Research Report Series 2/2026

Otford Palace, Otford, Sevenoaks, Kent

Tree-ring Analysis of Oak Timbers

Martin Bridge

Scientific Dating

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Summary

Six ex situ slices of oak were examined. Four were from lintels within the north-west tower, the other two being of uncertain origin, but almost certainly also came from the north-west tower. The ring series from the four lintels were successfully dated. These four timbers are clearly broadly coeval and probably all felled at the same, or similar, time. Only one sample retained any sapwood, this having a felling date range of *c*. AD 1508–18, which accords with the date attributed to the start of building at the site in AD 1512.

Timbers in the gatehouse were assessed as unsuitable for dating as they had too few rings or were clearly modern softwood.

Contributors

Martin Bridge

Acknowledgements

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Front cover image

Otford Palace. [© Historic England. Photograph Martin Bridge]

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Date of investigation

Fieldwork was undertaken in May 2024 and the report written in 2025.

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Introduction

The Archbishop's Palace in Otford is a Scheduled Monument (National Heritage List Entry Number: 1005197; https://historicengland.org.uk/listing/the-list/list-entry/1005197), situated on the west facing slope to the east of the River Darent, at the foot of the Darent Valley (Fig. 1). It dates back to AD 821, but in AD 1512 Archbishop Warham started to build one of the largest palaces in England. The surviving above ground remains consist of part of the northern range of the outer court, the north-west tower, and one side of the gatehouse (https://otfordpalace.org). The remains of the gatehouse are currently on the Heritage at Risk register, and urgent repairs were undertaken in 2017, during which a number of oak lintels were removed from the north-west tower and replaced with new timbers, as described in Archbishop's Palace Conservation Trust 2017 (unpubl). These potentially original ex situ timbers are the main focus of this study, but an overall assessment of dendrochronological potential of the limited extant in situ timber elements in the standing remains was also requested by Lena Delaney (Historic England Assistant Inspector of Ancient Monument), in order to inform future works on the remains.

