Historic England

Scientific Dating

Falcon Hotel
Chapel Street
Stratford-upon-Avon
Warwickshire

Tree-ring Analysis of Elm and Oak Timbers

Martin Bridge and Cathy Tyers

Discovery, Innovation and Science in the Historic Environment

Research Report Series no. 106-2019

Front Cover: Falcon Hotel, Stratforn-upon-Avon, Warwickshire. Photograph: Bob Bearman courtesy of Nathaniel W. Alcock.

Research Report Series 106-2019

FALCON HOTEL
CHAPEL STREET
STRATFORD-UPON-AVON
WARWICKSHIRE

Tree-ring Analysis of Elm and Oak Timbers

Martin Bridge and Cathy Tyers

NGR: SP 20055 54760

ISSN 2059-4453 (Online)

The Research Report Series incorporates reports by Historic England's expert teams and other researchers. It replaces the former Centre for Archaeology Reports Series, the Archaeological Investigation Report Series, the Architectural Investigation Report Series, and the Research Department Report Series.

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

For more information write to Res.reports@HistoricEngland.org.uk
or mail: Historic England, Fort Cumberland, Fort Cumberland Road, Eastney, Portsmouth PO4 9LD

Opinions expressed in Research Reports are those of the author(s) and are not necessarily those of Historic England.

SUMMARY
Nine samples (eight elm and one oak) were taken from a roof of unknown age built next to the main Chapel Street range of the Falcon Hotel, Chapel Street, Stratford-Upon-Avon as part of a research project into *Developing the dendrochronology of elm in historic buildings*. No acceptable cross-matching was found between the samples and neither did they date individually against the oak database.

CONTRIBUTORS
Martin Bridge and Cathy Tyers

ACKNOWLEDGEMENTS
We are very grateful to the owners, Somerston Capital, who were funding dendrochronological work of the oak elsewhere in the building, for allowing this additional elm sampling, and to the contractors, Stepnell, who were most accommodating. We'd also like to thank Nat Alcock and Bob Bearman who gave background information on the development of the site.

ARCHIVE LOCATION
Warwickshire Historic Environment Record
Archaeological Information and Advice
Communities
Warwickshire County Council
PO Box 43
Shire Hall
Warwick, CV34 4SX

DATE OF INVESTIGATION
2017–20

CONTACT DETAILS
Martin Bridge
UCL Institute of Archaeology
31–34 Gordon Square
London WC1H 0PY
martin.bridge@ucl.ac.uk

Cathy Tyers
Historic England
Cannon Bridge House
25 Dowgate Hill
London EC4R 2YA
cathy.tyers@historicengland.org.uk

CONTENTS

INTRODUCTION

The investigation of the timbers in a roof at the Falcon Hotel, Stratford-Upon-Avon, contributes to an on-going research programme, funded by Historic England through its Heritage Protection Commissions programme, and led by Martin Bridge from the UCL Institute of Archaeology.

Developing the dendrochronology of elm in historic buildings

Ring-width dendrochronology of oak timbers from historic buildings in England is well established, with dating having been obtained on more than 3000 buildings (or parts thereof), with nearly one third of these having been funded by Historic England (and its predecessors). Dendrochronological evidence is a valuable component underpinning the discovery and identification of assets in the historic environment, aiding decisions relating to protection, management, and conservation, enhancing appreciation and inspiring enjoyment of these buildings.

During this work on oak timbers, a significant amount of historic fabric constructed from timbers other than oak, most notably elm, has been identified, but this has previously been rejected as unsuitable for dendrochronological investigation. Elm in buildings has been identified in counties from Cornwall to Kent and up into the Midlands and beyond, but formal records of the presence of elm are scant as such buildings were generally dismissed for dating purposes and thus the presence of elm in the published record is rare. The inability to date historic buildings (or sections of buildings) constructed of elm by ring-width dendrochronology is seen as problematic in some areas of the country which have a comparatively high proportion of such buildings; buildings which nevertheless form a significant part of the historic environment but could not be afforded the same level of understanding in comparison to their oak counterparts.

