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Studland Bay Wreck, nr Poole Harbour, Dorset Dendrochronological and radiocarbon analysis of a ship timber

Derek Hamilton and Ian Tyers

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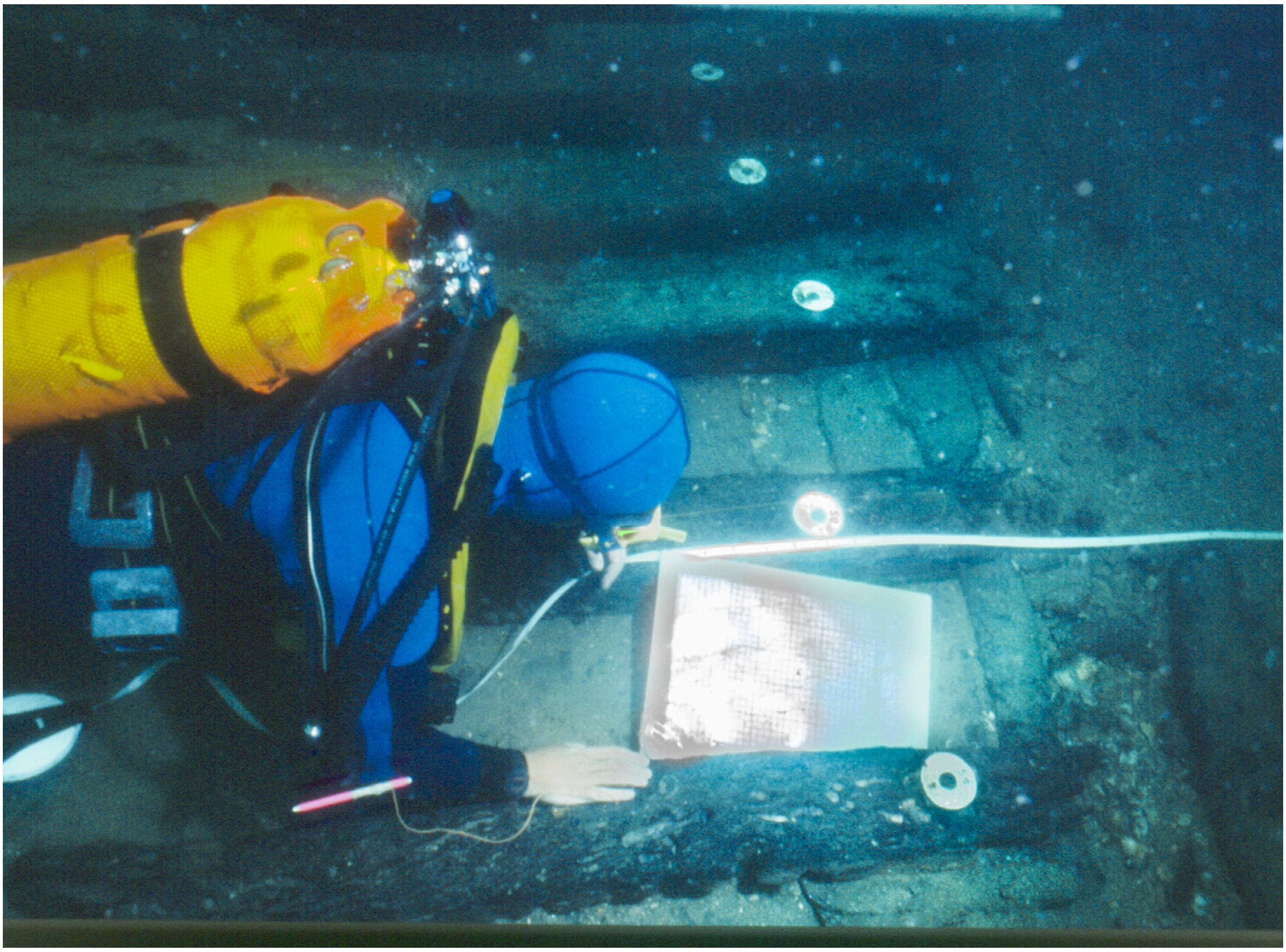