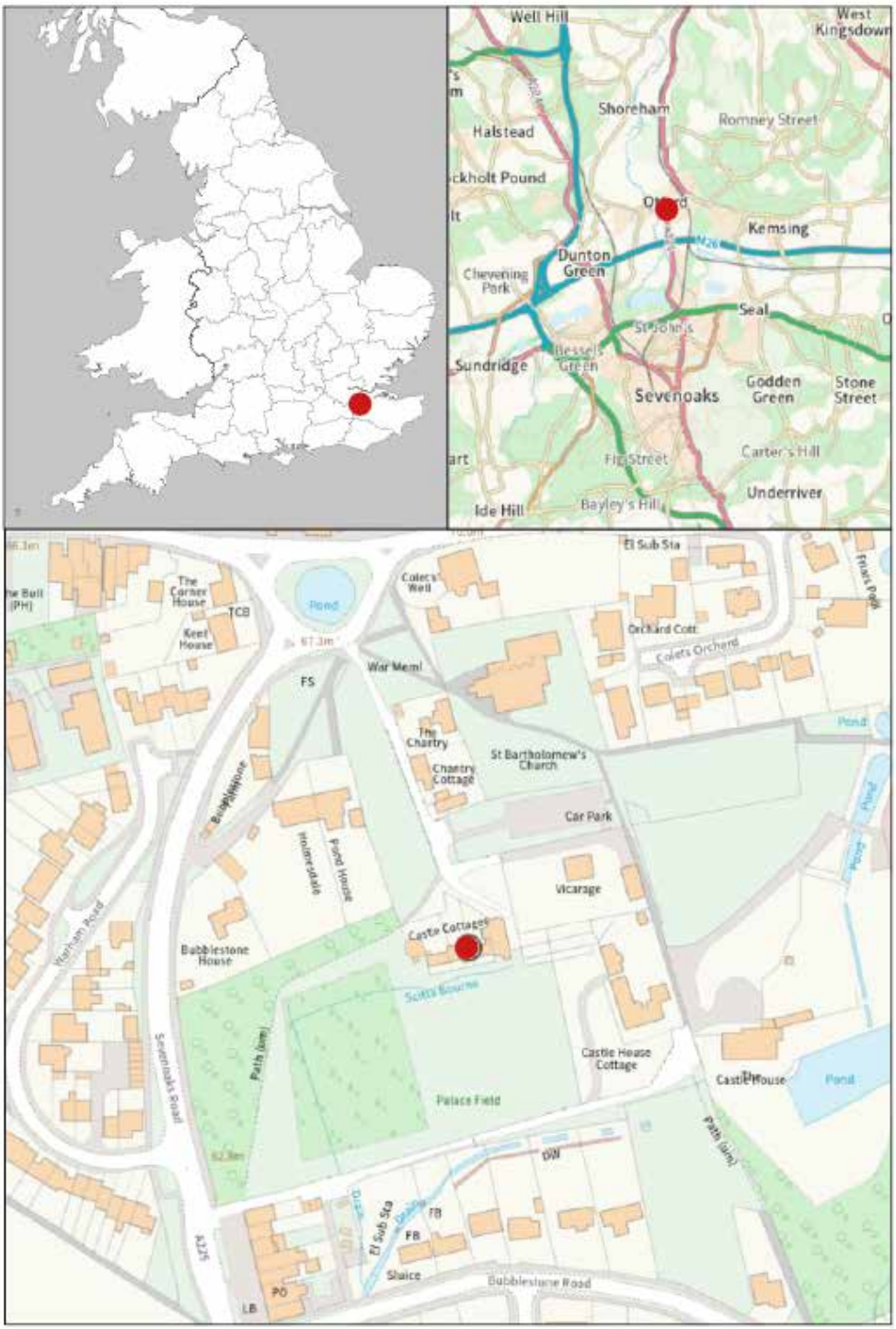

Figure 1: Maps to show the location of Otford Palace in Otford, Sevenoaks (marked in red). Scale: top right 1:120,000; bottom 1:2000. [© Crown Copyright and database right 2026. All rights reserved. Ordnance Survey Licence number 100024900].

Methodology

An initial assessment of the timbers, ex situ and in situ, for dendrochronological potential sought those with more than 50 rings and, where possible, traces of sapwood, although slightly shorter sequences are sometimes sampled if little other material is available. The ex situ timbers judged to be potentially useful had slices removed on a site visit in May 2024. These were labelled and stored for subsequent analysis. The assessment of the limited number of in situ timbers included those present in the gatehouse and the north-west tower, whilst an ex situ door was also assessed.

The samples were polished on a belt sander using 80 to 400 grit abrasive paper to allow the ring boundaries to be clearly distinguished. The samples had their tree-ring sequences measured to an accuracy of 0.01mm, using a specially constructed system utilising a binocular microscope with the sample mounted on a travelling stage with a linear transducer linked to a PC, which recorded the ring widths into a dataset. The software used in measuring and subsequent analysis was written by Ian Tyers (2004). Cross-matching was attempted by a process of qualified statistical comparison by computer, supported by visual checks. The ring-width series were compared for statistical cross-matching, using a variant of the Belfast CROS program (Baillie and Pilcher 1973). Ring sequences were plotted on the computer monitor to allow visual comparisons to be made between sequences. This method provides a measure of quality control in identifying any potential errors in the measurements when the samples cross-match.

In comparing one sample or site master against other samples or chronologies, *t*-values over 3.5 are considered significant, although in reality it is common to find demonstrably spurious *t*-values of 4 and 5 because more than one matching position is indicated. For this reason, dendrochronologists prefer to see some *t*-values in the range of 5, 6, and higher, and for these to be well replicated from different, independent chronologies with both local and regional chronologies well represented, except where imported timbers are identified. Where two individual samples match together with a *t*-value of 10 or above, and visually exhibit exceptionally similar ring patterns, they may have originated from the same parent tree. Same-tree matches can also be identified through the external characteristics of the timber itself, such as knots and shake patterns. Lower *t*-values however do not preclude same tree derivation.

Ascribing felling dates and date ranges

Once a tree-ring sequence has been firmly dated in time, a felling date, or date range, is ascribed where possible. With samples which have sapwood complete to the underside of,

or including bark, this process is relatively straightforward. Depending on the completeness of the final ring (i.e. if it has only the spring vessels or early wood formed, or the latewood or summer growth) a precise felling date and season can be given. If the sapwood is partially missing, or if only a heartwood/sapwood transition boundary survives, then an estimated felling date range can be given for each sample. The number of sapwood rings can be estimated by using an empirically derived sapwood estimate with a given confidence limit. If no sapwood or heartwood/sapwood boundary survives then the minimum number of sapwood rings from the appropriate sapwood estimate is added to the last measured ring to give a *terminus post quem* (tpq) or felled-after date.