Prior to the start of this project, only four instances of dating elm by ring-width dendrochronology have been successful (Groves and Hillam 1997; Haddon-Reece *et al* 1989, 1990; Bridge and Miles 2015). Each of these studies involved matching elm with oak from the same site, although the Ashdon, Essex example matched oak chronologies over a wide area (Bridge and Miles 2015). This project aimed to establish whether the use of standard ring-width dendrochronology could be extended to the dating of historic buildings in England where elm (*Ulmus* sp.) is the sole, or predominant species used rather than oak (*Quercus* sp.). A systematic approach was adopted concentrating on elm in the geographical areas where it is most commonly found. Buildings were thus sought that contained a significant number of elm timbers with sufficient numbers of rings that might be matched against either oak timbers in the same building or oak chronologies from the surrounding area (Fig 1).

An article will summarise the overall outcomes of the project (Bridge and Tyers forthcoming). However, each building sampled for dendrochronology has an associated building survey report or similar publication, whilst the primary archive of the dendrochronological analysis is reported in the Historic England Research Report Series.

Falcon Hotel

Listed as The Falcon Hotel (List Entry Number 1187771) but also known as the Falcon Inn (Ross 2016), this imposing three storey building sits in the central area of the town (Fig 2; Bearman 1988), and is recorded as an inn from AD 1655–61 onwards (Ross 2016). A full three volume report on the building was produced by Kay Ross of McLaughlin Ross LLP (Ross 2016). There are two major ranges, one facing Chapel Street, the other facing Scholars Lane. Although the Listing Description suggests that the building dates to *c* AD 1500 with the second floor added in *c* AD1645, Ross (2016, 23) outlines how this cannot be so, and that the building of the Chapel Street Range is all of one build, as evidenced by the dragon beams. The upper storey jetty has been cut back at some stage, and many of the timbers re-used.

Dendrochronological investigations of the oak revealed that the three storeys of the Chapel Street range were indeed built in a single campaign, with trees felled in winter AD 1621/2 and spring AD 1622, although a purlin at the north end was a later insertion, using a tree felled in AD 1660/1 (Bridge and Miles 2018). The Scholar's Lane range was found to have a mix of very fast-grown oaks and re-used timbers, and was not dated (Bridge and Miles 2018). The elm roof investigated here was built up against the Chapel Street range, so is presumably later in date, but it has few distinguishing features, and there is no indication of its age.

METHODOLOGY

Fieldwork for the present study was carried out in November 2017, during a dendrochronological investigation of the Chapel Street range of the inn. In the initial assessment, based on the general criteria used for oak timbers, accessible elm timbers with more than 50 rings and where possible traces of sapwood were sought, although slightly shorter sequences may be sampled if little other material is available. Those timbers judged to be potentially useful were cored using a 15mm auger attached to an electric drill. The cores were labelled, and stored for subsequent analysis. A single oak timber in the roof was also sampled.

The cores were polished on a belt sander using 80–400 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 combination of visual matching and a process of qualified statistical comparison by computer. 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 oak 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*-value ranges 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 oak 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. Threshold values for elm samples are as yet unknown, but are likely to be of similar value.

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, ie if it has only the spring vessels or earlywood 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. In oak, 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 oak timbers has shown that a sapwood estimate relevant to the region of origin should be used in interpretation, which in this area is 9–41 rings (Miles 1997). The equivalent values for elm are as yet unknown, but the results of this project suggest that the range of the number of sapwood rings in elm timbers is likely to be much lower. One problem that has been encountered in considering elm is that it has often proved very difficult to determine the position of the heartwood/sapwood boundary, even when it is known that the complete sapwood is present on a timber. 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 AND DISCUSSION