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STUDLAND BAY WRECK, NR POOLE HARBOUR, DORSET

DENDROCHRONOLOGICAL AND RADIOCARBON ANALYSIS OF A SHIP TIMBER

Derek Hamilton and Ian Tyers

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SUMMARY

The Studland Bay Wreck was excavated between 1984 and 1992. Timbers and other finds from the vessel are displayed in Poole Museum. The wreck is thought to be that of a lightly armed Spanish merchant vessel dating to *c* AD 1520–30. A total of 189 timbers were assessed for their dendrochronological potential with 17 oak timbers subsequently being sampled for analysis. None of the tree-ring sequences obtained from this material were found to cross-match each other, and none of the individual series were successfully matched to available reference data. Following the unsuccessful dendrochronological analysis, the only structural timber that retained sapwood was sub-sampled and underwent radiocarbon wiggle-matching in order to ascertain whether this supported the proposed early-sixteenth century date.

CONTRIBUTORS

Derek Hamilton and Ian Tyers

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CONTENTS

INTRODUCTION

The Studland Bay wreck is thought to be that of a lightly armed Spanish merchant vessel dating to *c* AD 1520–30. The vessel's construction is strikingly similar to the Basque Red Bay vessel, and so may well have been constructed in the Basque region (Thomsen 2000).

The dendrochronological analysis is reported elsewhere (Tyers 2009) but summarised within this report which is primarily focussed on the radiocarbon analysis of a structural timber from the vessel. Following the unsuccessful dendrochronological analysis, the only structural timber that retained sapwood (Timber 19) was sub-sampled for a programme of radiocarbon wiggle-match dating to provide dating evidence for the wreck and to corroborate the archaeological dating of the recovered artefacts.

METHODOLOGY

Dendrochronology

Tree-ring dating employs the patterns of tree-growth to determine the calendar dates for the period during which the sampled trees were alive. The amount of wood laid down in any one year by most trees is determined by the climate and other environmental factors. Trees over relatively wide geographical areas can exhibit similar patterns of growth, and this enables dendrochronologists to assign dates to some samples by matching the growth pattern with other ring-sequences that have already been linked together to form reference chronologies.

This preparation revealed the width of each successive annual tree ring. Each prepared sample could then be accurately assessed for the number of rings it contained, and at this stage it was also possible to determine whether the sequence of ring widths within it could be reliably resolved. Dendrochronological samples need to be free of aberrant anatomical features, such as those caused by physical damage to the tree, which may prevent or significantly reduce the chances of successful dating.

Standard dendrochronological analysis methods (see eg English Heritage 1998) were applied to each suitable sample. The complete sequences of the annual growth rings in the suitable samples were measured to an accuracy of 0.01mm using a micro-computer based travelling stage. The sequences of ring widths were then plotted onto semi-log graph paper to enable visual comparisons to be made between sequences. In addition, cross-correlation algorithms (eg Baillie and Pilcher 1973) were employed to search for positions where the ring sequences were highly correlated. Highly correlated positions were checked using the graphs and, if any of these were satisfactory, new composite sequences were constructed from the synchronised sequences. Any *t*-values reported below were 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 need to have been obtained from a range of independent sequences, and that these positions were supported by satisfactory visual matching.

Not every tree can be correlated by the statistical tools or the visual examination of the graphs. There are thought to be a number of reasons for this: genetic variations; site-specific issues (for example, a tree growing in a stream bed will be less responsive to rainfall); or some traumatic experience in the tree's lifetime, such as injury by pollarding, defoliation events by caterpillars, or similar. These could each produce a sequence dominated by a non-climatic signal. Experimental work with modern trees shows that 5–20% of all oak trees cannot be reliably cross-matched, even when enough rings are obtained.

Converting the date obtained for a tree-ring sequence into a useful date requires a record of the nature of the outermost rings of the sample. If bark or bark-edge survives, a felling date precise to the year or season can be obtained. If no sapwood survives, the date obtained from the sample gives a *terminus post quem* for its use. If some sapwood survives, an estimate for the number of missing rings can be applied to the end-date of the heartwood. This estimate is quite broad and varies by region.

Where bark-edge or bark survives, the season of felling can be determined by examining the completeness or otherwise of the terminal ring lying directly under the bark. Complete material can be divided into three major categories:

- 'early spring', where only the initial cells of the new growth have begun – this is equivalent to a period in March/April, when the oaks begin leaf-bud formation;
- 'later spring/summer' where the early wood is evidently complete but the late wood is evidently incomplete, which is equivalent to May-through-September of a normal year;
- 'winter' where the latewood is evidently complete and this is roughly equivalent to September-to-March (of the following year) since the tree is dormant throughout this period and there is no additional growth put on the trunk.

