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Article *in* Antiquity · December 2001

DOI: 10.1017/S0003598X00089237

Alex Bayliss
Historic England and the University of Stirling

New AMS radiocarbon dates for the North Ferriby boats—a contribution to dating prehistoric seafaring in northwestern Europe

EDWARD V. WRIGHT, ROBERT E.M. HEDGES, ALEX BAYLISS & ROBERT VAN DE NOORT*

A new series of radiocarbon measurements on three sewn-plank boats from North Ferriby, Yorkshire, has provided consistent new dating for these craft, which suggests that the appearance of such boats may fall in the early Bronze Age.

Key-words: Yorkshire, boat, radiocarbon dating, Bronze Age, exchange

Introduction

The Ferriby boats (F1, F2 and F3) were discovered on the Humber foreshore between 1937 and 1963 (Wright & Wright 1939; Wright 1990; FIGURES 1 & 2). All three boats have been dated to the Bronze Age and are similar in design: planks are stitched together with yew withies, and systems of cleats with transverse timbers provide structural integrity to the hull, which was perhaps amplified by inserted frames. These craft, with other related British finds, constitute an unparalleled series that provides insight into the mechanisms of prehistoric transport.

Previously, it was generally assumed that these boats were used predominantly for inland water transport, but a more recent assessment argued that the craft were used for long-distance exchange, including seafaring (Van de Noort *et al.* 1999). Sewn-plank boats are so far unique to the coastal waters of England and Wales, sharply contrasting with the distribution of log-boats of prehistoric date which concentrate around inland waterways. No prehistoric sewn-plank craft are known from the Continent, except for the much later Hjortspring canoe from Iron Age Denmark (Rosenberg 1937).

When F1 and F2 were excavated in 1946, radiocarbon dating had not been discovered, and their conservation preceded the first attempts to date the boats by radiocarbon assay. F3 was discovered in 1963, but conserved without samples being removed for dating. The sample size required for conventional (radiometric) dating meant that uncontaminated short-lived material could not be obtained for each boat. Furthermore, the chemical processing that could be applied was constrained by the limited amount of wood available.

The current dating programme was prompted by the concentration of the surviving timbers in Hull and East Riding Museum in the early 1990s, facilitating the selection of short-lived samples from each boat for AMS dating. Further impetus to refine the chronology of these finds was provided by the discovery of the examples of sewn-plank boats from Caldicot, Dover, Goldcliff, and Kilnsea (McGrail 1997; Clark forthcoming; Bell *et al.* 2000; Van de Noort *et al.* 1999).

Background

Early attempts at radiocarbon dating the Ferriby boats could not fully remove the contamination produced by the conservation treatments. Consequently dating relied on *ex situ* material associated with the finds. In 1953 a sample of oak sealing-lath found some 10 m southwest of the site of F1 was submitted to the British Museum, producing a result of 1260–400 cal BC (BM-58; 2700±150 BP; Barker & Mackey 1960).

* Wright, deceased. Hedges, Oxford Radiocarbon Accelerator Unit, 6 Keble Road, Oxford OX1 3QJ, England. Bayliss, English Heritage, 23 Savile Row, London W1S 2ET, England. Van de Noort, Department of Archaeology, University of Exeter, Exeter EX4 4QE, England.

Received 6 March 2001, accepted 25 June 2001, revised 29 August 2001

In 1963, following the discovery of F3, a piece of stitch and a sealing lath collected in 1941 and probably related to F2, which had been air-dried without any treatment, was submitted for dating to Cambridge University. This yielded two replicate determinations, which calibrate to 2120–1520 cal BC (Q-837a, 3393±210 BP; Q-837b, 3506±110 BP; Godwin & Switsur 1966; weighted mean 3482±97 BP, T'=0·2, T'(5%)=3.8, v=1; Ward & Wilson 1978). A second sample, a 12-year-old alder branch collected from immediately beneath F3 in 1963, yielded a date of 1620–1050 cal BC (Q-715, 3120±105 BP; Wright & Churchill 1965; Godwin *et al.* 1965). Although these measurements are probably accurate estimates of the radiocarbon content of the wood submitted for dating, their association with the sewn-plank boats is uncertain to varying degrees. This is demonstrated by a hazel loop found near F3 in 1963, which provided a date of 14,350–12,370 cal BC (Q-836; 12,950±240 BP; Godwin & Switsur 1966).

