134 134 118 142 160
139 130 118 121 102 120 90 135 107 95
119 167 149 117 105

QS5590

140 130 135 108 73 142 159 148 126 118
181 177 166 197 147 150 155 218 218 129
166 179 143 155 138 234 255 257 247 111
138 174 221 293 332 285 203 325 229 207
186 142 232 256 236 261 221 195 168 150
202 217

QS5591

34 81 63 75 55 32 36 50 57 77
64 76 58 36 53 42 51 89 82 70
65 94 83 127 158 86 100 96 87 35
38 85 125 51 100 79 52 47 48 57
74 83 42 52 74 76 50 47 52 29
26 30 46 48 141 75 90 65 91 132
164 108 126 126 91 46 89 202 140 170
152 165 175 149 96 104 210 197 198 166
197 200 267 130 151 132 124 215 238 221
135 220

QS5592

98 88 85 98 103 123 106 106 110 158
133 117 126 97 104 73 81 85 105 97
110 104 98 88 92 114 114 90 95 178
170 143 105 111 126 96 83 84 85 88
63 81 80 91 100 79 88 98 61 79
107 83 85 102 92 76 86 89 67 77
69 102 74 60 78 80 72 83 87 72
79 103 77 90 77 93 89 83 83 92
81 76 83 83 72 58 87 74 90 100
120 61 85 89 115 82 81 100 80 93
83 92 111 112 102 94 93 84 94 108
111 105 96 96 97 101 96 127

QS5596

98	90	82	98	87	90	87	90	100	91
127	128	92	135	110	109	135	120	89	103
100	104	102	91	112	98	104	101	97	108
119	101	126	106	99	114	88	95	91	99
90	69	69	83	69	96	104	96	96	93
77	71	80	106	96	99	78	71	89	93
73	112	105	78	89	82	101	109	80	96
91	91	79	113	99	90	99	95	83	122
106	96	85	111	111	110	83	87	77	101
88	79	104	81	91	95	93	131	102	95
89	86	107	94	82	71	103	79	77	60
80	69	74	80	81	79	85	81	95	78
84	105	85	79	65	92	71	101	93	100
101	83	98	72	65	65	86	83	88	82
86	76	72	88	62	82	85	84	89	83
90	77	69	75	73	64	81	72	99	82
81	78	77	89	60	61	70	65	71	63
61	75	64	62	65	66	61	72	63	65
69	66	70	69	69	77	72	74	78	68
78	72	53	82	79	75	84	69	80	74
76	79	90	71	81	73	82	84	74	95
99	97	93	91	72	80	84	75	85	68
90	77	70	91	81	106	78	87	80	73
75	73	75	70	92	78	71	84	75	70
81	72	76	72	72	61	75	72	84	60
77	70	56	79	82	70	68	77	63	90
77	76	62	71	74	70	67	55	58	54
60	58	66	58	57	64	64	61	49	77
62	65	64	56	60	57				

QS5600

191	246	142	176	112	195	164	136	76	128
163	149	201	248	249	168	127	145	254	166
156	160	145	161	238	179	107	155	199	192
147	143	239	211	150	227	182	171	199	156
195	173	248	233	322	220	269	107	202	198
316									

QS5603

258	311	139	208	182	196	224	173	140	142
173	171	163	152	169	93	128	144	120	181
146	108	120	136	97	92	101	199	185	153
91	163	120	148	139	63	77	108	99	134
124	95	107	119	118	134	149	153	164	93
94	132	91	67	78	91	96	76	30	38
37	50	59	79	81	105	92	77	48	56
39	63	100	78	65	45	46	46	57	55
59	85	98	75	65	53	84	125	143	123
208	159	212	137	159	131	183	250	179	162
172	125	119	134	141	77	75	169	101	113
76	122	109	107	125	95	79	119	101	141
65	94								

QS5605

199	254	234	166	207	154	133	289	270	192
179	163	229	214	164	146	176	133	166	163
168	124	133	175	161	155	132	114	89	116
155	125	156	99	145	115	118	117	91	129
87	106	70	94	80	79	84	61	90	80
72	70	73	57	36	71	76	80	106	80
84	87	111	74	99	76	57	86	98	101
100	92	82	76	86	75	63	76	62	57
36	32	35	40	55	42	43	46	49	61
53	52	43	35	33	35	45	58	78	43
51	44	54	50	45	50	51	57	55	31
25	25	29	39	50	50	52	57	58	47
55	57	51	41	46	77	54	50	74	57
50	46	54	55	58	65	63	74	60	61
52	39	27	32	27	47	46	53	41	36
48	44	60	50	46	44	51	40	31	38
37	28	51	38	49	53	37			

QS5607

185	156	154	180	124	143	108	115	140	98
119	128	95	121	118	104	129	152	132	112
131	127	149	116	183	163	137	132	141	143
163	160	142	115	132	127	140	174	192	148
152	205	116	110	111	139	202	127	125	115
144	145	108	165	158	144	144	97	143	123
110	117	100	172	104	157	126	101	102	114
104	150	149	156	135	138	152	146	122	113
108	129	132	141	127	114	144	131	133	144
128	123	119	136	150	132	124	108	135	109
135	78	129	101	87	118	158	124	100	105
142	131	109	103	111	116	127			

QS5613

207	200	178	272	237	207	244	224	247	225
141	223	163	246	224	121	211	227	169	177
200	211	174	160	155	129	141	177	103	143
172	203	148	161	159	184	164	211	241	280
225	165	211	279	185	207	250	303	154	99
189	201	198	158	251	209	216	224	186	114
159	116	179	172	160	160	271	300	189	208
214	186	157	187	318	183	126			

QSTEMP10

129	135	131	110	228	106	165	167	111	132
92	141	122	153	148	130	160	102	163	136
108	99	108	96	118	93	99	131	89	86
82	112	84	103	142	117	120	117	122	84
91	73	108	133	126	128	123	149	101	120
136	119	93	146	183	130	121	200	151	123
118	145	129	138	195	253	145	116	135	113
116	112	135	120	169	135	171	139	87	116
97	96	135	116	78	106	96	95	67	

QSTEMP7

108	29	51	57	61	53	56	56	49	49
81	55	71	56	72	79	63	65	58	59
68	53	65	41	41	51	47	66	56	62
83	68	62	83	47	64	57	50	60	55
75	66	67	58	49	59	64	58	50	45
33	29	23	35	53	60	54	68	52	73
73	74	87	62	125	89	81	68	63	99
54	44	49	79	54	62	64	59	49	44
46	55	43	33	66	70	64	63	74	97
47	59	76	57	38	44	103	73	50	81
67	47	64	37	57	49	54	35	69	55
59	59	44	38	30	19	23	36	30	37
23	52	35	50	55	110	78	60	65	64
30	20	44	53	76	58	118	93	158	116
58	124	145	89	143	145	216	181	95	148
124	126	172	190	179	114	131	139	197	142
174	167	139	107	225	129	61	56		

QSTEMP9

107	197	223	172	153	136	164	190	226	165
161	224	162	178	114	177	171	103	172	158
138	143	112	123	143	120	191	124	177	179
124	140	96	169	132	174	137	121	149	103
174	150	109	123	110	93	108	100	114	139
84	81	95	110	84	93	142	112	122	115
120	93	91	82	105	120	116	140	113	141
114	114	127	98	90	144	170	123	120	202
147	120	113	151	109	124	181	231	136	116
143	100	111	104	137	108	165	135	162	138
86	155	89							

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