These categories can overlap as, for example, not all oaks simultaneously initiate leaf-bud formation. It should also be noted that slow-growing or compressed material cannot always be safely categorised.

Radiocarbon wiggle-matching

Wiggle-matching is the process whereby a series of radiocarbon determinations which are separated by a known number of years are fitted, or 'matched', to the shape of the radiocarbon calibration curve. At its simplest, this can be done visually, although statistical methods are usually employed. Floating tree-ring sequences are particularly suited to this approach as the calendar age separation of different blocks of wood submitted for dating is known precisely by counting the rings in the timber.

Radiocarbon wiggle-matching of tree-ring sequences that cannot be absolutely dated through dendrochronology is not new (eg, Clarke and Renfrew 1972; Clarke and Morgan 1983; Baillie 1995, 69–70), although until now it has been largely confined to assemblages of waterlogged wood (eg van der Plicht *et al* 1995; Bayliss and Pryor 2001; Kromer *et al* 2001; Bayliss *et al* 2004). This is because large samples of wood were required for high-precision radiocarbon dating by Liquid Scintillation Spectrometry or Gas Proportional Counting. Recent advances in the accuracy and precision of radiocarbon measurements produced by Accelerator Mass Spectrometry (eg Bronk Ramsey *et al* 2004; Dellinger *et al* 2004), however, now make this approach feasible for small wood samples, such as those available from cores taken for tree-ring dating. An excellent summary of the history and variety of approaches employed for wiggle-matching is provided by Galimberti *et al* (2004).

A variety of the wiggle-matching approach has also been applied to validate, or choose between, different matching positions of a floating tree-ring sequence against the absolutely dated master chronologies (Bayliss *et al* 1999). This is useful in situations where possible cross-matching positions have been identified by the tree-ring analysis, but where these are not strong enough statistically to be accepted without independent, confirmatory, evidence.

RESULTS

Dendrochronology

Between 2004 and 2008 a total of 189 timbers were assessed for their dendrochronological potential. The vessel material was in poor physical state with multiple *Teredo* holes. The timbers had also shrunk and this had introduced some distortions into the material. A total of 17 oak (*Quercus* spp.) timbers were sampled for dendrochronological analysis, comprising nine structural elements from the vessel and eight barrel staves. Once the surfaces were prepared for analysis it was evident that some of the material had regular growth reduction and recovery patterns and included some with marked growth trends which are all likely to be anthropogenic in origin. Only 12 of the sampled timbers proved suitable for analysis, six from the vessel and six barrel staves.

None of the tree-ring sequences obtained from this material were found to cross-match each other. Consequently each individual series was separately checked against a very large number of reference tree-ring chronologies, as well as individual dated and undated tree-ring sequences. No high correlations with good visual matching at the same relative or absolute positions were obtained for any of the 12 measured sequences, thus the Studland Bay wreck material remains undated by dendrochronological analysis.

For the purposes of this report basic details of Timber 19, the only structural element from the vessel which had retained any sapwood, and the tree-ring measurement data are presented (Table 1; Appendix 1).

Radiocarbon

Seven decadal blocks of wood taken at decadal intervals from Timber 19 were sampled for radiocarbon dating, as shown in Table 2. The samples were submitted to the Scottish Universities Environmental Research Centre, East Kilbride (SUERC) for dating by Accelerator Mass Spectrometry (AMS). The samples were pretreated using the alpha cellulose scheme (Hoper *et al* 1998). They were then combusted to carbon dioxide (Vandeputte *et al* 1996), graphitised (Slota *et al* 1987), and measured by AMS (Xu *et al* 2004).

Material from all seven samples that remained after the initial pretreatment was then reprocessed a second time following Hoper *et al* (1998) as the initial results were thought by the submitter to possibly still suffer from contamination by polyethelene glycol (PEG).

SUERC maintains a continual programme of quality assurance procedures and participates in international inter-comparisons (Scott 2003), the results of which confirm the absence of laboratory offsets and to demonstrate the validity of the precision quoted.