A review of the geographical distribution of dated sapwood data from historic timbers has shown that a sapwood estimate relevant to the region of origin should be used in interpretation, which for oak in this area is 9–41 rings (Miles 1997). It must be emphasised that dendrochronology can only date when a tree has been felled, not when the timber was used to construct the structure or object under study.

Results

The roof of the gatehouse appears to be a modern (twentieth century) softwood replacement, constructed following a fire, and assessment of in situ lintels found these to have no sapwood or to have been replaced, again, relatively recently. The dovecote roof, at the southern end of the gatehouse, is of twentieth-century softwood. Some binding joists and lintels in the north-west tower are still in situ but are not accessible until such time as the interior of the tower is scaffolded. The ex situ door, which it has previously been suggested could be an original exterior Tudor door, was also assessed. It has limited potential, but the assessment raised questions as to its Tudor origins. Overall, there appears to be very limited scope for further dendrochronological work in the above ground remains of the Palace.

Four oak lintels, removed from the north-west tower, along with two other timbers, also thought to have come from the tower and kept in store, were cut with a chainsaw to provide samples for dendrochronology. The cross-sectional slices obtained were quite degraded, hence the removal of the timbers from load-bearing positions in the structure. The slices obtained were removed to the laboratory. Details of the samples are presented in Table 1, and the raw ring-width data of all measured samples are given in the Appendix.

Two radii were measured for samples otfd02 and otfd04, in order to get the longest series possible, and these were combined to form a single series for each timber in subsequent analysis, otfd02a and otfd02b matching with a *t*-value of 10.6 and otfd04a and otfd04b matching with a *t*-value of 7.4. The outer rings of all samples were quite degraded, with the

exception of otfd01 which retained complete sapwood. However, the individual rings in this 20mm band of complete sapwood could not be reliably distinguished.

Comparison of the ring-width series, from all six samples, identified a strong match between otfd02 and otfd03 (*t* = 13.8 with 129 years overlap), and these were combined to form a single series (otfd32m) used in subsequent analysis, including the formation of a site master chronology. There were no other significant matches between the samples, thus they were compared individually to the database of reference chronologies. Series otfd32m, otfd01 and otfd04 produced strong consistent matching with reference chronologies, as shown in Tables 2 a–c allowing all three series, representing four samples, to be securely dated. It was then noted that samples otfd01 and otfd04 produced a *t*-value of 3.3 at the relative date identified by individual dating. When combined, the three series (otfd01, otfd32m, and otfd04) form a 226-year long site chronology (OTFORD), the strongest matches for which are shown in Table 2d. The relative positions of overlap of the dated samples are shown in Figure 2.

Sample otfd05 had only 30 rings and unsurprisingly could not be securely dated, neither could the 90-year long sequence from otfd06, despite it not appearing to have any unusual growth characteristics.

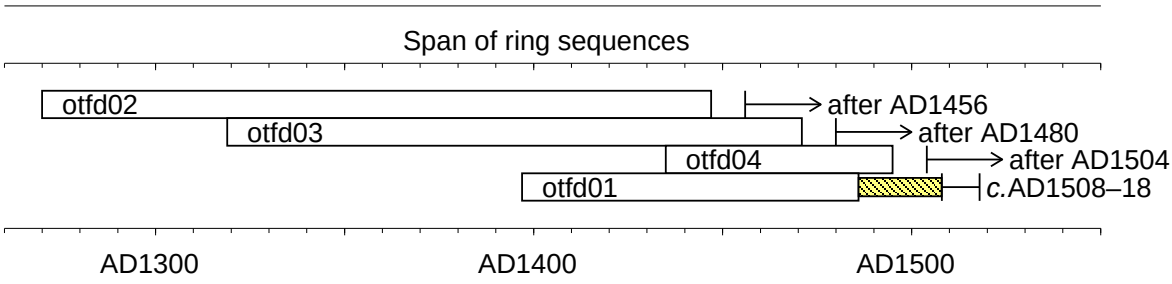

Figure 2: Bar diagram showing the relative positions of overlap of the dated ring sequences and their individual felling date ranges. White bars represent measured heartwood rings, hatched yellow sections represent sapwood rings, and narrow sections represent unmeasured additional rings