To provide dates from samples of unimpeachable contextual integrity, two samples from F1 were submitted for dating in 1973. Both had been contaminated by glycerol (Q-1197 and Q-1217; McGrail & Switsur 1975). A series of six further samples from the boats themselves were dated in subsequent years (Q-3043–5, Q-3047 and Q-3123–4) in an attempt to replicate these results and tackle the different problems of chemical contamination presented by F2 and F3 (Switsur & Wright 1989; Switsur 1989). Unfortunately, insufficient short-lived material was available for conventional dating from F2, and only oak heartwood could be dated. One of the samples dated in 1973 from F1 was also part of the main planking of the craft. This material is an unknown number of years older than the construction of the boat because of the age-offset between the tree-rings dated and the date when the tree forming the plank was felled (Bowman 1990: 15).

Tree-ring analysis carried out between 1978 and 1985 did not produce absolute dating, although cross-matching between the timbers of F1 and F2 suggests that they are broadly contemporary (Hillam 1985). Neither boat has any evidence of sapwood, but their chronologies end just six years apart. This may suggest that only the delicate sapwood was removed from these timbers. The tree-ring sequences from F3 did not match this chronology and so this boat is likely to be either earlier or later in date than F1/F2.

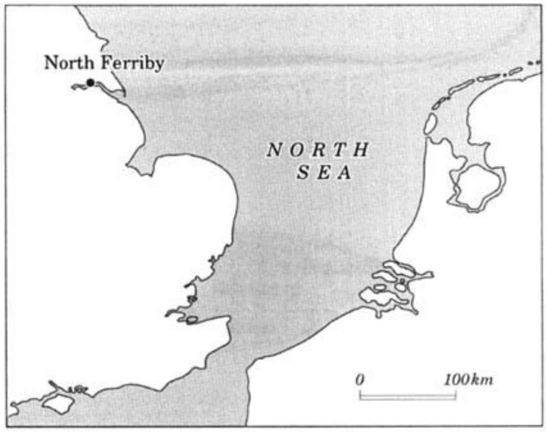

FIGURE 1. *Location map.*

Methodology

A set of new samples, taken from short-lived conserved fragments were dated by the Oxford Radiocarbon Accelerator Unit between 1998 and 2000 (Hedges *et al.* 1989). The major difficulty in this process is to ensure the complete removal of the carbonaceous materials used in the preservatives. The radiocarbon content of these is likely to vary from almost zero (petroleum-based products) to >25% greater than that of the wood. To reduce errors from this source to less than 20 years, approximately 99% of the preservatives must be removed.

In 1998 four samples were processed using a combination of non-polar solvent extraction and the 'standard treatment' for wood, namely acid/base/acid treatment with bleaching to remove lignins. The residue is essentially cellulose and partially hydrolysed and degraded products (Hoper *et al.* 1998). The pretreatment method, designated with the code UV* in TABLE 1, is described in APPENDIX A. In 2000, a further 23 measurements were made, which included replicates of cellulosic material from the stitches and measurements on the solvent extracts, in order to understand their nature and assess the likelihood of radiocarbon dating errors due to incomplete extraction of contaminants. Thus six samples were processed according to method UW* (also described in APPENDIX A). The water soluble contaminants, recovered in the water solvent extracts, were also dated (NRC1 in TABLE 1), as were the non-