Table 2 includes the radiocarbon results, quoted in accordance with the international standard known as the Trondheim Convention (Stuiver and Kra 1986). These are conventional radiocarbon ages (Stuiver and Polach 1977). The calibrated date ranges in Table 2 have been calculated using the maximum intercept method (Stuiver and Reimer 1986), the calibration curve of Reimer *et al* (2013) and the computer program OxCal v4.2 (Bronk Ramsey 1995; 1998; 2001; 2009). They are quoted with endpoints rounded outwards to 10 years, following Mook (1986).

DISCUSSION

Dendrochronology

The lack of intra-correlation and the unusual growth characteristics within the Studland Bay wreck samples may indicate that a varied wooded landscape, either geographically spread, or individual woodland plots, or individual trees with varied micro-histories, may have been exploited, either deliberately or by happenstance, for the ships structural timbers. Future work may create appropriate regional datasets that enable some or all of the shipwreck timbers to be successfully dated by dendrochronological analysis.

Radiocarbon

The graphical distributions of the calibrated results are derived from the probability method (Stuiver and Reimer 1993). A Bayesian wiggle-match model (Fig 1) that combines the radiocarbon results with their age differences, was constructed using OxCal v4.2 (Bronk Ramsey 2009; Christen and Litton 1995; Bronk Ramsey *et al* 2001; Galimberti *et al*

2004). The samples were of decadal blocks, and it is assumed that the radiocarbon measurements date the midpoint of each decade sampled. There is a 20-year gap between each sample, and the date of the final radiocarbon sample, 19G, is two years earlier than the heartwood/sapwood transition. Nine rings of sapwood survive on the timber.

The model, shown in Figure 1, shows a poor fit between the calibrated radiocarbon dates and the relative dating required by the dendrochronological sequence (A_{comb}=17.4%, A_n= 26.7%, n=7; Bronk Ramsey *et al* 2001). Perhaps not surprisingly, three of the seven results in this model have low individual indices of agreement (<60). The timber had been treated with polyethylene glycol, and given the poor quality of this wiggle-match, it raised uncertainties as to whether all the contaminant had been removed from the samples during the initial pretreatment. The material that was left over from the initial pretreatment was treated again and then processed to graphite targets for AMS dating.

Figure 2 shows the wiggle-match of this second round of results. This model shows a good fit between the calibrated radiocarbon results and the relative dating required by the dendrochronological sequence (A_{comb}=72.9%, A_n= 26.7%, n=7; Bronk Ramsey *et al* 2001). Each radiocarbon sample from the Studland Bay wreck consisted of a decadal block from the floating dendrochronological sequence, and the calibration data spanning this period are composed of radiocarbon measurements attributed to the midpoints of blocks of dendro-dated wood from each calendar decade. The ranges for *posterior density estimates* given in Table 2 have been rounded outwards to the nearest five calendar years. There is thus at least a 95% probability that the midpoint of the decadal block sampled dates to within the corresponding range. The model estimates that *ring_135* of Timber 19 (Fig 2) formed in *cal AD 1460–1490* (*95% probability*) and probably in *cal AD 1470–1485* (*68% probability*).

Timber 19 retained nine sapwood rings, with an unknown number lost in antiquity. It is, in this instance, not possible to directly derive an estimated felling date for the tree represented from the data in this model. This is because the timber is of unknown origin and thus it is not appropriate to apply a probability distribution for the number of sapwood rings from, for example, native English oak. However, given the estimate for the date of formation of the last ring of Timber 19 from the wiggle-match, it is possible that the vessel dates to the late-fifteenth or early-sixteenth century.

Particularly noteworthy with the two sets of radiocarbon results from the Studland Bay wreck are that each set of paired measurements is statistically consistent when subjected to a chi-square test (Table 3). If the paired results are combined using a weighted mean (Ward and Wilson 1978) and then run through the wiggle-match model, they are in poor agreement (A_{comb}=13.9%, A_n= 26.7%, n=7).

CONCLUSION

Analysis has shown that the single scientifically dated timber from the Studland Bay wreck was likely to have been felled in the late-fifteenth or early-sixteenth century. This estimate accords well with analysis of the boat and ballast that suggested the vessel sank sometime towards the end of the fifteenth or beginning of the sixteenth century (Thomsen 2000) and the cargo of Spanish ceramics made at Seville at the beginning of the sixteenth century it was carrying (Gutiérrez 2003).