The third elm truss from the entry into the roof from the main range was behind a brick stack (Figs 3 and 4), and where the floor was unsafe, thus this truss was not sampled. Nine samples, eight elm and one oak (Table 1; Figs 4 and 5), were taken however the plans and photographs available did not make it possible to show the locations of samples falcB03, falcB05, falcB06, and falcB07. The elm samples showed a range of lengths of sequence, and one sample showed a clear distinction between heartwood and sapwood, not always evident in elm. The ring width measurements are given in the Appendix. Comparison of all nine series highlighted some potential matches statistically, but these were short overlaps, and none were

thought to be reliable. Comparisons of the individual series with the oak database failed to establish any consistent acceptable matches, and the samples therefore remain undated.

REFERENCES

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

Bearman, R, 1988 *Stratford Upon Avon: A History of its streets and buildings*, Nelson, Hendon

Bridge, M C, and Miles, D, 2015 Tree-Ring Date Lists, *Vernacular Architect*, **46**, 102–7

Bridge, M C, and Tyers, C, forthcoming Elm in vernacular buildings and its potential for dating, *Vernacular Architect*

Bridge, M C, and Miles, D, 2018 Tree-Ring Date Lists, *Vernacular Architect*, **49**, 135–41

Groves, C, and Hillam, J, 1997 Tree-ring analysis and dating of timbers, in *Multiperiod Saltmaking at Droitwich, Hereford & Worcester - excavations at Upwich,1983-4*, (ed J D Hurst), CBA Res Rep, **107**, 74–88, London

Haddon-Reece, D, Miles, D H, and Munby, J T, 1989 List 32 - Tree-ring dates, *Vernacular Architect*, **20**, 46–9

Haddon-Reece, D, Miles, D H, and Munby, J T, 1990 List 38 - Tree-ring dates, *Vernacular Architect*, **21**, 46–50

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

Ross, K, 2016 *Historic building report on the Falcon Inn, 1-4 Chapel Street, Stratford-upon-Avon, Warwickshire*, McLaughlin Ross LLP, Upton Cheyney

Tyers, I, 2004 *Dendro for Windows Program Guide 3rd edn*, ARCUS Report, **500b**, Sheffield

TABLE

Table 1: Details of the samples taken from the predominantly elm roof of The Falcon Hotel, Chapel Street, Stratford-upon-Avon

Sample number	Timber and position	No of rings	Mean ring width	Sapwood rings	Mean sensitivity
falcB01	South principal rafter, T2	37	3.10	-	0.34
falcB02	North upper purlin, east bay	92	1.20	?h/s	0.28
falcB03	North lower purlin, east bay	67	2.49	22C	0.25
falcB04	Collar, T2 (oak)	50	2.01	h/s	0.20
falcB05	Axial ceiling beam, east bay	82	1.19	-	0.29
falcB06	Axial ceiling beam, west bay	88	1.09	?h/s	0.20
falcB07	Tiebeam, T2	32	3.18	-	0.32
falcB08	North principal rafter, T1	51	1.39	-	0.31
falcB09	South principal rafter, T1	41	1.50	-	0.31