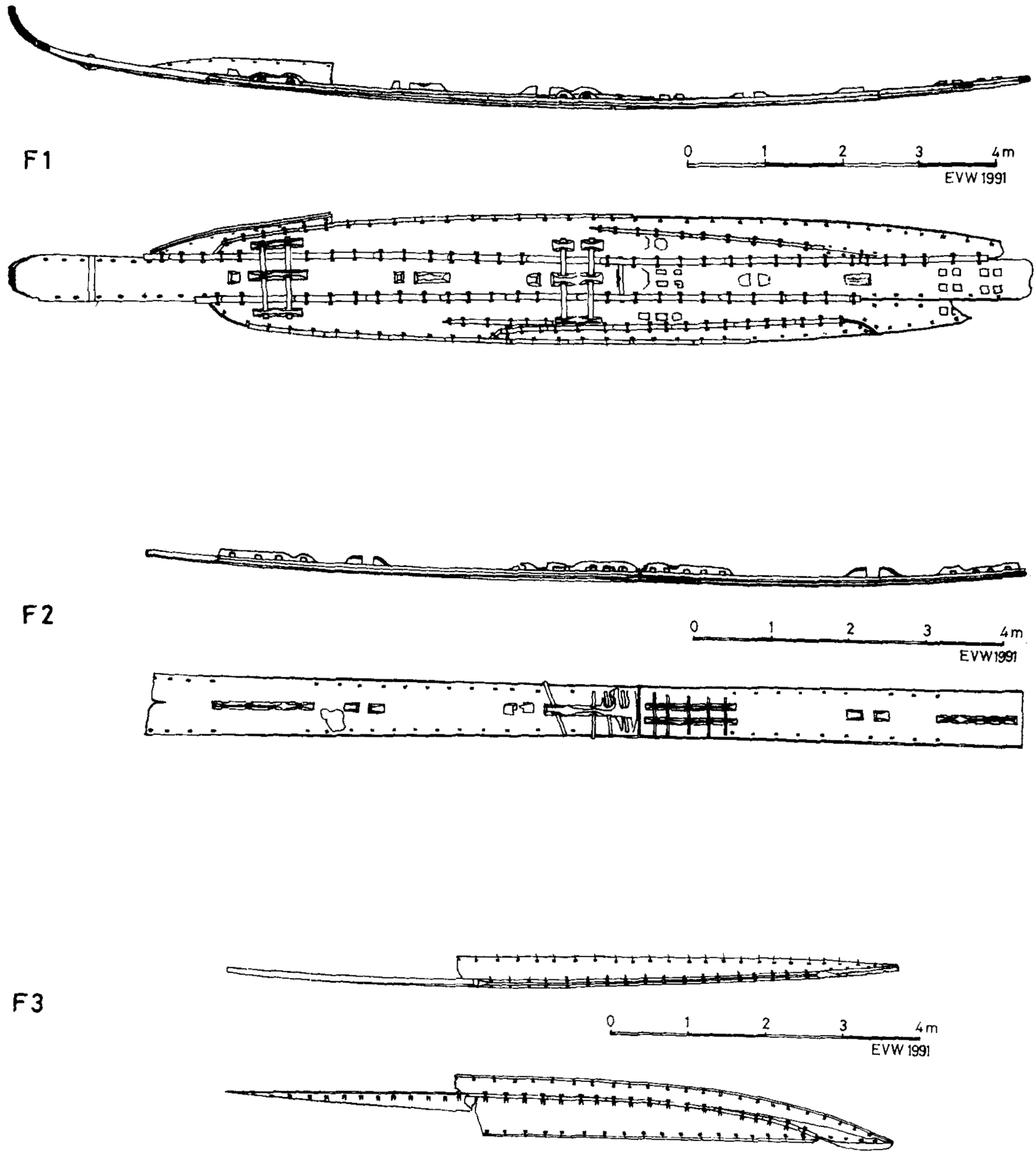

FIGURE 2. *The Ferriby boats.*

polar extracts, combined from chloroform, methanol, and acetone extracts (NRC2 in TABLE 1). As a further step, a portion of the 'cellulose' product from the first processing was subjected to a second round of solvent extraction before combustion and graphitization (NRC4 in TABLE 1). Agreement between UW* and NRC4 implies that no further contaminants (in terms of ^{14}C content) are removable by the repeated pre-treatment, suggesting that the single round of pre-treatment (i.e. the UW* method) has successfully removed all such contaminants. The extracts from this round of double pre-treatment were also dated. There was insufficient material for replicate dating of F3 stitch A.

The measurements relating to the NRC1 and NRC2 fractions do not date the boats, but they do help in understanding the potential for ^{14}C

contamination in the dates. The results from material treated by UW* and NRC4 methods are on the material most likely to represent the original wood. Unfortunately, there is no useful analytical test which can demonstrate the presence or absence of the suspected contaminants at the 1% level; methods that are specific for cellulose, for example enzymic methods, are insufficiently developed to be reliably free of systematic error (Hodgins *et al.* forthcoming).