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TABLES

Table 1. Details of the radiocarbon sampled timber from the Studland Bay wreck site PM38

Timber	Description	Size (mm)	Total rings	Sapwood
19	Ship Frame #19	165 x 155	135	9

Table 2. Radiocarbon results, Studland Bay wreck Timber 19

Sample	Laboratory Code	Radiocarbon age (BP)	$\delta^{13}C$ (‰)	Calibrated date, cal AD (95% confidence)	*Posterior density estimate, cal AD (95% probability)*
Tranche 1					
#19A (yrs 1–10)	SUERC-29164	600 ±30	-25.0	1290–1420	
#19B (yrs 21–30)	SUERC-29165	685 ±30	-25.2	1270–1390	
#19C (yrs 41–50)	SUERC-29166	700 ±30	-25.0	1260–1390	
#19D (yrs 61–70)	SUERC-29167	600 ±30	-24.8	1290–1390	
#19E (yrs 81–90)	SUERC-29168	575 ±30	-25.1	1300–1430	
#19F (yrs 101–110)	SUERC-29169	460 ±30	-24.4	1410–1460	
#19G (yrs 121–130)	SUERC-29170	475 ±30	-25.4	1410–1460	
Tranche 2					
#19A (yrs 1–10)	SUERC-30163	635 ±40	-25.5	1270–1410	*1330–1360*
#19B (yrs 21–30)	SUERC-30167	710 ±40	-25.1	1250–1390	*1350–1380*
#19C (yrs 41–50)	SUERC-30168	635 ±40	-24.9	1270–1410	*1370–1400*
#19D (yrs 61–70)	SUERC-30169	565 ±40	-24.8	1290–1440	*1390–1420*
#19E (yrs 81–90)	SUERC-30170	485 ±40	-25.1	1400–1460	*1410–1440*
#19F (yrs 101–110)	SUERC-30171	465 ±40	-24.6	1400–1470	*1430–1460*
#19G (yrs 121–130)	SUERC-30172	445 ±40	-24.8	1410–1610	*1450–1480*

Each sample represents one decade of growth from a single oak (*Quercus* spp) tree with 135 measured annual rings, including 9 sapwood rings (see Table 1, Appendix 1). Posterior density estimates are based on the model shown in Figure 2.

Table 3. Results of chi-square test on the paired radiocarbon measurements from Studland Bay wreck, following Ward and Wilson (1978). The 5% critical value for each pair is 3.8

Sample	Test result
#19A (yrs 1–10)	0.5
#19B (yrs 21–30)	0.3
#19C (yrs 41–50)	1.7
#19D (yrs 61–70)	0.5
#19E (yrs 81–90)	3.2
#19F (yrs 101–110)	0.0
#19G (yrs 121–130)	0.4

FIGURES

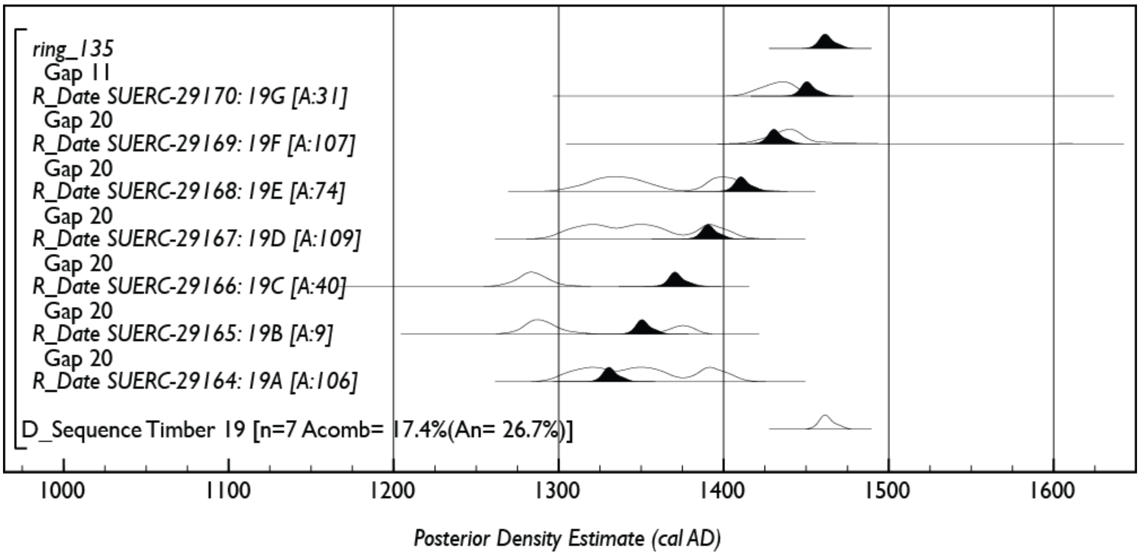


Figure 1. Probability distributions of the initial tranche of dates obtained on Timber 19 from the Studland Bay wreck. Distributions in outline are the results of radiocarbon calibration (Stuiver and Reimer 1993). The solid distributions are based on the wiggle-match sequence (Bronk Ramsey et al *2001). The OxCal keywords define the model exactly*