Table 1: Details of tree-ring samples taken from Otford Palace, Otford, Sevenoaks, Kent

Sample number	Timber and location	Number of rings	Date of measured sequence (AD)	Sapwood rings	Mean ring width (mm)	Mean sensitivity	Felling date / date range (AD)
otfd01	North-west tower, ex situ window lintel	90	1397–1486	h/s (+20mm CNM)	1.44	0.20	*c*. 1508–18
otfd02	North-west tower, ex situ window lintel	178	1270–1447	-	1.56	0.21	After 1456
otfd02a	*ditto*	*136*	*1271–1406*	-	*1.79*	*0.22*	-
otfd02b	*ditto*	*178*	*1270–1447*	-	*1.48*	*0.21*	-
otfd03	North-west tower, ex situ window lintel	153	1319–1471	-	1.28	0.22	After 1480
otfd04	North-west tower, ex situ window lintel	61	1435–95	-	2.30	0.16	After 1504
otfd04a	*ditto*	*53*	*1436–88*	-	*1.92*	*0.17*	-
otfd04b	*Ditto*	*61*	*1435–95*	-	*2.51*	*0.16*	-
otfd05	Other ex situ timber	30	-	-	2.64	0.15	-
otfd06	Other ex situ timber	90	-	-	1.58	0.16	-

Key: h/s = heartwood-sapwood boundary; CNM = complete sapwood on sample, outer 20mm to bark edge not measured.

Table 2a: Strongest matches for site sequence, OTFD01, dated AD 1397–1486

Source region	Chronology:	Publication reference:	Filename:	Span of chronology (AD)	Overlap (years)	*t*-value
Devon	Holcombe Court, Holcombe Rogus	Miles and Bridge 2012	HOLCOMBE	1349–1536	90	7.5
Hampshire	Street House Farm, Lower Farringdon	Miles et al. 2009	STRHOFM2	1379–1492	90	7.0
Oxfordshire	Princes Manor, Harwell	Miles et al. 2006	PRINCES2	1355–1497	90	6.8
Oxfordshire	Kingsholm, East Hagbourne	Arnold and Howard pers. comm.	DID-B	1355–1548	90	5.9
Devon	The Ship Inn, Morwellham Quay	Tyers et al. forthcoming	MWQASQ01	1361–1508	90	5.5
Buckinghamshire	Old Moat Farmhouse, Stoke Mandeville	Miles et al. 2007	STOKEMAN	1420–1498	67	5.3
Kent	Cobham Hall, Cobham	Arnold et al. 2003	COBHSQ01	1317–1662	90	5.3
Oxfordshire	Stonor Park Chapel, Stonor	Miles and Bridge 2015	STONOR2	1402–1504	85	5.3
Somerset	Manor Court House, Chard	Arnold et al. 2004	SMCASQ01	1409–1517	78	5.1
Herefordshire	St Barnabas Church, Brampton Bryan	Arnold et al. 2021	BRMCSQ01	1233–1644	90	5.1

Table 2b: Strongest matches for site sequence, OTFD32m, dated AD 1270–1471

Source region	Chronology:	Publication reference:	Filename:	Span of chronology (AD)	Overlap (years)	*t*-value
Kent	94 High Street, Edenbridge	Howard et al. 1991	KEDCS101	1275–1388	122	8.5
London	White Tower, Tower of London	Miles 2007	WHTOWR5	1260–1489	202	7.8
Berkshire	Song School, Windsor Castle	Bridge and Miles 2016	WINDSOR5	1316–1478	156	7.2
Kent	St Mary Magdelene' Church, Cowden	Howard et al. 1999	CWDASQ03	1254–1439	170	7.1
London	Westminster Abbey	Miles and Bridge 2005	WMNSTR7	1262–1369	100	6.8
Hampshire	Rye Cottage, Mapledurwell	Miles and Worthington 1999	RYECOTT1	1317–1486	155	6.8
London	Sutton House, Hackney	Tyers and Hibberd 1993	SUT91	1319–1534	153	6.8
Wiltshire	Leaden Hall, Salisbury	Bridge and Miles 2024	LDNx	1181–1448	179	6.8
Oxfordshire	New Inn, Oxford	Miles and Haddon-Reece 1996	ZACHS	1164–1381	112	6.7
Essex	St Laurence Priory Church, Blackmore	Miles et al. 2005	BLCKMORE	1266–1329	130	6.7