Full details of all samples and results are given in TABLE 1. All results are conventional radiocarbon ages (Stuiver & Polach 1977).

F1

The dated stitch was excavated from the boat in 1938/9 or in 1946. The timbers were trans-

lab. no.	sample no.	material	^{14}C age (BP)	δ^{13}C (‰)	chemistry
Ferriby 1					
Q-1217	stitch	*Taxus* sp.	3312±100		McGrail & Switsur 1975
Q-1197	plank	*Quercus* sp.	3380±100		McGrail & Switsur 1975
Q-3124	F1 withy	*Taxus* sp.	3020±40		Switsur 1989
Q-3043	F1 withy	*Taxus* sp.	2980±55		Switsur 1989
OxA-7457	stitch	*Taxus* sp.	3470±30	−22·9	UV*
OxA-9236	F1 stitch A	*Taxus* sp., roundwood with 13 growth rings	3419±30	−21·9	UW*
OxA-9307	F1 stitch A	*Taxus* sp., roundwood with 13 growth rings	3409±40	−18·6	NRC1
OxA-9308	F1 stitch A	*Taxus* sp., roundwood with 13 growth rings	3472±40	−22·5	NRC2
OxA-9519	F1 stitch A	*Taxus* sp., roundwood with 13 growth rings	3501±34	−21·8	NRC4
OxA-9237	F1 stitch B	*Taxus* sp., roundwood with 13 growth rings	3520±45	−22·0	UW*
OxA-9309	*F1 stitch B*	*Taxus* sp., roundwood with 13 growth rings	3240±36	−18·3	NRC1
OxA-9310	F1 stitch B	*Taxus* sp., roundwood with 13 growth rings	3260±40	−23·6	NRC2
OxA-9520	F1 stitch B	*Taxus* sp., roundwood with 13 growth rings	3403±35	−21·5	NRC4
Ferriby 2					
Q-3044	top of cleat	*Quercus* sp.	3095±40		Switsur 1989
Q-3123	top of cleat	*Quercus* sp.	3120±45		Switsur 1989
OxA-7458	stitch	*Taxus* sp.	3515±30	−24·5	UV*
OxA-9196	F2 stitch A	*Taxus* sp., roundwood with 5 growth rings	3750±45	−25·1	UW*
OxA-9299	F2 stitch A	*Taxus* sp., roundwood with 5 growth rings	2075±36	−24·4	NRC1
OxA-9311	F2 stitch A	*Taxus* sp., roundwood with 5 growth rings	1445±65	−25·5	NRC2
OxA-9521	F2 stitch A	*Taxus* sp., roundwood with 5 growth rings	3510±38	−23·9	NRC4
OxA-9197	F2 stitch B	*Taxus* sp., roundwood with 5 growth rings	3750±45	−25·1	UW*
OxA-9312	F2 stitch B	*Taxus* sp., roundwood with 5 growth rings	1983±34	−24·5	NRC1
OxA-9313	F2 stitch B	*Taxus* sp., roundwood with 5 growth rings	8120±90	−25·3	NRC2
OxA-9522	F2 stitch B	*Taxus* sp., roundwood with 5 growth rings	3536±35	−23·8	NRC4
Ferriby 3					
Q-3047	F3 withy	*Taxus* sp.	2945±40		Switsur 1989
Q-3045	F3 withy	*Taxus* sp.	2975±45		Switsur 1989
OxA-7459	F3 stitch	*Taxus* sp.	4000±110	−22·7	UV*
OxA-7532	F3 stitch	*Taxus* sp.	3340±50	−21·9	UV*
OxA-9198	F3 stitch A	*Taxus* sp., roundwood with 4 growth rings	3550±40	−24·1	UW*
OxA-9314	F3 stitch A	*Taxus* sp., roundwood with 4 growth rings	5225±45	−25·2	NRC1
OxA-9315	F3 stitch A	*Taxus* sp., roundwood with 4 growth rings	33640±390	−25·2	NRC2
OxA-9199	F3 stitch B	*Taxus* sp., roundwood with 4 growth rings	3625±45	−24·0	UW*
OxA-9316	F3 stitch B	*Taxus* sp., roundwood with 4 growth rings	5450±40	−24·8	NRC1
OxA-9317	F3 stitch B	*Taxus* sp., roundwood with 4 growth rings	32870±290	−25·2	NRC2
OxA-9524	F3 stitch B	*Taxus* sp., roundwood with 4 growth rings	3560±40	−24·3	NRC4