Key: h/s = heartwood-sapwood boundary; C = complete sapwood, felled in winter

FIGURES

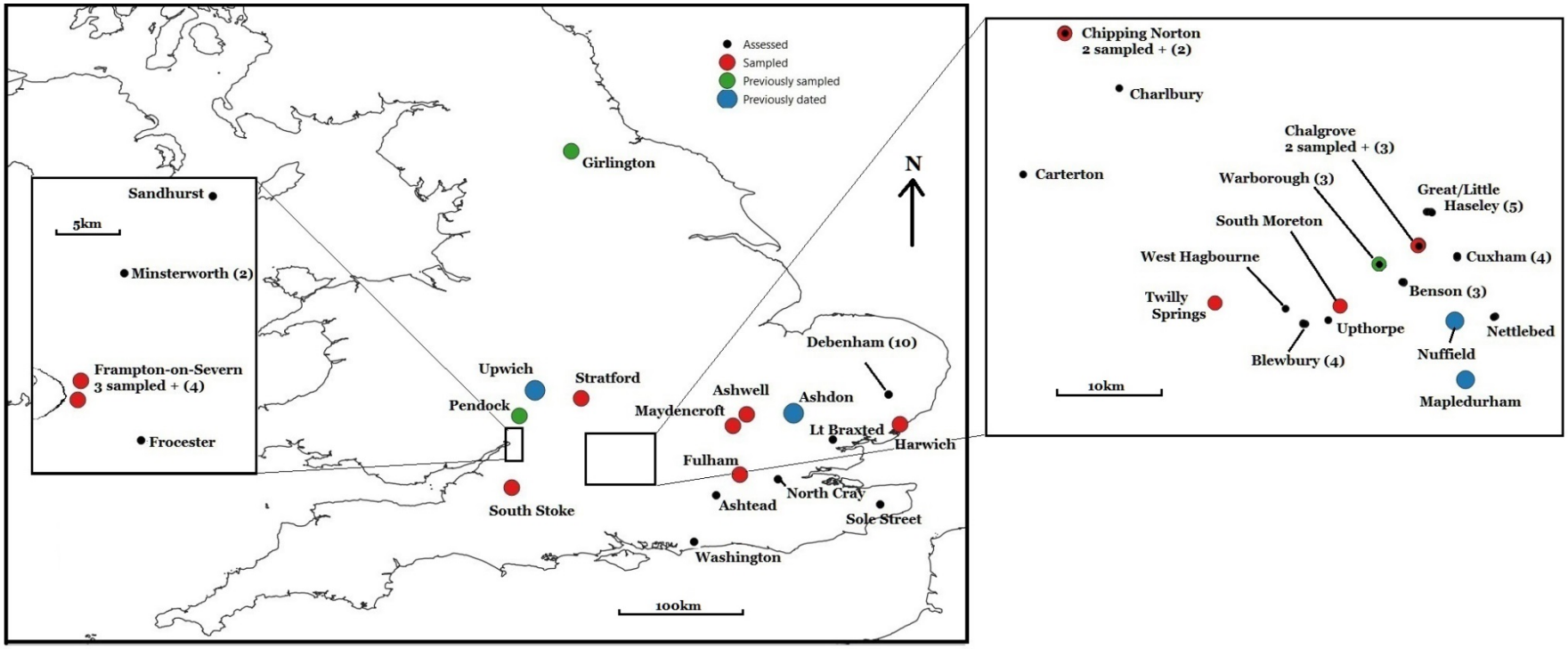

Figure 1: Map showing the distribution of sites sampled, some of which were dated, prior to the start of this project, and sites assessed and sampled properties for this project. Numbers in brackets after a place name represent the number of properties assessed in that location