Table 2c: Strongest matches for site sequence, OTFD04, dated AD 1435–95

Source region	Chronology:	Publication reference:	Filename:	Span of chronology (AD)	Overlap (years)	*t*-value
London	Wolsey Buttery Roof, Hampton Court	Miles and Bridge 2013	HMPTNCT4	1340–1516	61	6.5
Surrey	St Peter's Church, West Molesey, Elmbridge	Arnold and Howard 2006	MOLASQ02	1382–1502	61	6.2
East Sussex	Ellen Archers, Bodiam	Bridge et al. 2019	ARCHERS	1399–1520	61	5.9
London	Sutton House, Hackney	Tyers and Hibberd 1993	SUT91	1319–1534	61	5.9
Kent	Restoration House, Rochester	Howard et al. 1997	RCHASQ08	1378–1505	61	5.9
Wiltshire	Salisbury Cathedral	Miles 2005	SARUM11	1409–1541	61	5.8
Berkshire	Windsor Castle kitchen	Hillam and Groves 1996	WC KITCH	1331–1573	61	5.8
London	White Tower, Tower of London	Miles 2007	WHTOWR6	1370–1532	61	5.7
Wiltshire	Daubeneys, Colerne	Tyers et al. 2014	CLDBSQ01	1347–1497	61	5.6
London	Westminster School	Miles et al. 2008	LIDDELLS	1346–1540	61	5.5

Table 2d: Strongest matches for site master, OTFORD, dated AD 1270–1495

Source region	Chronology:	Publication reference:	Filename:	Span of chronology (AD)	Overlap (years)	*t*-value
London	White Tower, Tower of London	Miles 2007	WHTOWR5	1260–1489	220	8.5
London	Sutton House, Hackney	Tyers and Hibberd 1993	SUT91	1319–1534	177	7.4
Kent	Cobham Hall, Cobham	Arnold et al. 2003	COBHSQ01	1317–1662	179	7.1
Kent	Walmer Castle, Deal	Arnold and Howard 2015	WLMCSQ01	1396–1523	100	7.1
West Sussex	St Andrew's Church, Ford	Bridge 2000	FORD	1286–1511	210	7.0
Hampshire	Rye Cottage, Mapledurwell	Miles and Worthington 1999	RYECOTT1	1317–1486	170	6.9
Bedfordshire	Chicksands Priory, Chicksands	Howard et al. 1998	CHKSPQ01	1200–1541	226	6.9
Kent	Manor Barn, Frindsbury	Arnold et al. 2019	FRDBSQ01	1252–1403	134	6.9
London	Westminster Abbey	Miles and Bridge 2005	WMNSTR7	1262–1369	100	6.8
Gloucestershire	St Mary Magdelene’ Church, Twyning	Tyers 1996	TWYNING	1251–1452	183	6.8

Discussion

Only one timber retained any sapwood, and it was complete to bark edge. As indicated above, the individual sapwood rings could not be reliably distinguished, but the overall width of the band of sapwood rings was measured as 20mm. Taking the average ring width of the outermost 10 heartwood rings (0.75mm), this would suggest approximately 27 rings of sapwood are present, but a conservative range of 22–32 rings is used to give a likely felling date range of circa AD 1508–18. All four dated timbers appear to be broadly coeval and thus the three dated timbers with no traces of sapwood appear likely to have been felled around the same time (Fig. 2), in the early decades of the sixteenth century. This suggests that the dated timbers are associated with the construction of the Palace, thought to have occurred around AD 1518.

The fact that the matching between the individually dated series otfd01, otfd04, and otfd32m is poor, suggests that the timbers represented came from diverse sources. This interpretation is supported by the matches for each individual series with reference chronologies (Tables 2a–c) which imply slightly different geographical woodland sources.