TABLE 1. *Radiocarbon determinations.*

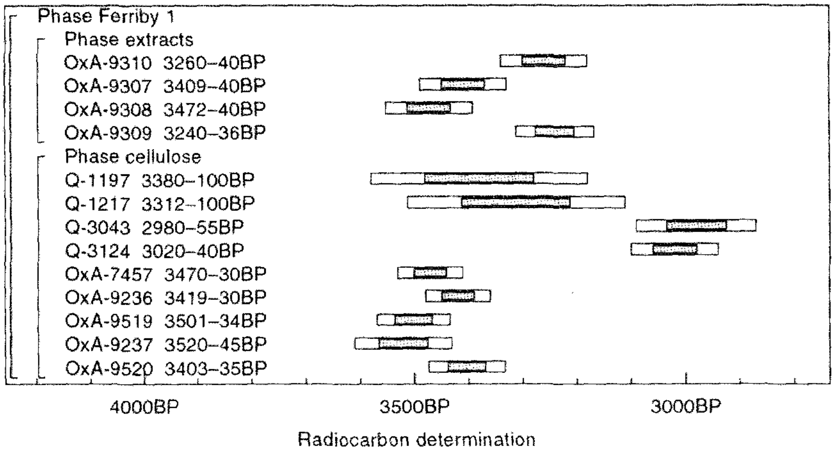

FIGURE 3. *Radiocarbon determinations on material from F1.*

ported to the National Maritime Museum at Greenwich, where in 1948, after a period in the open during which they were subjected to considerable desiccation, they were placed in tanks of glycerol in an effort to preserve them (Plenderleith 1956: 141–2). After some time disagreeable smells issued from the tanks and the Trustees of the Museum decided to 'dispose' of the remains of F1. The Keeper, Commander G.P.B. Naish RN, did so in an act of Nelsonian insubordination, and squirreled away the better-preserved pieces of timber in a dry basement under the Queen's House, thus preserving irreplaceable evidence for future study.

The five new dates on the cellulose fraction (OxA-7457, OxA-9236–7 and OxA-9519–20) are statistically consistent (T'=7·8; T'(5%)=9·5; ν=4).

The four results on the soluble fractions are significantly different from these results (T'=55·4; T'(5%)=15·5; ν=8), and show that the contamination is rather younger (FIGURE 3). This can be attributed to the removal of the glycerol which was used to treat this find, because this is an oilseed rape product containing modern carbon.

The results of the measurements undertaken at Cambridge are also significantly younger than those on the cellulose fractions recently dated (T'=162·2; T'(5%)=15·5; ν=8). This suggests that the various chemical treatments of the samples used at Cambridge (McGrail & Switsur 1975; Switsur 1989) failed to remove all the contaminating glycerol.

The most reliable date for the construction of Ferriby 1 is provided by the weighted mean of the consistent results on the cellulose fraction (OxA-7457, OxA-9236–7 and OxA-9519–20). This is 3457±15 BP. The dating measurement may have a systematic error of up to 10 years (this corresponds to independent determination and de-calibration of known-age wood). Any systematic error due to additives cannot be strictly estimated, although the variance in the five results is likely to be a useful clue. Taking these into account, a minimum error of ±25 years for the combined result is, we think, realistic. This calibrates to 1880–1680 cal BC (at 95% confidence).

F2

The dated stitch was excavated in 1946 and placed in tanks of glycerol in 1948 along with F1. When the decision was taken to dispose of F1, it was decided that F2 was in better condition and potentially exhibitable. The pieces were therefore coated with an 'epoxy-based varnish' selected by H.J. Plenderleith, believed to have been a product made commercially by CIBA-Geigy (probably 'Bedacryl, ICI', a solution of a polymethacrylic ester in xylene). This was designed to prevent undue weeping of sticky glycerol solution. The boat was stowed in heavy glass-topped boxes and stored until the 1970s, when the parts of F2 were removed from the boxes and placed in reserve storage with what was left of F1.