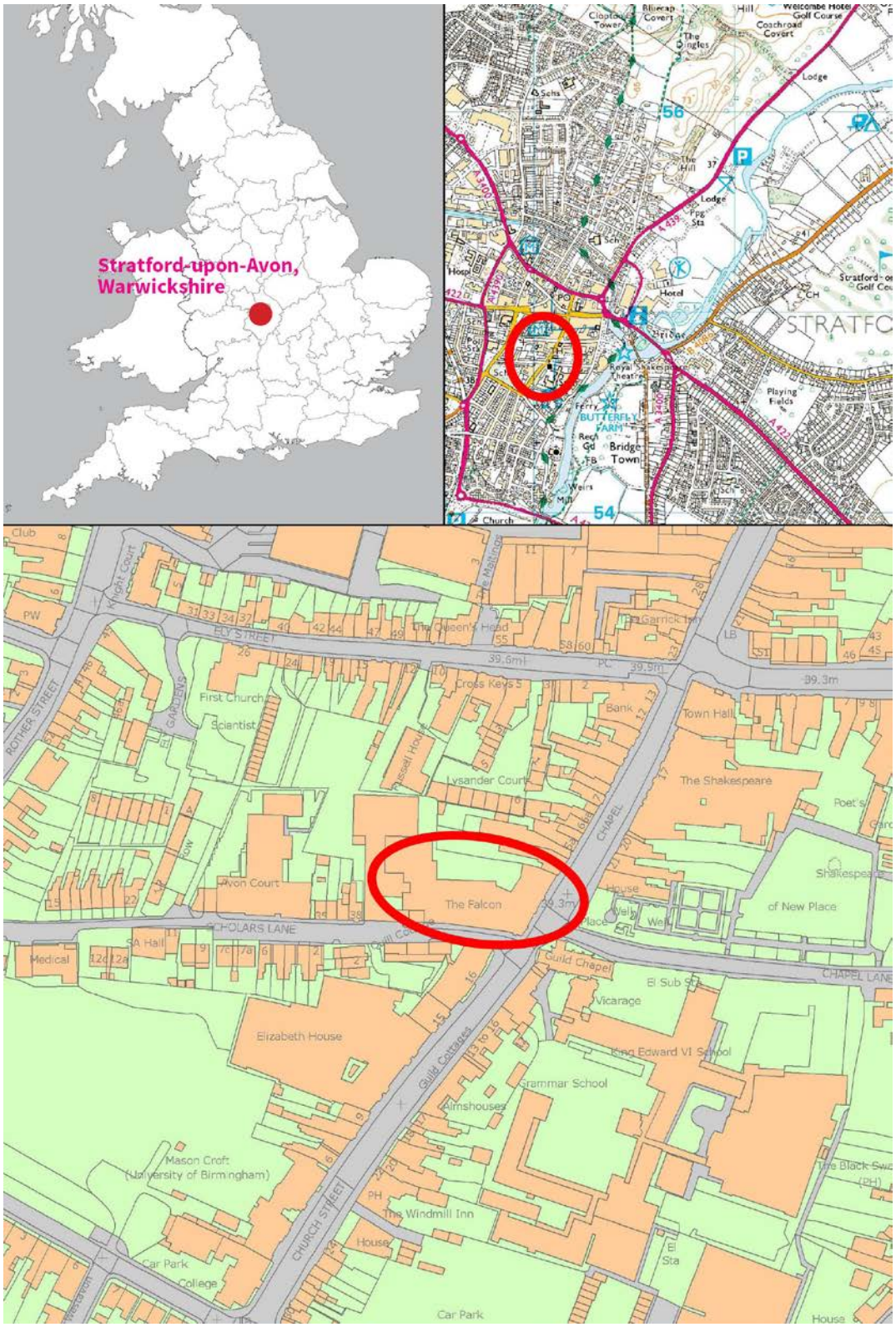

Figure 2: Maps to show the location of the Falcon Hotel within Stratford-upon-Avon, Warwickshire, marked in red. Scale: top right 1:25000; bottom 1:2000. © Crown Copyright and database right 2020. All rights reserved. Ordnance Survey Licence number 100024900. © British Crown and SeaZone Solutions Ltd 2020. All rights reserved. Licence number 102006.006. © Historic England