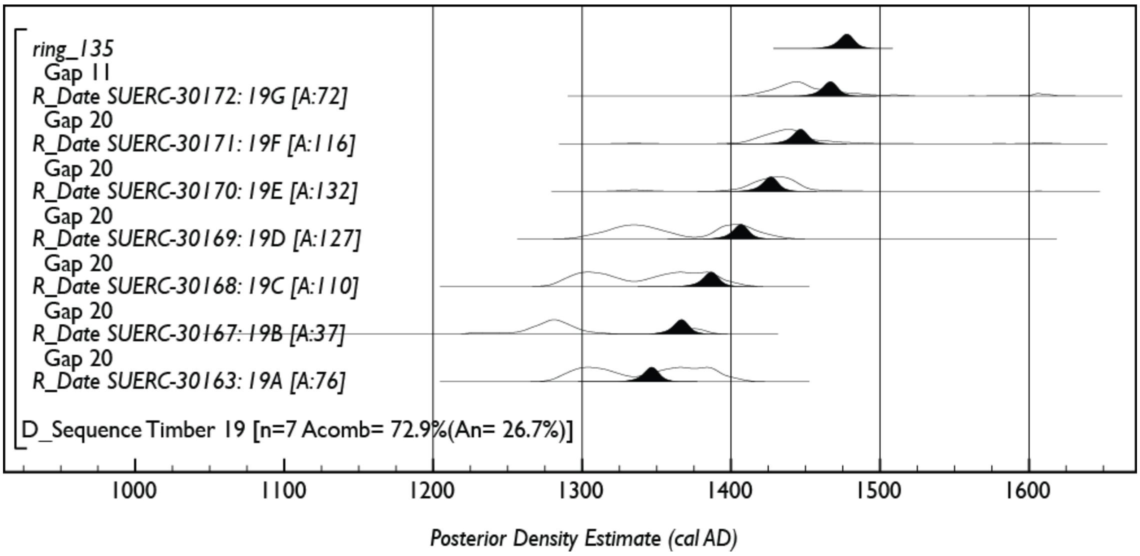


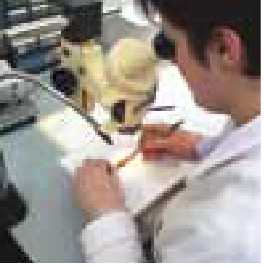
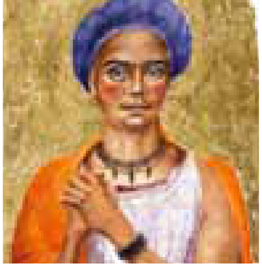
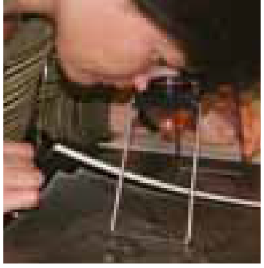
Figure 2. Probability distributions of the second tranche of dates obtained on Timber 19 from the Studland Bay wreck. The model is as described in Fig 1

APPENDIX 1

Measurements in units of 0.01mm

PM38 19

102	103	107	130	56	69	105	68	145	41
58	44	37	84	69	126	73	57	56	44
55	58	52	54	62	34	43	59	52	53
63	67	61	67	84	112	83	142	112	89
81	66	81	90	151	58	118	127	129	104
164	80	102	104	84	81	83	66	66	71
144	106	94	60	34	38	66	50	83	91
69	53	26	47	49	63	45	33	45	31
42	41	52	61	94	61	122	92	74	102
86	59	58	79	97	99	52	120	103	106
74	75	82	58	43	31	39	57	46	127
179	138	156	101	85	72	77	69	79	46
57	77	72	84	73	57	52	49	44	44
58	38	65	61	65					



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