The four replicate measurements on the cellulose fraction (OxA-9196–7 and OxA-9521–2) are not statistically consistent (T'=30·9; T'(5%)= 7·8; ν=3). The two results on material that underwent processing twice are significantly later than those which underwent sol-

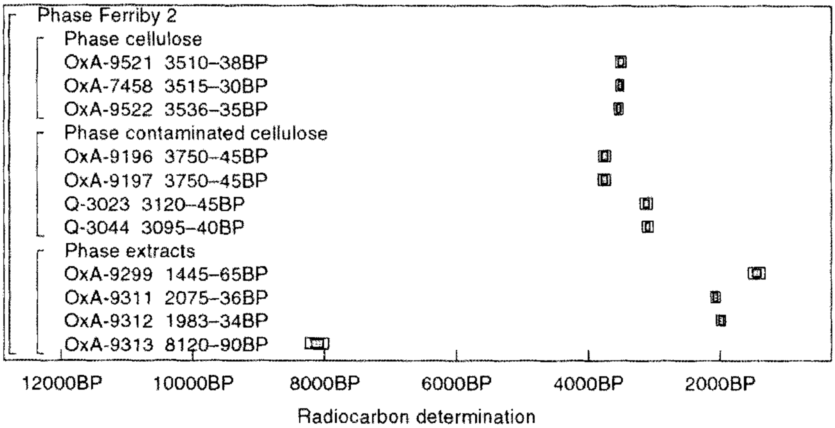

FIGURE 4. *Radiocarbon determinations on material from F2.*

vent extraction just once (FIGURE 4), but the pairs on each chemical process are internally consistent (two extractions: T'=0·3; T'(5%)=3·8; ν=1; one extraction: T'=0·0; T'(5%)=3·8; ν=1). The measurements on material which underwent processing twice are statistically consistent with OxA-7458, which underwent the standard wood processing technique (T'=0·3; T'(5%)=6·0; ν=2).

This suggests that there was chemical contamination in the samples which was not removed by the first extraction, but which was removed by the bleaching. As these results from the first extraction are older than those on material which was processed twice, it seems that the contamination which was not removed was of old carbon (i.e. OxA-9313). This material may have been derived from the 'epoxy-based varnish', as the glycerol appears to have been of recent date (FIGURE 4).

Again, the results of the measurements undertaken at Cambridge are significantly younger than those on the consistent cellulose fractions (T'=132·1; T'(5%)=9·5; ν=4; FIGURE 4). This suggests that the chemical treatment of the samples used at Cambridge (Switsur 1989) again failed to remove all the contaminating glycerol.

The most reliable date for the construction of F2 is provided by the weighted mean of the consistent results on the cellulose fraction (OxA-7458 and OxA-9521–2). This is 3520±20 BP, and again a minimum error of ±30 years, which takes qualitative account of the consistent difference between the UW* and NRC4 pre-treated samples, is suggested as realistic for the combined result. This calibrates to 1940–1720 cal BC (at 95% confidence).

F3

The dated stitch was excavated in 1963, lifted and removed to Hull Museums where it was placed in shallow water-filled holding tanks. These too began to give off disagreeable odours and so, at the request of John Bartlett, then Director of the Museums, the first author (EW) obtained a powerful bactericide from the laboratory at Reckitt & Colman. This was added to the water. There is no contemporary record of the identity of this substance, but the supplier suggests that it was either pentachlorophenol, tributyl tin oxide or lauryl guanidine ('Dodine'). Because of the decidedly harsh solution in which the boat had to be recorded, pentachlorophenol is the most likely culprit. Progressively parts of the boat were removed from storage and conserved with PEG 4000, in a galvanized iron tank with pentachlorophenate as a bactericide. After the appearance of zinc chloride in the tank, pH was kept between 7·5 and 10 by the addition of sodium carbonate. This treatment was started by W.H. Southern and completed by Terry Suthers. The boat was in the National Maritime Museum in the 1980s, but was returned to Hull in the early 1990s.