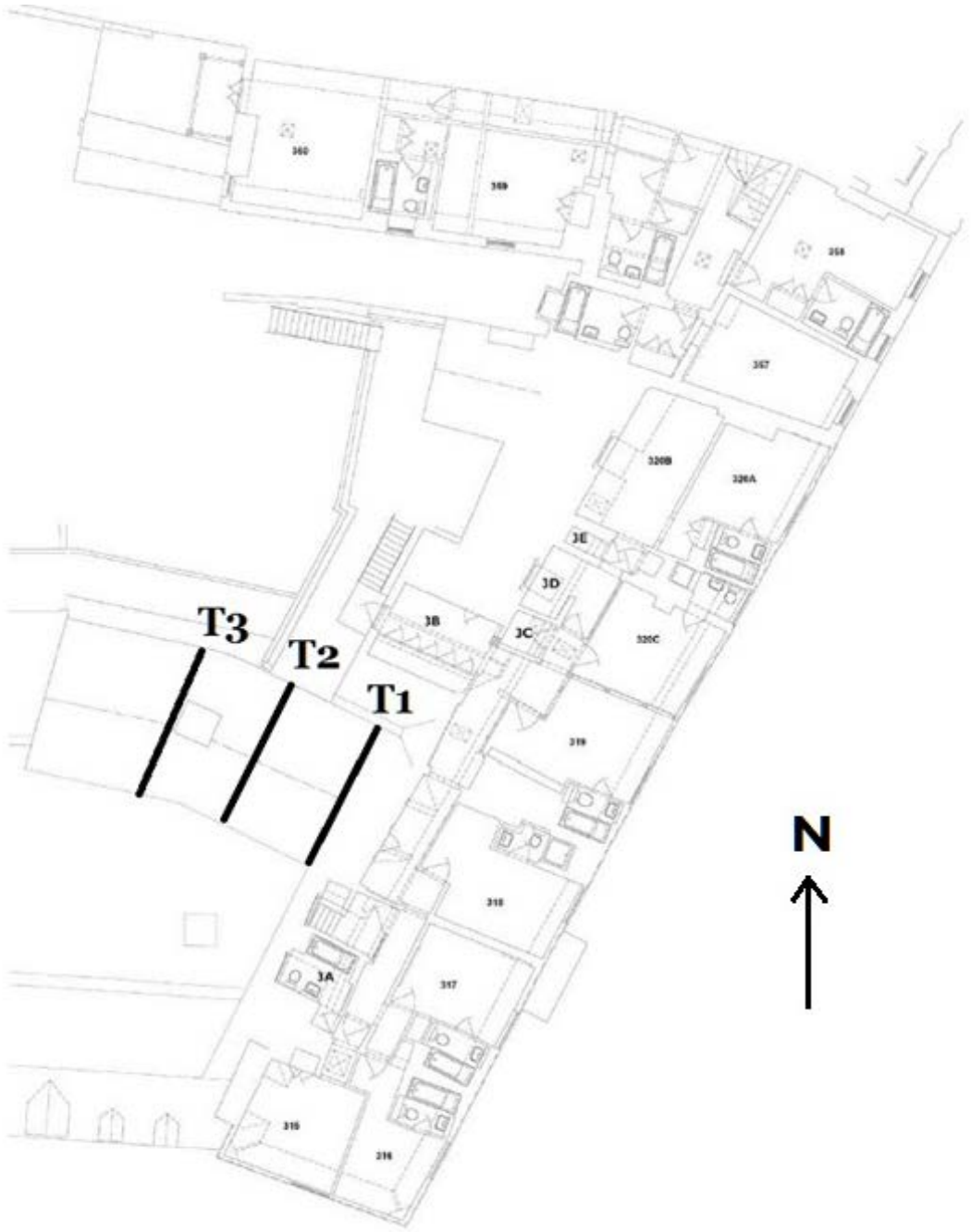

Figure 3: Plan of the top floor of the Chapel Street range of the Falcon Hotel, showing the position of the trusses of the elm roof sampled, adapted from Ross (2016, plate 31)

Figure 4: View looking west from the entry into the elm roof, showing truss 2 and the stack behind, with some of the timbers sampled (photograph Martin Bridge)

Figure 5: View looking east, showing truss 1, with some of the timbers sampled (photograph Martin Bridge)