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Appendix

Ring width values (0.01mm) for the sequences measured

otfd01

339	365	361	320	258	225	257	275	247	183
167	189	149	184	117	149	141	152	127	159
292	257	248	367	296	244	302	196	141	108
191	246	252	205	226	153	135	162	261	118
135	105	95	124	96	98	87	77	83	94
80	97	98	84	112	87	79	104	120	117
96	87	79	70	89	53	95	80	71	87
83	50	48	65	57	55	53	74	100	87
50	57	64	66	82	80	93	101	74	83

otfd02a

519	451	514	363	320	276	267	258	238	444
273	289	343	284	388	328	265	270	372	422
299	498	453	231	166	197	171	150	233	381
455	358	256	249	214	248	205	180	197	132
146	184	144	178	232	212	162	169	199	197
230	169	238	123	117	131	180	173	218	117
98	96	183	189	137	106	73	81	147	90
104	96	56	94	117	95	103	99	66	120
176	125	176	127	96	71	99	86	110	112
97	113	232	238	173	157	99	116	122	122
88	116	84	94	125	123	99	118	148	143
128	146	119	111	98	123	158	121	116	87
120	73	90	97	88	105	87	122	103	80
85	83	92	86	87	115				

otfd02b

473	483	407	454	359	390	276	316	327	316
560	504	452	442	449	497	438	247	216	268
264	237	241	184	293	164	155	194	169	247
255	163	164	164	126	162	184	167	171	184
154	111	159	100	126	126	109	102	103	119
135	129	128	180	120	113	115	167	137	154
96	92	101	138	141	100	103	84	92	126
72	91	65	37	71	96	82	68	64	42
79	108	87	109	71	67	64	78	65	73
76	58	55	116	155	131	117	77	132	164

140 87 102 71 91 108 126 97 120 143
173 117 146 138 120 115 108 157 111 96
55 123 74 70 74 74 107 100 136 83
64 78 101 93 120 109 143 63 107 107
107 101 118 75 75 60 112 89 97 141
119 114 92 151 127 108 76 90 83 92
95 141 170 113 137 131 87 82 89 110
102 142 150 137 127 124 101 107

otfd03

251 282 305 181 226 145 130 124 203 126
306 137 145 156 145 172 123 159 127 128
202 130 161 85 89 149 190 179 134 118
79 129 158 123 151 96 89 113 103 85
91 111 82 96 183 225 207 147 126 152
181 148 85 118 78 100 130 125 108 122
145 133 116 187 144 123 144 141 168 88
85 71 75 75 72 96 116 111 118 152
101 71 107 100 105 148 121 183 72 135
119 120 133 136 82 76 73 130 119 123
131 130 129 105 170 159 107 75 75 96
107 93 148 164 127 170 134 114 105 96
104 130 160 169 148 161 126 126 131 113
140 112 128 121 119 122 101 115 130 95
92 80 89 73 120 67 117 128 104 106
71 95 108

otfd04a

258 175 184 162 175 199 217 274 235 164
143 159 215 210 210 246 166 166 221 244
244 194 198 160 154 149 120 231 149 212
171 130 182 185 194 177 173 189 225 306
171 142 173 198 243 261 196 182 184 168
143 170 178

otfd04b

351 279 196 208 213 254 298 288 315 256
205 202 233 288 319 278 252 217 192 281
217 273 229 261 209 192 186 136 187 123
191 216 191 202 265 263 259 254 245 258
352 210 209 171 236 312 317 247 297 266
248 204 224 324 401 359 313 276 291 320

262

otfd05

389	402	316	399	426	366	244	217	239	256
286	287	258	273	346	222	293	245	216	189
202	234	159	188	256	233	191	188	212	197

otfd06

389	254	319	323	363	316	263	243	292	313
297	212	224	207	197	136	130	165	154	160
178	169	129	174	224	228	247	231	227	243
240	215	183	206	294	247	245	166	128	156
136	114	121	119	138	140	133	100	103	62
101	86	105	118	108	110	113	80	83	58
96	90	95	56	97	100	105	114	136	116
93	130	94	111	128	97	81	93	100	99
103	95	82	91	100	84	82	92	130	137

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