The three replicate measurements on the cellulose fraction (OxA-9198–9, OxA-9524) are statistically consistent (T'=1·8; T'(5%)=6·0; ν=2). Unfortunately the fourth measurement of this type failed. Both sets of solutions show signs of contamination by old carbon, probably relating to the petroleum-based PEG (FIGURE 5). Similarly, OxA-7459 seems to be contaminated by old carbon, although OxA-7532 and the radiometric measurements from Cambridge appear to have been contaminated by more recent

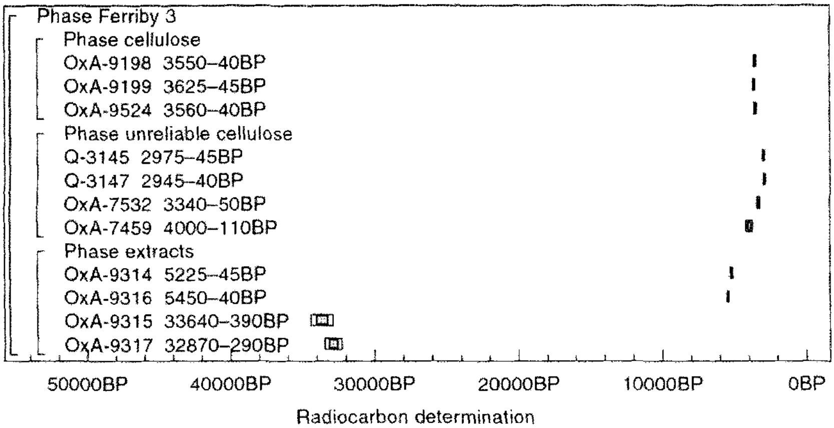

FIGURE 5. *Radiocarbon determinations on material from F3.*

carbon (FIGURE 5). The derivation of this contamination is unknown.

These uncertainties make the dating of F3 the least satisfactory, although it appears that the most reliable date for the construction of the boat is provided by the weighted mean of the consistent results on the cellulose fraction (OxA-9198–9 and OxA-9524). This is 3575±24 BP, with a minimum error of ±30 years quoted as realistic for the combined result (see F2 above). This calibrates to 2030–1780 cal BC (at 95% confidence).

The new measurements from F2 and F3 have very similar carbon stable isotope values. F1 has a different and unusually heavy value. This cannot be explained by contamination, since the solvent extracts show relatively little difference in value. Unfortunately no stable isotope measurements are available for previous attempts to date these finds.

The calibrated dates of the three boats are shown in FIGURE 6 and TABLE 2. The measurements have been calibrated using OxCal v3.5 (Bronk Ramsey 1995) and the calibration curve of Stuiver *et al.* (1998). The ranges given in TABLE 2 have been calculated according to the maximum intercept method and rounded outwards to 10 years (Stuiver & Reimer 1986). The distributions in FIGURE 6 have been calculated

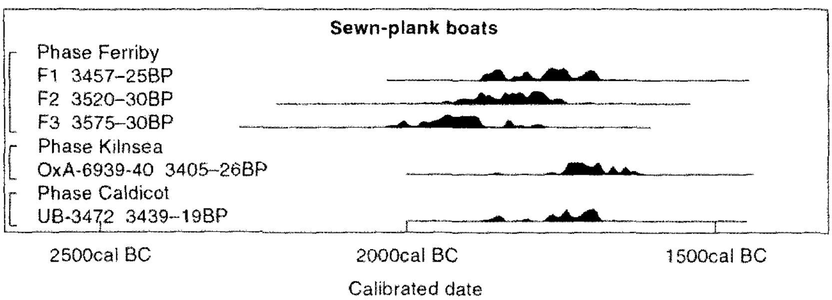

FIGURE 6. *Radiocarbon dates for early Bronze Age sewn-plank boats from Britain.*

boat	^{14}C age (BP)	lab. nos.	calibrated date range (95% confidence)	reference
F1	3457±25	OxA-7457, OxA-9236–7 and OxA-9519–20	1880–1680 cal BC	this paper
F2	3520±30	OxA-7458 and OxA-9521–2	1940–1720 cal BC	this paper
F3	3575±30	OxA-9198–9 and OxA-9524	2030–1780 cal BC	this paper
Kilnsea	3405±26	OxA-6939–40	1750–1620 cal BC	Van de Noort *et al.* 1999
Caldicot	3439±19	UB-3472	1870–1680 cal BC	McGrail 1997