APPENDIX

Ring width values (0.01mm) for the sequences measured

falcB01

157	298	297	389	197	714	417	263	271	300
377	133	383	226	310	280	245	215	268	318
401	508	553	428	465	479	354	197	176	361
499	257	245	139	149	136	75			

falcB02

402	555	447	429	455	288	246	276	352	343
181	221	242	147	274	184	137	151	151	109
104	89	81	99	139	96	183	333	240	63
59	48	78	150	208	105	87	125	125	73
50	48	21	22	36	34	35	29	30	35
31	35	31	56	42	35	35	58	71	134
268	331	199	163	175	144	83	50	41	19
19	25	21	25	37	29	25	44	46	27
37	34	23	15	20	26	29	27	29	40
32	39								

falcB03

164	172	175	207	203	247	337	295	288	425
300	317	189	247	267	332	345	324	116	93
118	141	210	243	194	77	84	119	207	305
319	429	587	597	811	702	507	386	472	407
586	833	638	506	146	142	119	111	63	86
107	85	72	133	139	83	71	69	94	101
88	80	66	52	46	82	101			

falcB04

241	363	289	479	302	315	382	346	297	299
203	146	203	170	242	267	218	170	193	244
205	253	214	144	175	134	193	216	199	201
210	137	151	90	111	120	144	175	138	146
134	121	125	156	147	125	158	120	101	142

falcB05

352	377	435	193	195	264	333	255	200	223
264	165	246	232	216	62	95	78	258	222
175	87	145	226	377	285	187	108	170	122
217	137	149	62	89	136	183	157	111	103
74	59	43	52	56	84	61	74	46	66
77	64	74	68	32	43	39	49	48	46
37	48	38	30	30	32	23	36	46	32
29	29	33	24	31	33	24	30	29	28
21	38								

falcB06

373	269	294	321	424	237	135	128	232	176
284	210	222	253	261	239	297	273	280	139
185	347	335	316	314	77	38	37	48	68
73	77	73	82	93	76	53	61	48	33
29	26	27	33	32	35	30	34	44	40
42	41	29	36	40	45	48	51	48	81
69	75	51	46	49	45	35	33	40	35
44	42	42	39	53	67	64	53	46	48
46	40	37	52	31	28	30	41		

falcB07

625	179	304	240	392	416	308	319	352	418
544	375	495	433	333	434	663	443	294	310
149	87	123	121	195	301	240	181	281	265
151	200								

falcB08

317	300	535	321	272	324	237	215	314	272
292	308	54	46	50	54	49	48	54	81
96	126	143	124	144	57	37	96	130	156
101	91	61	52	70	60	54	42	35	41
67	59	53	95	138	242	119	173	79	140
75									

falcB09

185	272	237	155	186	245	369	318	144	147
163	76	174	256	246	192	124	103	71	98
145	248	155	230	274	234	230	76	61	136
114	104	64	31	33	31	33	39	37	63
60									

Historic England Research and the Historic Environment

We are the public body that looks after England's historic environment. We champion historic places, helping people understand, value and care for them.

A good understanding of the historic environment is fundamental to ensuring people appreciate and enjoy their heritage and provides the essential first step towards its effective protection.

Historic England works to improve care, understanding and public enjoyment of the historic environment. We undertake and sponsor authoritative research. We develop new approaches to interpreting and protecting heritage and provide high quality expert advice and training.

We make the results of our work available through the Historic England Research Report Series, and through journal publications and monographs. Our online magazine Historic England Research which appears twice a year, aims to keep our partners within and outside English Heritage up-to-date with our projects and activities.

A full list of Research Reports, with abstracts and information on how to obtain copies, may be found on www.HistoricEngland.org.uk/researchreports

Some of these reports are interim reports, making the results of specialist investigations available 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, you should consult the author before citing these reports in any publication. Opinions expressed in these reports are those of the author(s) and are not necessarily those of Historic England.

The Research Reports' database replaces the former:

Ancient Monuments Laboratory (AML) Reports Series
The Centre for Archaeology (CfA) Reports Series
The Archaeological Investigation Report Series and
The Architectural Investigation Reports Series.

ISSN 2059-4453 (Online)