TABLE 2. *Radiocarbon dates for early Bronze Age sewn-plank boats from Britain.*

according to the usual probability method (Stuiver & Reimer 1993). As suggested independently by the tree-ring analysis, F1 and F2 are very close in age and may be precisely contemporary (T'=2·6; T'(5%)=3·8; ν=1). F3 is also close in date, although it may be slightly earlier as its radiocarbon content is significantly different from that of the other boats (T'=9·3; T'=6·0; ν=2).

Archaeological significance of new dating

This reappraisal of the date of the Ferriby boats provides a history of radiocarbon dating in microcosm, demonstrating an increasing awareness of the associated chemistry. The dating of conserved material in this case has been shown to be fraught with difficulties, with samples producing dates that are younger (eg where glycerol was used in conservation) or older (where PEG or epoxy-based materials were used). However, in most cases such material can be dated accurately, although it requires close liaison with the dating laboratory and replicate determinations. A recorded conservation history is invaluable.

The redating of the Ferriby boats has now produced the oldest known sewn-plank boat in western Europe, that is F3 dated to 2020–1780 cal BC. It has also produced more precise and reliable estimates for the dates of F1 and F2.

More to the point, the redating of these craft to the earlier 2nd millennium cal BC, rather than to *c.* 1500 cal BC (Switsur & Wright 1989: 65), shifts the archaeological context of the finds from the middle to the early Bronze Age. The three Ferriby boats now join those from Kilnsea and Caldicot to form a convincing group that suggests the appearance of plank-built boats in the early Bronze Age (FIGURE 6), used for seafaring.

The final question we have to ask is this: 'why were sewn-plank boats, arguably capable of open sea travel, invented in the early 2nd millennium cal BC in northwestern Europe?' The answer to this question must be sought in the performance of the craft, based on hypotheses for complete reconstructions (Wright 1990: figure 5.2).

The exchange networks for exotic and long-distance traded goods had been widening from the early Neolithic, and the later Neolithic saw the development of different regional networks within Britain (Bradley & Edmonds 1993: 204). These regional networks appear to extend into continental Europe by the early Bronze Age. The British archaeological record, with most finds of prehistoric amber dated to this period and with the early bronzes of apparent continental origin, supports such a hypothesis (Beck & Shennan 1991: 71; Rohl & Needham 1998: 177–80).

It is our argument that the expansion of élite networks across Europe was enabled by sewn-plank boats. Alternatively, the need for regular contact and exchange with continental Europe instigated the innovative design of these boats. This may have been the culmination of a development that had commenced in the later Neolithic. McGrail (1993), for example, has suggested that hide boats may have been used for prehistoric seafaring, although no examples survive. The sewing of the hides may have inspired the builders of the first sewn-plank boats to build more robust craft for open sea travel. The appearance of sewn-plank boats provides a plausible mechanism for the development of regular continental exchange processes in the early Bronze Age.

Acknowledgements. We gratefully acknowledge the receipt of funding for this research from English Heritage, the Ferriby Heritage Trust, and Oxford University. Hull and East Riding Museum, and in particular the Keeper of Archaeology, Gail Foreman, provided every facility for the necessary sampling to take place.

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Appendix A: Pre-treatment methods

The * in the code refers to solvent extraction.

The method adopted for the Ferriby boats was to use a Soxhlet extraction for several hours in a sequence of solvent comprising: chloroform/methanol, followed by methanol, followed by acetone, followed by water.

UV and UW are essentially the same. The acid-base-acid treatment is 1·5 hours at 80°C in 1M HCl, 0·2M NaOH and 1M HCl, followed by 1 hour at pH3 2·5% (UV) or 5% (UW) NaOCl for bleaching.

NRC1 and NRC2 fractions are the water extracts and the accumulated chloroform/methanol/acetone extracts respectively, without further pretreatment.

NRC4 is UV* followed by a second complete sequence of extractions.